TECHNOLOGY ENHANCED ACCESSIBLE INTERACTION FRAMEWORK AND A METHOD FOR EVALUATING REQUIREMENTS AND DESIGNS

By

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ABSTRACT

FACULTY OF PHYSICAL SCIENCES AND ENGINEERING

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The motivation for this thesis was the lack of any existing comprehensive framework or method to help developers with the evaluation or gathering of requirements and the evaluation or designing of technology solutions to accessible interactions between people, technology and objects, particularly in face-to-face situations involving people with disabilities. A Technology Enhanced Interaction Framework (TEIF) and TEIF Method for enhancing interactions with people, technology and objects through the use of technology was developed and successfully validated by three developer experts, three accessibility experts, and an HCI professor. The TEIF main components are people, objects, technology, interactions, time / place, and context while the TEIF Method involves requirement questions with multiple choice answers and technology suggestions, Interaction Diagrams and Use Case Diagrams. For evaluation of the TEIF Method, an example scenario involving a hearing impaired visitor to a Thai small local museum was developed along with corresponding requirement questions and answers, technology suggestions, technology solutions, an Interaction Diagram and a Use Case Diagram. While the TEIF has all the necessary components and sub components to be a general framework, the TEIF Method is focused on accessible interactions, and the content of the method used in this research was focused on people with hearing impairment because of time limitations. An experiment with 36 developers showed they were able to use the TEIF Method to evaluate requirements for technology solutions to problems involving interaction with hearing-impaired people better than the Other Methods. The TEIF Method helped developers select a best solution significantly more often than the Other Methods and rate the best solution significantly closer to expert ratings than the Other Methods. The TEIF Method also helped differentiation between solutions to be closer to experts' differentiation than the Other Methods for some solutions and requirements. Questionnaire results showed that the developers thought that the TEIF Method helped to evaluate requirements and technology solutions to interaction problems involving hearing impaired people and would also help with gathering requirements and designing technology solutions for people with other disabilities. The developers also thought that the TEIF Method helped improve a developer's awareness of interaction issues and understanding of how environment context affects interaction. Suggestions for future developments include extending the TEIF Method for other disabilities, including a more nuanced multi-level classification of how well different technologies meet different requirements and the use of the TEIF and TEIF Method as an index for case based solutions.

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Declaration of Authorship

I, Kewalin Angkananon, declare that this thesis and the work presented in it are my own and has been generated by me as the result of my own original research.

Title of thesis: Technology Enhanced Interaction Framwork and Method

I confirm that:

1. This work was done wholly or mainly while in candidature for a research degree at this University;
2. Where any part of this thesis has previously been submitted for a degree or any other qualification at this University or any other institution, this has been clearly stated;
3. Where I have consulted the published work of others, this is always clearly attributed;
4. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this thesis is entirely my own work;
5. I have acknowledged all main sources of help;
6. Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself;
7. Parts of this work have been published as can be seen in section 1.6, chapter 1.

Signed: ....

Date: ....

Acknowledgements

I would like to thank my supervisors Mike Wald and Lester Gilbert for their wonderful support, guidance, patience, and always having time for me whenever I needed help.

I am grateful to the participants and experts who so generously gave their time to take part in my experiments.

My Phd would not have been possible without the generosity of Suratthani Rajabhat University Thailand giving me a full scholarship for my studies at Southampton University.

I would also like to thank Suchat Trapsin, the owner of Shadow Puppet Museum, Thailand for his hospitality in showing me around his museum and answering my many questions.

Last but not least, I would like to thank my family and friends for their support.

Definitions and Abbreviations Used

Communication	The process of passing information from one person to another (Davis, 1977)
Technology	A tool that helps people achieve their purpose
People	Anyone involved in direct communication or interaction with an object, technology, or other people
Object	A real object not virtual and anything that is not a technology or a person involved in communication or interaction.
Interactions	Interactions can be between people and objects (P-O) or people and technology (P-T). People can also use technology to mediate interaction with people (P-T-P) or objects (P-T-O).
TEIF	Technology Enhanced Interaction Framework
TEIF Method	Technology Enhanced Interaction Framework Method
Complex situation	A situation which has the interactions in form of P-P, P-O, P-T, P-T-P and P-T-P, especially when disabled are involved

Chapter 1 Introduction

This chapter introduces the motivation for this thesis in section 1.1. An example is presented in section 1.2 to illustrate the problems that the research documented in this thesis can help to address. Section 1.3 explains the research challenges. The research questions and sub-research questions are identified in section 1.4. Section 1.5 presents the report structure and section 1.6 presents the publication list of published articles based on material from this thesis.

1.1 Motivation

Thai culture is changing over time because of exposure to other nationalities whether face to face or through the Internet, television, or films. Small local Thai museums run by their owners help preserve Thai everyday culture in its original position or place by passing on knowledge and wisdom. Visiting such local museums is more realistic and authentic compared to an experience inside a large museum but there is less budget support from the government (Princess Maha Chakri Sirindhorn Anthropology Centre, 2005) so owners of such local sites often do not have enough funding to provide accessible information for hearing impaired people. People with hearing impairments have difficulties in their access to Thai in situ authentic culture because they have problems with understanding spoken or complex text information during their visit. There is more research into helping people with hearing impairments in their access to large museums compared to in situ authentic culture (Proctor, 2005).

People with hearing loss of any age who know written language and use lip-reading to support their access to spoken language will in the future be an even larger group compared to sign language users as deaf people are now being fitted with cochlear implants to help improve their listening ability. Mather, Gregory, and Archbold (2011) reported that 15 young people who had received sequential bilateral cochlear implants all found improvements in listening with the second implant, even those who did not carry on wearing it. There are also an increasing number of elderly people who have difficulties in hearing as they were approximately 12.5% of the population in 2010 and the percentage is predicted to peak at 20% by 2025 (National Electronics and Computer Technology Center & The National Telecommunications Commission, 2009).

1.2 Example Museum Illustrating Problem

The following scenario based on an existing Thailand Tourism Award winning (ThailandTourist, 2014) small local museum visited by the author is presented to show current problems which affect people with hearing impairments in their access to Thai culture and history in local museums.

Suchat Trapsin, who is the owner of the museum, allocated some parts of his house to become the Museum of Folk Art and Shadow Puppets in order to preserve the culture of shadow puppetry by teaching the public more about it. However, there is no information provided in text format inside the museum because normally Suchat will explain the history and tradition behind shadow puppetry by talking with visitors. When people with a hearing impairment watch the shadow puppet show, they cannot hear the conversation clearly because of the background music and the shadow puppet show is also fairly dark with Suchat operating the puppets from behind a screen, which makes lip-reading very difficult for them. Moreover, the language, which is used in the show, is quite complicated, and therefore sometimes difficult to understand if hearing impairment at birth affected their learning of language.

1.3 Research Challenges

In order to reduce discrimination in access to information in Thai local museums, technology developers need to produce solutions at low cost (e.g. using visitors' own mobile devices).

An extensive review of the literature presented in chapter 2 found that there was no framework to guide developers in developing technology solutions for such face-to-face situations for people with hearing impairment, other disabilities or no disabilities. The research challenges that were therefore identified were to develop a Technology Enhanced Interaction Framework (TEIF) and TEIF Method regarding disabled people interacting with people, technologies and objects and from these challenges the following research questions and sub research questions were posed.

1.4 Research Questions and Contribution

This thesis's research contribution is addressing the research challenges discussed in section 1.3 by exploring the following research questions through expert reviews, expert validations, user evaluation experiments and user evaluation questionnaires. The findings are briefly presented after each research question:

- *Research question 1: Can the TEIF be developed regarding disabled people interacting with people, technologies, and objects?*

  The TEIF was successfully validated by three developer experts, and one HCI Professor (Sections 6.2.1, 6.3, and 7.1).

- *Research question 2: Can the TEIF Method be developed building on this TEIF to help design technology solutions for disabled people interacting with people, technologies, and objects?*

  The TEIF Method was successfully validated by three developer experts, three accessibility experts and one HCI professor and the improvements made following the experts' suggestions (Sections 6.2.2, 6.3, 7.2).

- *Research question 3: Can developers use the TEIF Method to help with the software development process when designing technology solutions to interactions for disabled people with people, technologies, and objects?*
  - *Sub research question 3.1: Can developers use the TEIF Method to help with evaluating requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?*

    The mean number of correct requirements was significantly higher for participants using the TEIF Method than the Other Methods (Sections 9.3 and 10.3.1).More participants in the TEIF Method group selected each correct requirement than the Other Methods group (section 9-3, and 10.3.1). The incorrect requirement selected by the greatest number of participants in the TEIF Method group was requirement 6. Six of the incorrect requirements were selected by none of the TEIF Method group. The incorrect requirement selected by the greatest number of participants in the Other Methods group was requirement 22. Three of the incorrect requirements (9, 18, and 19) were selected by none of the Other Methods group.

- *Sub research question 3.2: Can developers use the TEIF Method to help with evaluating technology solutions when designing technology solutions to interactions for disabled people with people, technologies, and objects?*

  Approach A: Investigated whether the TEIF Method helped developers select the best technology solution(s) more often than the Other Methods. The paired t test and the chi-square test were used for this investigation.
  The TEIF Method did not help developers select the exclusive best design solution(s) significantly more often than the Other Methods but it did help them select a solution significantly more often than the Other Methods that was not worse than a solution rated best by the experts (Sections 9.4.2 and 10.3.2).

  Approach B: Investigated whether the TEIF Method helped developers rate technology solutions closer to the experts' ratings than the Other Methods.
  The TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A but not for solutions B and C, and this applied similarly to each requirement (Sections 9.4.3.2 and 10.3.2).

  Approach C: Investigated whether the TEIF Method helped rate differences (measure amount and direction) between technology solutions closer to experts' difference scores than the Other Methods (Sections 9.4.3.3 and 10.3.2).

  Differential A-B
  The TEIF Method helped differentiation between solutions to be closer to experts' differentiation than the Other Methods for differential A-B for requirement 8 on measures amount and direction but not for other requirements (Sections 9.4.3.3.1 and 10.3.2.1).

Differential A-C

The TEIF Method did not helpe differentiation between solutions A and C to be closer to experts' differentiation than the Other Methods (Sections 9.4.3.3.2 and 10.3.2.2).

Differential B-C

The TEIF Method helped differentiation between solutions B and C to be closer to experts' differentiation than the Other Methods on both measures amount and direction for requirements 8 and 28 (Sections 9.4.3.3.3 and 10.3.2.3).

- *Sub research question 3.3: Can developers use the TEIF Method to help with gathering requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?*

  The participants thought that the TEIF Method would also help with gathering requirements for technology solutions to interaction problems involving hearing impaired people, and for other disabled people (Sections 9.5.4 and 10.3.7).

- *Sub research question 3.4: Can developers use the TEIF Method to help with designing technology solutions to interactions for disabled people with people, technologies, and objects?*

  The participants thought that the TEIF Method would help designing technology solutions to interaction problems involving hearing impaired people, and if information was provided for other disabled people (Sections 9.5.4 and 10.3.8).

- Research question 4: In what ways does the TEIF Method help developers?
  - *Sub research question 4.1: Does the TEIF Method help to improve awareness of interaction issues involving hearing impaired people?*

    Participants thought that the TEIF Method helped improve a developer's awareness of interaction issues involving hearing impaired people (Sections 9.5.3 and 10.4.1).

  - *Sub research question 4.2: Does the TEIF Method help to improve understanding of how environment context affects interaction when hearing impaired people are involved?*

Participants thought that the TEIF Method helped improve a developer's understanding of how environment context affects interaction involving hearing impaired people (Scetions 9.5.3 and 10.4.2).

- *Sub research question 4.3: Does the technology suggestions table in the TEIF Method help identify technology solutions to interaction problems involving hearing impaired people?*
  Participants thought that the technology suggestions table in the TEIF Method helped with identifying technology solutions to interaction problems involving hearing impaired people (Sections 9.5.3 and 10.4.3).

- *Sub research question 4.4: Is using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the Method?*
  Participants thought that using the whole TEIF Method would be more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the method (Sections 9.5.4 and 10.4.4).

1.5 Report Structure

The overview of the following ten chapters is as follows:

Chapter 2 discusses the background literature relating to the difficulties faced by hearing impaired people in their access to information about history and culture, the consideration of related interaction frameworks, guidelines for accessibility and usability, the concept of universal design, Thai Museums, and technologies which assist and improve access for hearing impaired people.

Chapter 3 introduces the development of a comprehensive TEIF whose components and sub components encompass all types of interactions in any time and place.

Chapter 4 describes the development of the TEIF Method for developers to apply the TEIF. An example scenario and a technology solution involving hearing impaired people visiting a Thai local museum were developed to help illustrate the TEIF Method through which the TEIF could be applied.

Chapter 5 describes the research methodology that has been used for review and validation of the TEIF and TEIF Method. The methodology for choosing the experts is also discussed.

Chapter 6 shows the findings of the pilot study and the successful expert validation and review of the TEIF and TEIF Method.

Chapter 7 discusses the findings of the successful expert validation and review of the TEIF and TEIF Method that answer research questions 1 and 2.

Chapter 8 explains an experimental design methodology for the user evaluation of the TEIF Method in order to answer research questions 3 and 4. The possible approaches to user evaluation are discussed. The design of the questionnaires is also presented.

Chapter 9 reports the statistical analysis and results for the experiments, and the analysis and results for the questions asked to participants following their completion of the experimental tasks.

Chapter 10 discusses the results related to the exploration of the research questions. Research questions 1 and 2 concern the development of the TEIF and the TEIF Method. Research question 3 addresses the use of the TEIF Method by developers. Research question 4 investigates the ways the TEIF Method helps developers. The limitations of the research are also discussed in this chapter.

Chapter 11 concludes the thesis by summarising the contribution to research and identifying directions for future work.

1.6 Publication list

The following peer reviewed conference papers and journals based on the work of this thesis have been accepted for publication:

1. Angkananon, K, Wald, M and Gilbert, L (2015). Technology Enhanced Interaction Framework and Method for Accessibility in Thai Museums. ICoICT 2015 (The 3rd International Conference of Information and Communication Technology). May 27-29, 2015, Bali, Indonesia.
2. Angkananon, K, Wald, M and Gilbert, L (2014). Developing and Evaluating a Technology Enhanced Interaction Framework and Method that can enhance the Accessibility of Mobile Learning. Themes in Science & Technology Education. Vol 7, No. 2, December, 2014.
3. Angkananon, K, Wald, M and Gilbert, L (2014). User Evaluation of Technology Enhanced Interaction Framework. In proceeding of the 14th International

Conference on Computers Helping People with Special Needs, Part II, LNCS 8548, pp. 342–349, 2014. © Springer International Publishing Switzerland 2014.

4. Angkananon, K, Wald, M and Gilbert, L (2014). Designing Accessible Technology Enhanced Interactions. In proceeding of the Young Researchers Consortium, 14th International Conference on Computers Helping People with Special Needs, July 07-08 2014, Paris, France.
5. Angkananon, K, Wald, M and Gilbert, L (2014). Applying technology enhanced interaction framework to accessible mobile learning. In procedia Computer Science, volume(s) 27, February 25 2014, pages 261-270.
6. Angkananon, K, Wald, M and Gilbert, L (2013). Technology Enhanced Interaction Framework: issues in evaluating a new software design framework and method. In International Journal of Advances in Computer Science and its Applications – IJCSIA, volume 4: issue 1 [ISSN 2250 – 3765], January 09 2014.
7. Angkananon, K, Wald, M and Gilbert, L (2013). Technology Enhanced Interaction Framework: issues in evaluating a new software design framework and method. In proceeding of International Conference on Advances in Computing, Electronics and Communication - ACEC, September 20-21, Zurich, Switzerland.
8. Angkananon, K, Wald, M and Gilbert, L (2013). Using the technology enhanced interaction framework for interaction scenarios involving disabled people. In International Journal of Advances in Computer Science and its Applications-IJCSIA, volume 3, pages 1-5.
9. Angkananon, K, Wald, M and Gilbert, L (2013). Findings of expert validation and review of the technology enhanced interaction framework. In, the 13th International Conference on Software Engineering Research and Practice, Las Vegas, US, July 22 – 25 2014.
10. Angkananon, K, Wald, M and Gilbert, L (2013). Towards a Technology Enhanced Interaction Framework. In GSTF International Journal on Computing (JoC), Vol. 3 No. 2, July 2013.
11. Angkananon, K, Wald, M and Gilbert, L (2013). Issues in conducting expert validation and review and user evaluation of the technology enhanced interaction framework and method. In, the Eighth International Conference on Internet and Web Applications and Services. ICIW 2013, IARIA, Rome, Italy, June 2013, pages 124-128.

12. Angkananon, K, Wald, M and Gilbert, L (2013). Designing mobile web solutions for interaction scenarios involving disabled people. In, 8th IASTED International Conference on Advances in Computer Science, Phuket, Thailand, April 10 – 12.
13. Angkananon, K, Wald, M and Gilbert, L (2013). Technology enhanced interaction framework. In, CGAT 2013 - 6th Annual International Conference on Computer Games, Multimedia and Allied Technologies, Singapore, SG, 22 - 23 Apr. 6pp.
14. Angkananon, K, Wald, M and Gilbert, L (2013). Using the technology enhanced interaction framework for interaction scenarios involving disabled people. In, 2nd International Conference on Advances in Information Technology, Bangkok, Thailand, April 06 –07 2013.

Chapter 2 Literature Review

This chapter discusses the background literature relating to the problem introduced in chapter 1. It begins by discussing related frameworks (section 2.1), guidelines for accessibility and usability (section 2.2), and the concept of universal design (section 2.3). Then, the use of interaction frameworks in the design process (section 2.4), and design patterns (section 2.5) are presented. The difficulties faced by hearing impaired people are identified in section 2.6. Section 2.7 explains about Thai Museums and technologies which assist and improve access to information for hearing impaired people are discussed in section 2.8. Section 2.9 explains technologies which assist hearing impaired people in their access to history and culture. Finally section 2.10 presents the summary of the chapter.

2.1 Review of Related Frameworks

As information and communication technology has become more important in society, many researchers have been concerned with how to use technology to support communication between people and improve interactions between people, technology, and people (Dix, 1994, 1995, 1997; Rukzio, 2008; Sung, Chang, Hou, & Chen, 2010; Vyas, Dix, & Nijholt, 2008) or improve interactions between people, technology and objects (Sung et al., 2010).

There has, however, been no framework that has helped technology developers to consider all of the possible interactions that occur at the same time and in the same place although there have been projects concerned with how to use technology to support some of these interactions. For example, artefact-mediated-communication has been used to support cooperative work (Dix, 1994; Vyas et al., 2008), a mobile digital guidebook has been used to enhance visitors' interaction with physical objects in museums (Rukzio, 2008; Sung et al., 2010) and mobile devices have been used as mediators for the interaction with a physical object using QR codes, RFID tags and NFC tags (Broll et al., 2007; Rukzio, 2008).

The frameworks that will be analysed in chapter 3 are briefly described in the following paragraphs. Tables 2-1 – 2-6 categorise the frameworks by extension, purpose, principle / theory, type of interaction, applicability, use, evidence, technology, and diagram type. The diagrams used by the authors of the frameworks to help explain their frameworks are also presented as they will also be analysed in chapter 3 to help identify the best way to illustrate technology enhanced interactions. The interaction Frameworks reviewed in this chapter are all based on principles rather than being an architecture of technical solutions.

Table 2-1 Review of related frameworks

Framework 's /model's name	Extended	Purpose	Principle /theory	Interaction types	Where	useful	Evaluated /evidence	Technology	diagrame	Role
Transactional analysis (Berne, 1964)	I'm ok, You're ok- Thomas Anthony Harris 1969	Analyse social psychology, analyse human behaviour, improve communication	Ego state, Life position, stroke, games, script	P-P	anywhere	Adult-adult relationship	Subjective, Recording conversation, transcription	No	-	Parent, adult, child
Conversational Framework (Laurillard, 1993)	The educational media support the conversatio nal framework	Describing the learning process, Analyse teaching media, design teaching material	Psychology, Principle of Educational media, a principled teaching strategy	T-S	Original in University	Identifying the activities to improve learning analysis media to offer interaction	Objective,tutorial simulations , observation, pre and post-test to check learning gain, open-ended questionnaire	Yes	Learning activities process	Teacher -student
Conversation Analysis Harvey Sacks (1972)		Study social interaction, psychology	International sociolinguistics, discourse analysis, discursive psychology, Transcription , turn taking	P-P	Anywhere	-Both verbal and non-verbal interaction -Knowing when and how to speak in the right turn -Cultural different in matters of turn taking can lead conversational breakdown	Subjective, Record, transcribing conversation	Yes	-	-

Table 2-2 Review of related frameworks (continued 2)

Framework 's /model's name	Extended	Purpose	Principle /theory	Interaction Type	Where	useful	Evaluated /evidence	Technology	diagrame	Role
Interaction Analysis Ned Flander		Analyse interaction in teaching and learning	Modern psychology, accessible theory, Flander's Interaction Analysis 10 Category	T-S	School - classroom	Verbal behaviour categories Constructing Interaction Matrix	Recording, Encoding & decoding process, observation procedure of interaction	no	Table Diagram chart	Teacher Student
Role of Artefacts in Mediated Communication (Vyas et al., 2008)		explored the role of artefacts supporting mediated communication	HCI	User-artefact-user	F-T-F	serve as a tool in artefact -mediated communication		Yes	-	User-artefact-user
Cooperative work framework (Dix, 1994)		Computer support - communication	CSCW Computer support cooperative work	P-C-A	anywhere	Computer support communication		Yes	diagram	Cooperative work framework (Dix, 1994)

Table 2-3 Review of related frameworks (continued 3)

Framework 's /model's name	Extended	Purpose	Principle /theory	Interaction Type	Where	useful	Evaluated /evidence	Technology	diagrame	Role
an electronic guild book for learning engagement in a museum of history (Sung et al., 2010)		Designing mobile guidebooks to enhance interaction and stimulate motivation.	HCCI	V-C V-C-O V-C-context V-P-C-Context		HCCI Design the interaction	Background knowledge Test Learning achievement test Experimental tools HCCI guidebook Video cameras	Yes	Matric diagram	
A Ecological Model of the Communication Process (Foulger, 2004)		Show process of communication	Psychology, sociology, anthropology, linguistics, media ecology and communication	P-P Consumer-creator Message-system	anywhere	Complex interactions between message, people, languages and media -Fundamental reading, a compact theory of messages and systems		Yes	process	Creator consumer
The time/space matrix Ellis et al, 1991 (Olesen & Myers, 1999)		Improve communication	Synchronous, asynchronous	P-C-P	anywhere	Improving communication		Yes	table	

Table 2-4 Review of related frameworks (continued 4)

Framework 's /model's name	Extended	Purpose	Principle /theory	Interaction Type	Where	useful	Evaluated /evidence	Technology	diagrame	Role
Multimodal Interaction Framework W3C 2003 (Larson, Raman, & Raggett, 2003)		Designing system	HCI	P-C	Computer system	HCI designing		Yes		
Norman's model of Interaction 1988		Execution and evaluation	1. establishing the goal 2. forming the intention 3. specifying the action sequence 4. executing the action 5. perceiving the system state 6. interpreting the system state 7. evaluating the system state with respect to the goals and intentions	H-C	anywhere	Execution and evaluation	Norman's model is that it does not make the UI explicit.	Yes		
The Interaction Model Abowd and Beale (1991)	Norman's model	Designed to be a more realistic model.	Norman's model User interface	U-S	Computer system	Extended making the UI explicit		Yes		

Table 2-5 Review of related frameworks (continued 5)

Framework 's /model's name	Extended	Purpose	Principle /theory	Interac-tion Type	Where	useful	Evaluated	Technology	diagrame	Role
Gain		a conceptual framework for person-computer interaction in complex systems	based on an analysis of systems theory literature to derive design principles for person-computer interaction and a hierarchical model of person-computer systems	S-S P-P P-C C-E P-E C-C	Computer system	Shows the relationship between system and components, person and computer and equipment		Yes	Yes	User-system
Human Activity Assistive Technology Model (HAAT) (Cook & Hussey, 1995)		Framework for studying human performance in tasks involving technology	HAAT	H-A-A-T	Computer system	Shows the interrelationship between system components.		Yes	Yes	H-A-A-T
Computer mediated communication (CMC) systems for supporting group learning (Lee, Armitage, Groves, & Stephens, 2009)		use of asynchronous CMC systems for supporting group learning	CMC	User-system	Computer system	representing missions or stakeholder goals		Yes	-	User-system

Table 2-6 Review of related frameworks (continued 6)

Framework 's /model's name	Extended	Purpose	Principle /theory	Interac-tion Type	Where	useful	Evaluated	Technology	diagrame	Role
Jetter	Jacob et al. (2008) Reality Based Interaction (RBI) Framework	Blended Interaction as a conceptual framework for the design of interactive spaces building on the four domains: a user's individual interaction, the users' social interaction and communication, their established workflows, and their physical environment. to include users' concepts learned from familiar digital technology.	design of interactive spaces	P-T	Leaning environment	Blend between F-T-F and computer mediated interaction		Yes	-	-
Blended learning (Klink, 2006)	-	evaluated the use of synchronous and asynchronous interaction methods in the blended learning environment	e-leaning, learning Blended learning	P-C	Leaning environment	Blend between F-T-F and computer mediated interaction	Evaluating the use of interaction methods in the blended learning environment	Yes	Conceptual framework	-

The detail of interaction frameworks are reviewed under the following four main category headings. Although two interaction frameworks (Dix, 1994; Klink, 2006) also include a direct communication element their main focus is interactions that include technology and so are explained under section 2.1.2 only.

2.1.1 Direct Communication

Berne (1964) analysed the interactions between people in terms of the roles they play (parent, adult, child) and showed communication could break down when interactions 'crossed' on his Interaction Diagram. Figure 2-1 shows a typical crossed transaction. An example is as below:

Agent's Adult: *"Do you know where my cuff links are?" (note that this stimuli is directed at the Respondents Adult).*

Respondent's Child: *"You always blame me for everything!"*

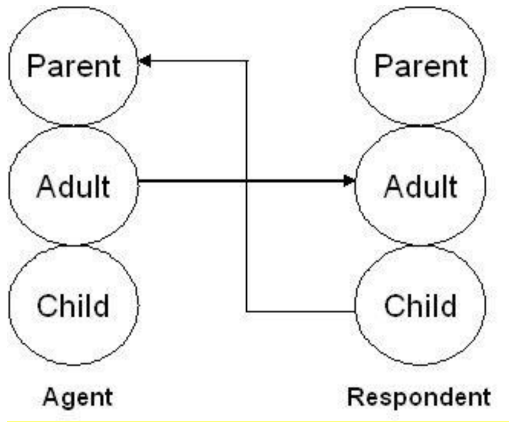


Figure 2-1 Crossed Transaction, Berne (1964)

Laurillard (1993) developed a conversational framework to describe the learning process involved between teacher and student in higher education and identified the activities required to improve learning and analysed the role technology might play in this process. Figure X shows how Laurillard's diagram illustrates the activities and purpose of interactions between teacher and student but does not include technology.

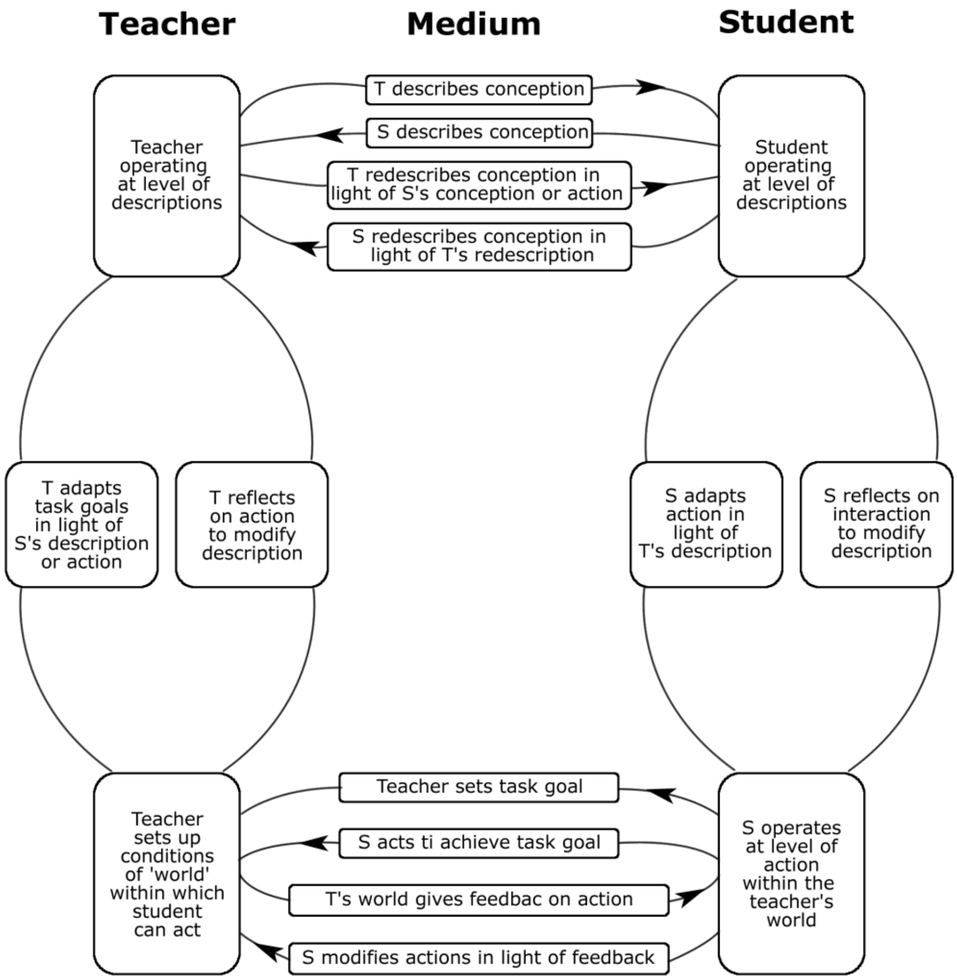


Figure 2-2 The conversational framework identifying the activities necessary to complete the learning process

Sacks (1974) identified roles and cultural differences in both verbal and non-verbal communication and through conversational analysis studied the real-time sequential ordering of actions and the structures of the interactions.

Flanders (1960) identified ten categories of teaching and learning interactions of teachers and students in school classrooms (shown in Table 2-7) in order to try and help teachers analyse what behaviours helped learning to occur through using the categories as a checklist.

Table 2-7 Ten categories of teaching and learning interactions of teacher and students in school classrooms

		Catagories
Teacher talk	Indirect Influence	1. Accept feeling
		2. Praises or encorages
		3. Accept idea
		4. Asks questions
	Direct Influence	5. Lectures
		6. Gives directions
		7. Criticises
Student talk		8. Pupil’s response
		9. Student talk intiation
		10. Silence or confusion

Foulger (2004) extended Shannon’s model by presenting an Ecological Model of the Communication Process (Figure 2-3) to better represent its structure and key constituents: creator and consumers; messages created using language within media; consumed from media and interpreted using media. He noted the importance of psychology, sociology, anthropology, linguistic, media, and communication in understanding such complex systems.

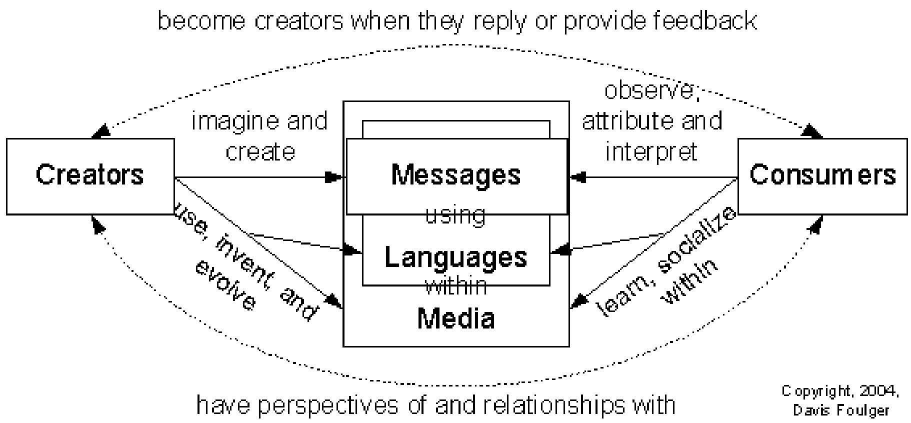


Figure 2-3 A Ecological Model of the Communication Process

2.1.2 Interactions

Sung et al. (2010) proposed a framework for designing a mobile electronic guidebook for a history museum. An electronic guidebook was implemented and evaluated in comparison to a worksheet and visiting without any guidebook or worksheet. Users spent the most time with exhibits when using the electronic guidebook but there were no significant differences in the knowledge gained about exhibits. Their framework did not consider a scenario where an expert presented or explained the exhibits as shown in Figure 2-4.

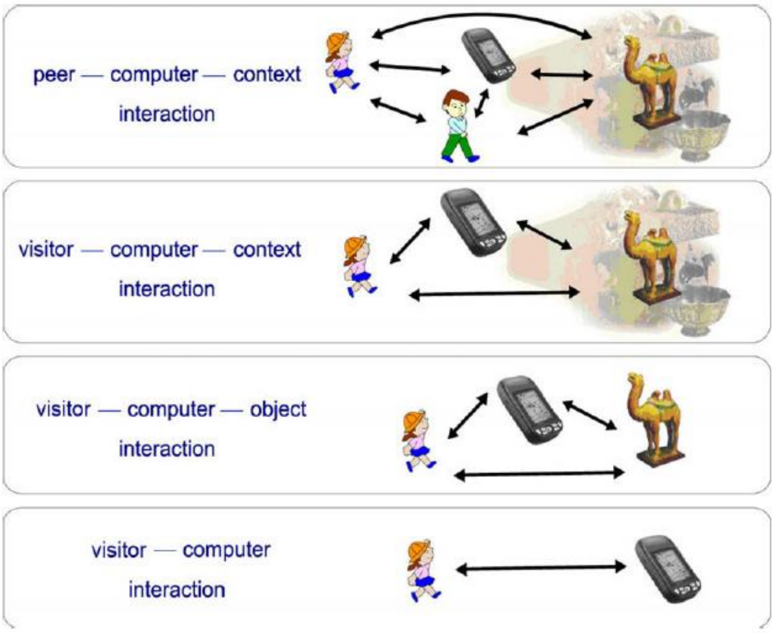


Figure 2-4 The framework of the human-computer-context interaction for designing mobile guidebooks

Rukzio (2008) presented a physical mobile interaction framework (Figure 2-5) for using mobile devices as mediator for the interaction with a physical object and discussed its implementation. The interactions were Human-Computer, Human-Real World, Computer-Real World, and Computer-Computer.

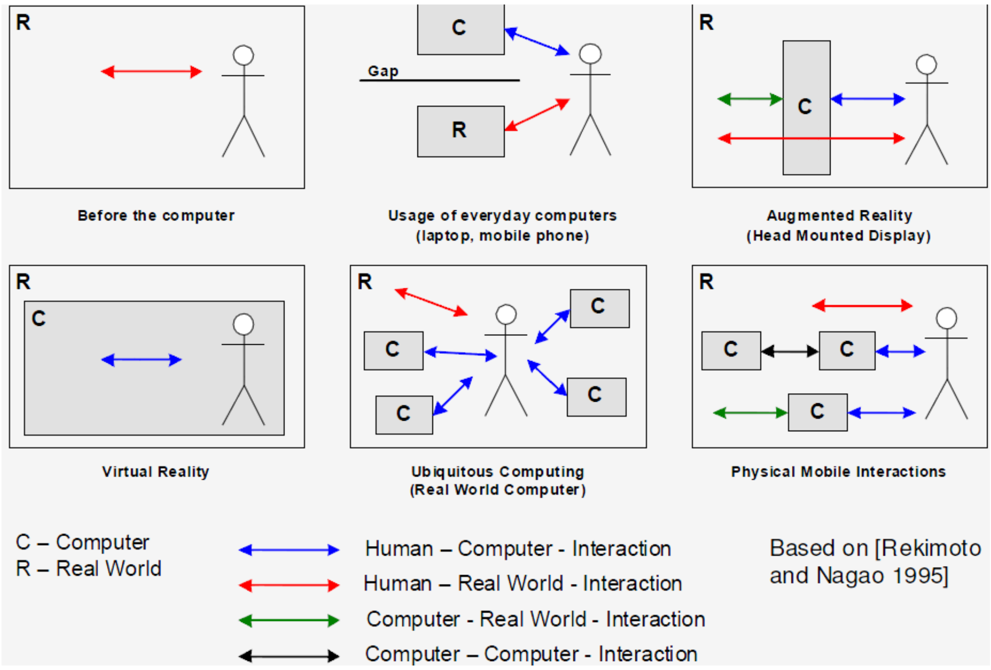


Figure 2-5 Physical mobile interaction framework

W3C Multimodal Framework (Larson et al., 2003) identifies the major components in a multimodal system and the mark up languages used to describe information and data flow. The basic components are human user, input, output, interaction manager, session, and system and environment as shown in Figure 2-6.

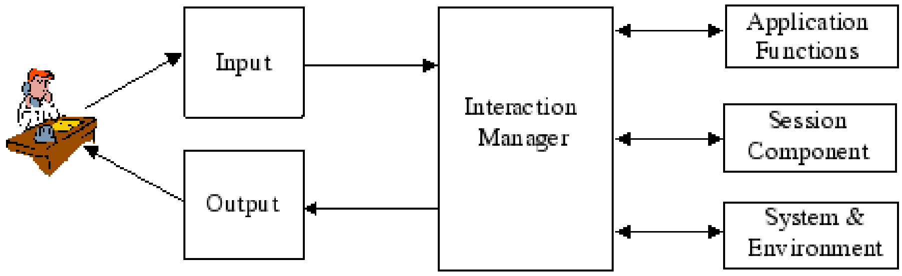


Figure 2-6 The W3C Multimodal Interaction Framework

Lee et al. (2009) produced a report commissioned by the JISC Technology Applications Programme on the use of asynchronous computer mediated communication (CMC) systems for supporting group learning and identified as critical success factors: educational purpose, need, training, information overload, item headings, initial items, and activity. Table 2-8 shows the components used with explanations.

Table 2-8 CMC Metaphor

Component	*Explanation*
Members	The users of the system
Personal Index	To track items
Roles	Privilege collections
Tickets	Privilege exceptions
Groups	Super members of the system
Membership List	Status of all members
Group Index	Shared by all members
Group Conference	Owned by group
Group Messages	Sent and received to group
Messages	Private, Group, and Public
Conferences	Topic communication space
Membership List	Status of all members
Conference Index	Comment keys
Comments	Entries in a conference
Directory	Of members, groups & message sending key
Interest Index	Member interests & message sending key
Topic Index	Group and conference topics
Activities	Executable programs
Notifications	Transaction notices
Forms	Structured data collection
Attachments	File attachments
Lists	Collections of item (e.g. marked list)
Index Entries	
Reference keys	Pointers to items
Filters	Screening terms
Labels	Substitutions for commands or strings

Gaines (1988) observed that recommendations based on practical experience of single users operating standard workstations had little to offer developers of complex systems integrating complex behaviour of people and computers. To address this issue he presents a conceptual framework for person-computer interaction in complex systems based on an analysis of systems theory literature to derive design principles for person-computer interaction and a hierarchical model of person-computer systems. His model (Figure 2-7) acknowledges a technological system’s behaviour reflects the value systems and inter-personal attitudes of the system designer and so the same systems principles apply to the psychology, sociology, human-computer interaction, and computer-computer interaction.

Through analysis of the principles underlying distinctions and interactions between people, computers, equipment and systems, and drawing the distinction between structure (what it is) and behaviour (what it does), and applying the same distinctions, terminology and models to people, their interactions with each other, their interface to the information technology, and its interface to other information technology he presents the key features of a computer system in terms of six hierarchical layers:

- *Cultural layer* reflecting purpose and structure
- *Intentionality layer* where the anticipatory nature of an intelligent system leads to the acquisition of knowledge.
- *Knowledge layer* supporting the modelling and control activities of an anticipatory system.
- *Action layer* transmits the activities supporting the interfacing to the world.
- *Expression layer* supports the encoding of actions and communications.
- *Physical layer* addresses how these encodings exist physically in the external world.

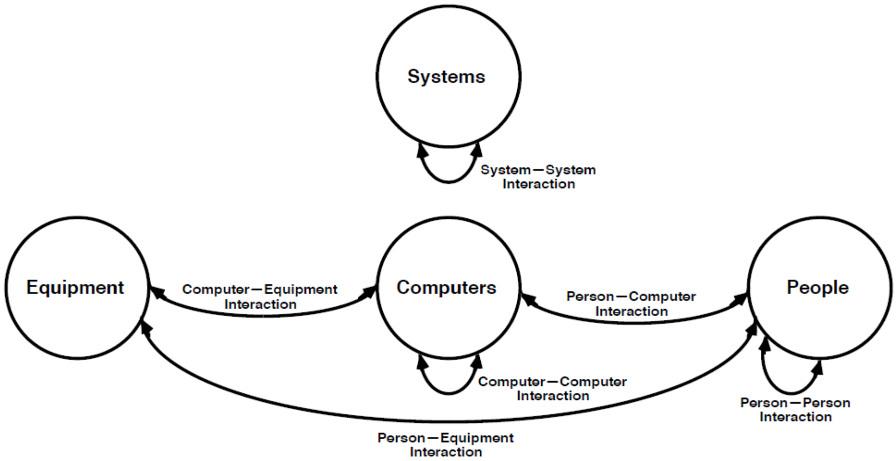


Figure 2-7 Abstraction and analogies in the analysis of person-computer interaction (Gaines, 1988)

Norman's model (Norman & Draper, 1986) of interaction is a useful means of understanding the interaction between human user and computer. It allows other works to extend the common model. However, the model only considers the system as the interface; it does not deal with the system's communication. Norman uses this model of interaction to illustrate why some interfaces cause problems to users. This is because the user and the system do not use the same terms to describe the domain and goals. Therefore the interface should aim to reduce this problem.

Seven stages in Norman's model are as follows:

1) Establishing the goal
2) Forming the intention
3) Specifying the action sequence
4) Executing the action

5) Perceiving the system state
6) Interpreting the system state
7) Evaluating the system state with respect to the goals and intentions

Abowd and Beale (1991) extended Norman's model to help clarify the role of the interface through the inclusion of the input and output components of the user interface with a simple diagram (Figure 2.8).

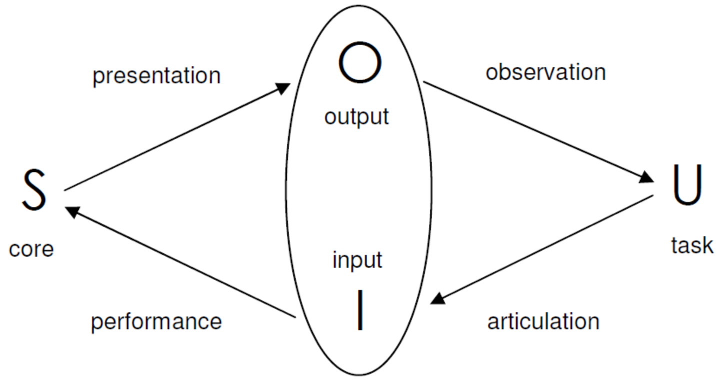


Figure 2-8 The General Interaction Framework

A framework for Computer Supported Cooperative Work (Dix, 1994) seems to address some of the possible interactions but it misses out some important interactions in the same time and at the same place situations such as people using technology to interact with real objects. In Dix's framework, the participants communicate with other participants in what is called 'direct communication'. Furthermore, the participants also interact with artefacts (man-made technology tools) by 'controlling' or 'acting'. Sometimes an artefact is shared between the participants; in this case, the artefact is not only the subject of communication but can become a medium of communication, called 'feedthrough'. In communication about work and the artefacts of work, various means are used to refer to particular artefacts, and Dix terms this 'deixis', as shown in Figure 2-9. Dix's Framework addressed that all interactions involve technology and so does not include a separate technology component.

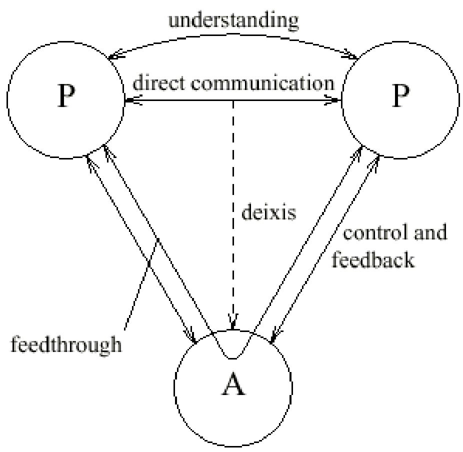


Figure 2-9 Computer Supported Cooperative Work – A framework (Dix, 1994)

Dix (1995) discussed the application of his CSCW Framework to mobile devices and Dix (1997) used his framework to investigate issues determining the viability of the World Wide Web as an infrastructure for cooperative work.

Vyas et al. (2008) explored the role of artefacts supporting mediated communication (Figure 2-10). They used the term ‘artefacts’ to refer to analogue and digital objects that can serve as a tool in artefact - mediated communication. They asked students of a master’s course on Visual Design to come up with and use a communication metaphor in their concept design process. They noted the use of communication metaphors is culturally dependent.

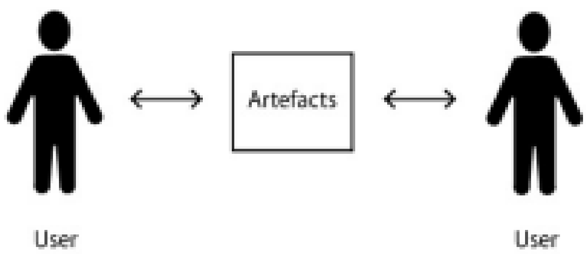


Figure 2-10 Artefact-mediated Communication

Jetter, Geyer, Schwarz, and Reiterer (2012) proposed Blended Interaction as a conceptual framework for the design of interactive spaces building on the four domains: a user’s individual interaction, the users’ social interaction and communication, their established workflows, and their physical environment. Their framework extended Jacob et al. (2008) Reality Based Interaction (RBI) Framework to include users' concepts learned from familiar digital technology.

Klink (2006) evaluated the use of synchronous and asynchronous interaction methods in the blended learning environment and concluded that more attention should be paid to online students and that there needs to be more variety in interaction methods. Critical success factors identified were lecturers' time and effort and cost of high quality resources (e.g. interactive animations). Klink identified classroom learning as offline interaction only and did not consider the use of technology to enhance face to face same time same place learning (Figure 2-11).

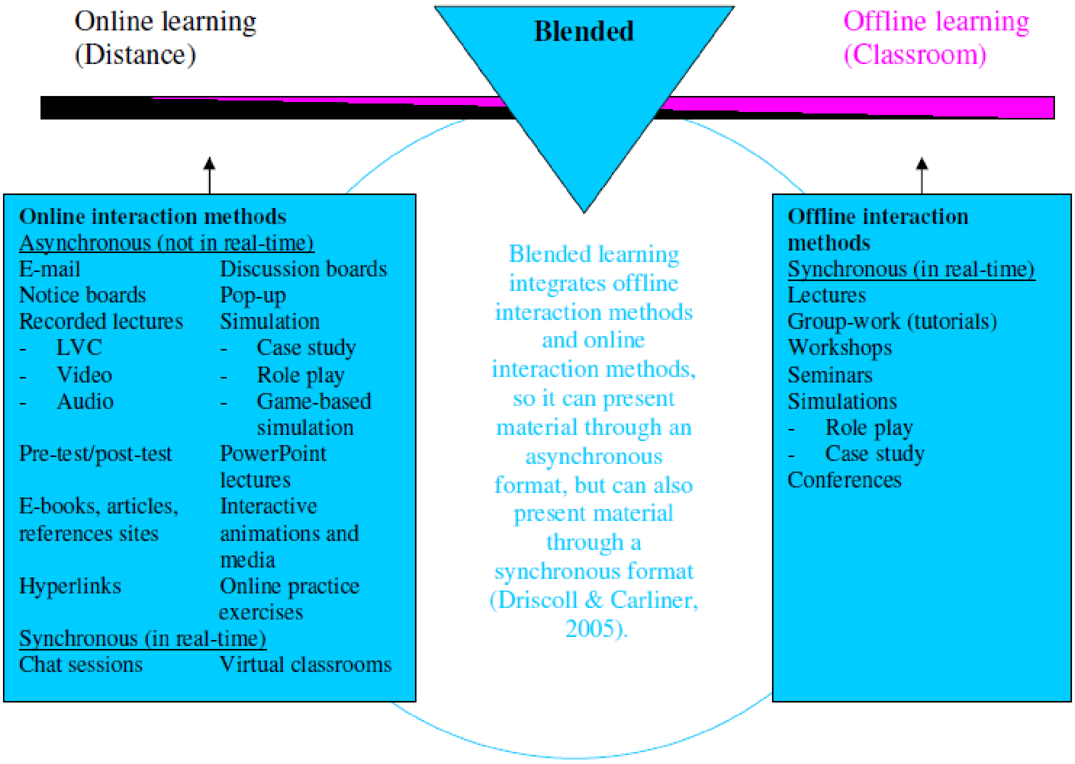


Figure 2-11 Blended learning model: possibilities to blend

2.1.3 Space / Time

Ellis, Ridolfi, and G. & Zwirner (1991) focused on a time / space matrix to classify synchronous and asynchronous technology by whether it facilitated interaction at the same or different time or place and provided some examples (Figure 2-12).

Time

Place		Same	Different
	Same	Electronic Meeting System Computer conferencing Group Decision Support Systems Presentation software PC screen sharing software	Teleconferencing Video Audio
	Different	Video Conferencing Synchronous chat systems	Asynchronous Groupware Email Bulletin Boards Internet News groups Workflow software Group authoring software

Source: Ellis *et al*, 1991

Figure 2-12 Time / space matrix to classify synchronous and asynchronous technology

2.1.4 Considering Accessibility

Cook and Hussey (1995) modified Bailey’s Human Performance Model in order to accommodate assistive technology. The components of their model are: human (abilities / skills), activity (determined by role), context (setting, social, cultural, physical), and assistive technology (hardware, software, non-electronic) which they illustrated as shown in Figure 2-13.

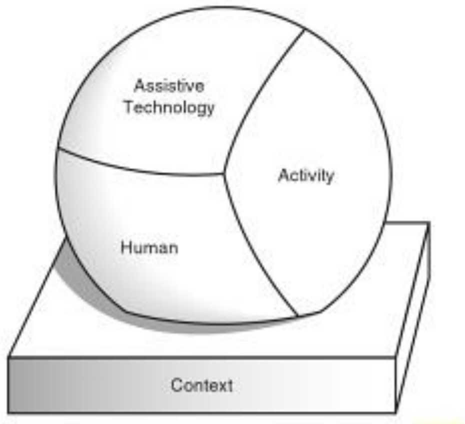


Figure 2-13 The Human Activity Assistive Technology Model

2.2 Guidelines for Accessibility and Usability

Petrie and Bevan (2009) discussed the concepts of accessibility, usability and user experience as criteria for developers to evaluate their system. They quote ISO usability and accessibility definitions and World Wide Web Consortium (W3C) Web Accessibility Initiative (WAI) definition of accessibility to highlight a current lack of agreement about whether accessibility means universal design or usability for older and disabled people. They also refer to the 2008 draft ISO standard for user experience (UX) which defines UX as ‘A person’s perceptions and responses that result from the use or anticipated use of a product, system or service’ and note that UX will become more important in the future. They also discuss the role of accessibility, usability, and UX evaluations in the design process and group them under the headings: automatic checks, experts, models and simulations, users, and usage data.

The extensive guidelines for accessibility and usability (e.g. WCAG 2.0, BS8878, Neilsen’s usability heuristics, Shneiderman’s 8 golden rules, W3C, and MWBP) refer only to the interactions between people and technologies and not interactions between people or people and objects.

2.3 Universal Design

Universal design is a concept of ‘design for all’ and represents an approach to designing products or building features which are suitable for many different types of users without the need for adaptation or specialized design (The Center for Universal Design, 1997).

2.3.1 Universal design principles

The term of universal design was first used by Mace, in the United States (Mace, 1985). The principles of universal design were developed by 10 experts in 1997. The Centre for Universal Design published the seven universal design principles as shown in Table 2-9. These seven principles will provide suggestions for both designers and users about the characteristics of more useable products and environments, which can be used to evaluate existing designs, to guide the design process and to educate. Moreover, universal design principles are required in terms of decreasing discrimination in society. However, not all accessible design can be considered universal design. For example, a control panel with large membrane switches may be suitable for people with limited manual control but not for people who are blind (Molly Follette Story M.S., 1998). Accessible design consists of three main factors: universal design, adaptable design and transgenerational design.

Table 2-9 the seven principles of universal design

Principle	Definition
1.Equitable use	The design is usable and marketable to people with diverse abilities
2.Flexibility in use	The design accommodates a wide range of individual preference and abilities.
3. Simple and intuitive use	The design is easy to use and understand, regardless of user's experience, knowledge, language skills or current concentration level.
4. Perceptible information	The design communicates necessary information effectively, regardless of ambient conditions or sensory abilities
5. Tolerance for error	The design minimizes hazards and adverse consequences of accidental or unintended actions.
6. Low physical effort	The design can be used efficiently and comfortably, with a minimum of fatigue.
7. Size and space for approach and use	Appropriate size and space for approach, reach, manipulation, and use regardless of body size, posture, or mobility.

Source: The Center for Universal Design (1997)

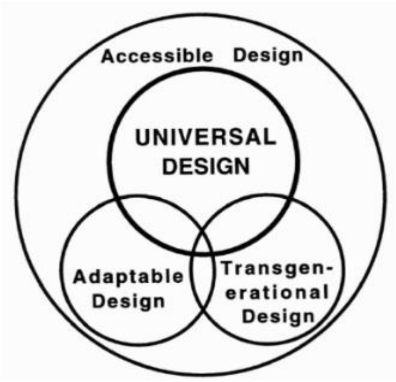


Figure 2-14 Relationship between accessible, adaptable, transgenerational, and universal design (Molly Follette Story M.S. (1998)

Figure 2-14 shows that universal design, adaptable design and transgenerational design are all subsets of accessible design. The design can be considered from two or three factors. In addition, universal design can sometimes also include adaptable design or transgenerational design.

Petrie et al. (2002) investigated the use of universal interfaces for multimedia documents. They surveyed 75 participants including blind, partially sighted, deaf and dyslexic readers, plus 31 experts in visual impairment, deafness and dyslexia using interviews and questionnaires. From the responses, it was found that the users' requirements varied depending on their disabilities, as shown in Figure 2-10.

Table 2-10 user requirements for the different target reader groups

Requirements	Blind readers	Partially sighted readers	Deaf readers	Dyslexic readers
Speech output for all text	✓			
Control of speech output (rewind, skip, forward, pause)	✓			
Volume and rate control	✓			
Good description of images and graphics (complete verbal descriptions of these objects)	✓			
Audio description in videos	✓			
Ability to vary font style and size		✓	✓	✓
Ability to vary text and background colour to increase contrast		✓	✓	✓
Ability to increase line spacing, line length			✓	✓
Word-by-word or sentence-by-sentence highlighting of text			✓	✓
Enlargement of images, graphics and video		✓		
Speech output to supplement visual output		✓		✓
Good navigational aids to facilitate ,movement around enlarged screens		✓		
Text or graphic output for all speech , sound effects, music and auditory signals			✓	
Extensive use of pictorial, graphic and video material			✓	
Online dictionary – in text and sign language			✓	
Translate text into sign language			✓	
Navigation by images/graphics rather than words				✓
Presentation of information in short and simple "bite sized" chunks for ease of reading and comprehension			✓	✓

Source: Petrie et al. (2002)

It is important to note that readers in each group have a significant difference in their requirement to access information. For instance, one partially sighted reader may have particular problems in colour blindness, or another may have no difficulties with colour but require enlargement of text and graphics. Deaf people require text or graphic output for all speech, sound effects, music and auditory signals while blind people require speech output for all text. However, there are some points for which different groups have the same requirement. For example, partially sighted readers, deaf readers and dyslexic readers agreed that they needed vary to be able to font style and size, as well as text and background colour to increase the contrast of written material. Additionally, deaf readers and dyslexic readers require increased line spacing or line length, word-by-word or sentence-by-sentence highlighting of text and presentation of information in short and simple "bite sized" chunks for ease of reading and comprehension. This diversity of reader requirements need to be considered in the provision of electronic information for different individuals and reader groups.

Petrie et al. (2002) also developed a tourist guide for the German town of Wernigerode using HTML 4.0 which is suitable for all the reader groups mentioned above. Multimedia documents with multimodal interfaces were developed with the aim of assisting disabled people in their access to electronic information sources. Readers have their own requirements which are needed in order to successfully access information. The multimedia tourist guide can be evaluated by considering the 4 user groups as follows:

- *Tourist guide for blind readers*

HTML 4.0 has been introduced in order to provide additional formatted textual contents for blind users via a screen reader. For instance, a listing is read cell by cell with row and column headings. For images, the developers revealed that they have inserted text through the alt-text attribute for use by synthetic speech renders.

- *Tourist guide for partially sighted readers*

Partially sighted readers need an assistive device for screen magnification of text and images. It is important to allow background and foreground colours to be easily adjusted to allow colour blind users to select the most appropriate colours. They developed Scalable Vector Graphic (SVG) versions of images and maps, which allow the output to be zoomed by up to 4 times without the quality degradation.

- *Tourist guide for deaf readers*

Subtitles, which can be both single-line and multi-line, are enriched for deaf people. Additionally, it is possible to use different font styles by using the SMIL-based tool, Magpie, to determine timing for subtitles.

- *Tourist guide for dyslexic readers*

A screen reader with text highlighting is essential for dyslexic readers in using the tourist guide. Furthermore, font style modifications and line distance variations are easily added into HTML through CSS. The developers created pages without text, instead consisting of videos to make the tour attractive to dyslexic users. Pages describing sightseeing stops have large meaningful photos. Background history information is considered and presented in video form if readers require it.

In conclusion, readers with different disabilities have their own requirements which need to be addressed so that they can successfully access information. Blind people require a system which describes text, images, video and background information by using voice. Partially sighted users need a system that can magnify text and images but designers have to be careful about designing content with colours which can affect colour blind people. Deaf users have a difficultly with auditory information so the information should be provided as text and images. Videos should provide subtitles including descriptions of background audio such as music, phone ringing and doorbells. Finally, dyslexic users who have reading difficulties can easily get confused when faced with lots of information. Therefore, the tour guide is designed to present meaningful and attractive information by using videos instead of presenting with long textual content.

Burgstahler (2002) introduced distance learning programs for making courses accessible to everybody. The programme focused on 5 groups of disabilities.

1) *Mobility Impairments*

   Some students who have mobility impairments with their hands use alternative keyboards, mice, speech control and other input devices to operate navigational tools and to access Internet-based courses. In the case of real time communication, if students type messages slowly, they are not able to effectively chat in real-time. Some students who have mobility impairments with their legs, require wheelchair-accessible locations to participate in on-site meetings as part of their courses.

2) *Visual Impairments*

   Screen reader software and speech synthesizers are important for enabling blind individuals to use their computers. The software will read the text which appears on the computer screen, so blind users will listen to the voice and operate the computer by pressing a keyboard or a mouse. Moreover, they might use a browser that can be read the text on the World Wide Web or they may use a multimedia browser with the graphical features turn off. Therefore, websites for blind students should be designed, so that the screen readers can make sense of the content. For students who have limited vision, they may require a special feature to enlarge screen images. Additionally, if web content is presented in a different colour, it might affect colour-blind students in their ability to distinguish the content.

3) *Learning Disabilities*

There are various types of learning disabilities. Some students have difficulty in their reading, writing and/ or processing of information. For students with reading difficulties, this can be aided by providing audiotaped books. The research found that students with a learning disability may not understand websites when the website provides too much information on when the layout of the website is changed.

4) *Hearing Impairments*

People with hearing impairments do not have barriers in their access to websites which provide text and images. However, they may suffer from websites which provide audio or video without providing captioning or transcription. Furthermore, audio with captioning is also a barrier for Deaf people who have a sign language as their primary language. Another difficult situation is in a conference or meeting when encountering people with hearing loss, unless sign language interpreters and captioning are provided.

5) *Speech Impairments*

Using text messaging (SMS or email) can provide benefits to students with speech impairments. Unfortunately, they are not able to participate in audio conferences which may from part of distance learning courses.

2.3.2 Mobile User Interface Design

Jaeyeob (2005) suggested factors which can be used in the design of mobile user interfaces in order to make them easily accessible for all users. The Heuristic-Evaluation method was used to evaluate these user interfaces (Lee su jung, 2003).

1) **Menus** should make it easy to go back to the home menu. Accurate information should be provided due to the size limitation of the screen. Moreover, easy navigation should be provided.
2) **Content menus** should not consist of more than one line and users also require a simple, clear and convenient way to move up and down.
3) **Functions**, such as commands, search or start functions should be designed to support the keypad of mobile devices and make users feel comfortable when compared to a personal computer.

4) Information that is **longer than the screen size** should be displayed such that page numbers and scroll bars are clearly seen when menus and the list of results are longer than the screen size.
5) **Important information** should be clearly distinguished from unimportant information, using font and colour.
6) **Labelling** should be simple in order to increase the users' understanding.
7) **Input** methods should be carefully chosen. Selecting from a set of options might be more convenient than typing information into a mobile device.
8) **Accurate processing state and feedback for the action** should be provided because of mobile internet has been improving by technical parts such as CPU speed and long last battery.
9) **Back and forward menus** should allow the users to return to the previous page and next page in order to help them to interact easily.
10) **Limited use of colour and images** can maintain consistency, reduce heading times and reduce distractions which may affect the user's connection.
11) **Bold fonts** should be used to indicate important information while small type can be used for additional explanations.
12) **Button and icon design** should be simple using concepts which are familiar to the users so that they can understand them easily.

To summarise, the purpose of this research into the design of mobile user interfaces is to develop the core elements for general design of mobile interfaces. They should be designed by considering the content, functionality, and limitations of mobile devices. However, the most important consideration will be to provide a better service and interface design for general use.

Mobile devices can be made accessible to people with different disabilities by compounding a variety of features in the hardware and software design. Additionally, providing specific services (screen readers, magnifiers or voice synthesizers) can assist users in their access to information (The centre for internet and society, 2011). There are a variety of different accessibility features that may be present on a mobile phone, as detailed in Table 2-11.

Table 2-11 Accessibility Features and Services on mobile phone for people with disabilities

Type of disability	Problem	Solutions
Hearing impairments	-unable to communicate by telephone or automated electronic messages -unable to access vital emergency services like contacting the police or medical assistance	**Accessibility features:** -visual or vibrating alerts -adjustable volume control -call logs: display of missed, received or dialled calls -visual or tactile indicators for the keypad (light, vibration) -messaging options (SMS, MMS, email) -Text Teletypewriter (TTY): transmitting typed text conversations over telephone lines by sending and receiving text messages in the same manner as regular phone calls - captioning : displaying a transcript of auditory information -video conferencing: face-to-face communication using sign language **Accessibility Services:** -relay services: human operated services for media and mode translation during phone conversations -SMS to Avatar translation for the illiterate hearing impaired: the software converts typed text into a real-time and on-line interpretation in sign language with the help of a dictionary of words and signs
Visual impairments	-unable to see screens, cannot access contact lists to call numbers in the address book -unable to send and read messages	**Accessibility features:** -screen readers -tactile markers -audible or tactile feedback -adjustable font sizes -adjustable brightness/contrast controls for display -basic text-to-speech functionality -screen magnifiers **Accessibility Services** - Digital Accessible Information System (DAISY): digital talking books for presenting written content in an audio-based format -GPS
Dexterity	-unable to use their limbs, or flex their arms/fingers	- Voice recognition: using for commanding cell phones for writing text messages, turning on and turning off applications, music and videos - Auto Text: reduce the number of keystrokes to type messages -call answer by pressing any key
cognitive disabilities	- struggle to carry out one or more functions - Depending on the type of disability(memory, analytical skills, attention, reading skills, mathematical or computational comprehension, reading comprehension, and communication)	- Predictive Texting: easy to compose messages - Speech recognition - Text-to-speech: convert electronic text into speech - Larger display screens and formatting options (more space between each word, bigger font and highlighted words)
Illiteracy	- Intuitive User Interface (graphical icons) - Audio-based interface	

Source: The centre for internet and society (2011)

In summary, information and communication technologies can provide many possible solutions to the needs of disabilities and universal design can benefit disabled people by increasing their culture, citizenship, democracy, and equality in accessing information. To design for all may not always be possible for all disabilities so designing based on the users' requirements may sometimes be a necessary solution. However, for both legal and economic reasons society and companies cannot ignore the potential offered for people with disabilities even though it may sometimes cost more in order to design for all.

2.4 Use of Interaction Frameworks in Design Process

There are several fields of design, for instance architectural design, graphic design, software design, and interaction design. Each discipline has its own interpretation of designing. Generating alternative designs is a primary principle in most design fields and the ability to brainstorm, contribute alternative ideas, and techniques from design disciplines can be successfully used in the design process (Preece, 2002).

Developers can use a wide range of traditional designing software engineering approaches ranging from the linear approach (e.g. 'waterfall life cycle model', and 'V-Model') to the more iterative approach (e.g. 'the spiral lifecycle model', and 'Rapid Applications Development (RAD)', 'Prototype Model', and 'Agile Model') to aid the design process and while they may vary in such aspects as the speed and number of iterations, the user involvement (e.g. user centred or participatory design which follow the ISO standard Human-centred design for interactive systems (ISO9241-210, 2010) and the starting point, all methods involve some element of requirements, designing and evaluating (Balaji & Murugaiyan, 2012; Maheshwari & Jain, 2012; Preece, 2002).

Martin, Moreno, and Iglesias (2012) explored the use of scenarios and personas for the elicitation of the requirements for mobile accessible chat system for synchronous Computer Supported Learning Environments. They note that this preliminary study would need real users and experts to evaluate the requirements.

Nevertheless, most of the software engineering approaches do not consider disabled people or complex situations which can result in lack of consideration of the needs of disabled people during the software engineering process. While ideally disabled users should be involved in the design of technologies, sometimes this is not possible. There are a few approaches, which focus on helping developers design technology in a situation involving disabled people. For instance, Nganji and Nggada (2011) proposed a user sensitive inclusive design method for software engineering, which considers the needs of disabled people for improving accessibility and usability. They have established an evaluation method for the disability-aware software engineering model with a wide range of disabilities present (e.g. visual impairment, mobility difficulties, hearing impairment, speech difficulty etc).

Danis and Boies (2000) found that using techniques from graphic design help in developing innovative interactive system designs in a complex situation. The benefits of innovative system design are: saving time, providing expertise, accommodating new technologies, and helping think about solutions not previously considered.

The common stages which all approaches mention in designing process are a requirement stage and a design stage. Most methods explain these two stages in a generic way, however, Wang and Zeng (2009) proposed a generic process to elicit precise and complete product requirements. The process consists of the recursive logic of design model (ROM), classification of product requirements based on environment and ROM. The semantics of the requirement text is captured by using ROM. An iterative question-asking approach is a process of asking the right questions by using two main algorithms: asking generic questions (identify the customer's real intent) and asking domain specific questions (collect the complete list of product requirement). The initial results show that the requirements elicitation approach is feasible and promising.

Chen and Zeng (2006) presented the eight levels of requirements which aims at understanding the source and structure of the product requirements as shown in Figure 2-3. The pyramid model can be divided into two groups: non-functional requirements (the lower four), and functional requirements (the upper four). The lower levels have higher priority in developing a design solution whereas the requirements at the higher levels give high usability products. The four lowest levels are objectives of requirements (almost impossible to change) whereas the highest four levels are not intrinsic qualities of product requirements. The distribution of higher-level requirements depends on the capacity to satisfy the lower-level requirements. Results from a software prototype showed how the research may be used as a core for a requirement system.

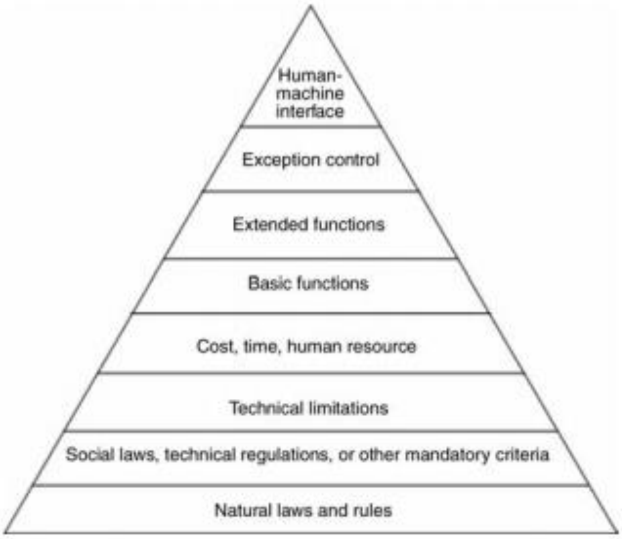


Figure 2-15 Eight levels of requirements (Chen & Zeng, 2006)

2.5 Design Patterns

Although examples of previous design solutions meeting similar requirements in theory should help developers when designing new solutions, research has demonstrated that it is difficult to develop an easy to use 'pattern' language to describe design patterns in such a way that reuse is practical.

Alexander (1979) presented the original idea of design patterns and pattern languages. His intention was to democratise architecture and town planning by providing a principled, structured but flexible approach for design as a set of conceptual resources that people could use in reshaping their environment. Löwgren (2007) agreed that providing a set of patterns can give developers an idea of how to solve problems, allow freedom in designing as many variations as desired, and increase user participation. Goodyear (2004) introduced the idea of design patterns and pattern languages for networked learning. This patterns-based approach provided the teacher-designer with a comprehensive set of design ideas in a structured way and clear articulation of design problem and a design solution, and encoded this knowledge in a way of supporting an iterative approach.

The techno-pedagogical framework is developed by Bower, Craft, Laurillard, Masterman, and Dimakopoulos (2011), at a very early stage of development, to link the Learning Designer with other learning platforms for designing, analysing and sharing learning designs across applications which support teachers in applying learning and teaching principles. The conceptual framework can also be used as a platform for research into teacher's practice.

Derntl and Motschnig-Pitrik (2004) presented a socio-technical, pattern-based approach to blended learning which focuses on educational processes and the use of learning technology. The benefits of using teaching and learning as patterns allow individuals to reuse successful didactic principles and improve the effectiveness of course design.

Borchers (2001) has confirmed the growing interest in pattern languages within the Human Computer Interaction (HCI) community. The design pattern helps to shape more precisely the notion of the HCI design patterns. However, less research has gone into formalising pattern languages for HCI, to make them more accessible to computer support. Wilde, Bruegger, and Hirsbrunner (2010) said that the diversity and abundance of the research in HCI indicated that it is difficult to create a pattern collection which is universally accepted and it is time consuming and expensive in testing each interaction pattern and evaluating the process of using them. Likewise, Landay and Borriello (2003) agreed that the developing of design pattern process is still fairly ad hoc but they suggested patterns have been successful in real products or systems by using good examples of the patterns.

2.6 Hearing Impairment

To understand the impact of hearing problems on visitors to places representing everyday culture, it is first necessary to understand the meaning and the levels of hearing impairment in order to consider the different types of hearing problems and their severity.

2.6.1 Definition

Hearing impairment or deafness is when hearing is affected by a condition or injury. Some people are born deaf while others may develop deafness when they get older. Hearing levels and types of hearing loss are important when considering the problems of hearing impaired people in their learning of language. People who are hard of hearing, with mild to severe hearing loss including conductive hearing loss can use hearing aids to amplify the sound in order to improve their ability to hold a conversation. However, people with sensorineural hearing loss can be treated by using a cochlear implant in their listening to speech. People who are Deaf normally have profound hearing loss and often cannot hear any sound, whether wearing hearing aids or not. Furthermore, people with hearing impairment can be different from other disabilities in terms of the culture and language. They may understand the world by using their eyes and their emotional feelings (Webster & Wood, 1994).

2.6.2 Levels of hearing and types of hearing loss

The levels of hearing and types of hearing loss are related to the ways that people with hearing loss use to communicate. Lip-reading is used widely for hearing impaired people who know the spoken language, while sign language is used by Deaf people. Additionally, it is important to explain that there are different sign languages just as there different oral and written languages throughout the world as many people assume that sign language is a universal deaf language. Therefore, lip-reading seems to be only a partial solution in communication for hearing impaired people in their access to audio information. In addition to hearing, there are three main difficulties in access to information for people with hearing impairments: speaking difficulty, writing difficulty, and reading difficulty (Reed, 1984).

2.6.3 Problem of hearing impaired people

The main problem hearing impaired people have in learning a language is that, by having inadequate access to auditory input, they have less chance to listen to words. As a result, deaf children may not understand the meaning of some words. To become readers, deaf children have to learn the mapping between the spoken language which they may not already know and printed words on a page. Meadow (2001) reports that a child with severe hearing loss may not hear even shouted conversation and is unable to learn speech as a hearing child would. T. E. Allen (1986) and T.E. Allen and Schoem (1997) state that hard of hearing children (even those with only mild to moderate hearing loss) read at lower median levels than hearing children. Uthairattanakit (1985) claims that people with hearing impairments have limited verbal skills to link their own experiences with those of others because they have limited input data, and lack of experience with language and speech. Therefore, they may not understand the speech and it can affect their communication. Moores (1996) and Paul (1998) agree that students who are deaf or hard of hearing have a difficulty in writing; they have difficulties in accessing and learning English linguistic and grammatical structures and they make various errors at the sentence level.

2.7 Thai Museums

There are 1,321 museums in Thailand which are located throughout the country. Some museums, offer free entry to visitors but at other museums, visitors have to pay to enter. These museums are managed by a variety of different organisations including local community groups, charitable foundations, non-profit organisations, local government, schools, state agencies, temples and privately owned companies. The museums are located all over Thailand in different regions: Central and West (543), North (308), East (85), Northeast (234) and South (151) (Princess Maha Chakri Sirindhorn Anthropology Centre, 2005). Museums in Thailand can be considered as 2 types: inside (33%) and outside (67%) museums. There are various kinds and sizes of Thai museums which can be found all over the country. Most museums are local wisdom museums which are managed privately or by temples or the local community. Local wisdom museums are normally free to visit and require an appointment before visiting (Princess Maha Chakri Sirindhorn Anthropology Centre, 2005). This is because they are run by the people who own the exhibits or places and there are not many visitors who know about the museums. Therefore, they will open the museums whenever the visitors want to visit. In addition, there is no permanent officer who works for them because some museums are very small and of limited interest and there is no financial support from the government. They support themselves by selling their own products. When compared to National Museums, there are 43 National Museums around Thailand (which is only 3.26% of all museums) that receive a budget from the government to arrange activities (Chin Corperation Company Limited, 2001). This funding may not be enough to develop them into modern museums. However, some local museums have closed because the owner may die and their family may not want to continue running the museum. It may be because they are not an expert in that field or they may not have enough budget to manage the museum. It seems that modern museums, which are managed by private organisations, have become more popular amongst visitors because they are applying technologies to museums in order to engage their visitors. Unfortunately, there are 885 out of 1,321 museums (67%) which are managed by private organisations (Princess Maha Chakri Sirindhorn Anthropology Centre, 2005), and so, they have to find strategies to survive by themselves.

2.8 Technologies which assist and improve access to information for hearing impaired people

There are a wide range of technologies which may be used to improve access to information for hearing impaired people as described in the following sections.

2.8.1 Automatic Speech Recognition (ASR)

Benjamins (2008) reported that speech recognition technologies are used at the Alexander Graham Bell National Historic Site, in Canada, for people with hearing loss and that they also benefit elderly people and non-native speakers. The real-time transcriptions are provided in several languages depending on the visitors: Japanese, Italian, Chinese and German. It was found that non-native speakers may have low auditory comprehension in English but they have high ability in reading English. Therefore, having text projection together with spoken tours can engage non-native visitors in their understanding and enjoyment of the culture. Tour guides can use ‘content spotting’ techniques to present the tour in one language, while the visitors can choose their preferred languages and the content spotting will display the content related to what the tour guide is talking about. There are various benefits of live captioning tours. Firstly, the live captioning gives a clear concept of the words which tour guides have said. Secondly, the visitors can ask questions, which are repeated and incorporated into the tour. Thirdly, the system can also switch between content-spotting and speech recognition, when it finds that there is a bad match between speech recognition decoded output and a pre-prepared version. Then, the system will switch automatically to live speech recognition. One noteworthy finding of the research is that text-projecting achieves a benchmark of 90 to 95% accuracy compared to captioning to the same level without using technology.

Automatic Speech Recognition provides another solution in access to audio and video, for people who are deaf or hard of hearing and it also benefits tourists. According to Bain, Basson, Faisman, and Kanevsky (2005), in IBM’s Liberated Learning Projects (LLP), instructors are trained to use IBM ViaScribe, which is a specialised speech recognition application, for classroom note taking. Multiple speakers can speak on topics without specialised training, and the speech would be shown as text for students who are hearing and non- hearing on the big screen or students’ handheld devices. Teachers can edit the text and upload it to the Internet. In addition, ViaScribe can combine the PowerPoint slides with sound and text, to generate a multimedia script. This has resulted in better engaging the students' attentions in classrooms. It was found that almost 40% of users reached at least 85% accuracy compared to a standard benchmark. However, to edit an hour long lecture which was 95% accurate requires about an hour of editing time, and a lecture which was 65% accurate requires much longer to achieve ASR accuracy. However, ViaScribe still requires less total time and cost than creating the transcription by typing it.

Iglesias, Jiménez, Revuelta, and Moreno (2014) describes a Spanish educational project that aims for inclusive education for all using real-time captioning through Dragon Spanish speech recognition. An evaluation conducted during a regular undergraduate course at a university and during a seminar at an integration school for deaf children showed that students were satisfied with the results.

Another speech recognition based system, called Synote has been designed by Wald (2010) as an advanced learning technology for disabled and non-disabled people. It uses speech recognition to synchronise audio or video recordings into a visual transcript including transcript, slides and notes. The function is tremendously valued by all students, not only for deaf students who use lip-reading and / or need a sign language interpreter but also for others who have difficulties taking notes such as dyslexic students or non-native speaker students. The questionnaire results from over 100 students showed, they were satisfied that Synote was easy to use and they also appreciated the design of synchronized slides, video, audio and transcripts with over 80% of them rating it as 4 or 5 on a 5 point scale. Moreover, 97% of students wanted all lectures to be available on Synote because it benefits all students (hearing impairment, dyslexic, non-native students) in learning with multimedia applications including PowerPoint, Twitter, and Speech Recognition Software.

Unfortunately, successful use of Thai dictation speech recognition does not appear currently possible because the Thai language has particularly challenging characteristics. Suebvisai, Charoenpornsawat, Black, Woszczyna, and Schultz (2005) reported that there are three main challenges of Thai speech recognition. Firstly, the usage of five tones to distinguish meaning, which affect the feature set used for acoustic modelling; each tone shows a different meaning of a word. Secondly, poor letter to sound relation which makes dictionary generation more challenging. Thirdly, there is not enough word segmentation which is needed for automatic segmentation because Thai is written without any spaces between words or sentences. For instance, the word ‘ตา กลม’ (ta: |klom = round eyes) and ‘ตาก ลม’ (ta:k| lom = to explode the wind). They are the same word written but different meaning, when there is no space between words so the readers need to know context in order to understand the word. There is no unambiguous rule to insert the space, sometime the space is only placed between adjacent sentences and also depends on the writers.

Although a Thai version of Dragon speech recognition for mobile devices is now available, their have been no papers published reporting on its performance and so it is not possible to say whether it can be used successfully.

In summary, speech recognition technologies are being continuously developed in various countries including Thailand. Successful use of Thai automatic speech recognition is not possible now despite the continuing developments. It may be because of the complexities of grammar and syntax making it difficult to find the way to develop effectively Thai automatic speech recognition. However, with the rapid advancement of technology, there may be a solution for Thai automatic speech recognition in the near future.

2.8.2 Captioning / subtitling

Subtitling for deaf people (known as captioning in North America) is one of the assistive technologies for deaf and hearing impaired people to represent audio dialogue of film and television programs. The subtitles are displayed in real-time as text on the lower part of the screen.

- *Types of captioning / subtitling*

There are two types of captions which need to be understood: live captioning and pre-prepared captioning (Martone, Taskiran, & Delp, 2003).

Live captioning runs during live programs, such as news, sports or special live broadcasts. The captioning is performed by an operator, using an electronic stenotype keyboard or more often, speech recognition revoicing by a human operator using IBM ViaVoice or Dragon Naturally Speaking to transcribe into text while the program is on air. However, there is a delay of a few seconds after the words were spoken, and the words are not altered to provide a ‘good’ sentence structure. Therefore, live captioning can have a large error rate.

Pre-prepared captioning can be created using standard keyboards or speech recognition revoicing. It is more accurate than live captioning but can require a lot of time to be spent on it, up to 15 hours per broadcast half-hour.

- *Subtitling for hearing impairments*

Cambra (2008) studied the level of comprehension of subtitled television programs in Spain by 20 students who have a severe or profound hearing loss. The experiment used visual, audio, oral and written information to assess the participants' levels of understanding. The first experiment was conducted without sound; the result showed that 30% of the students understood what had happened in the show by only watching the images. However, the percentage of understanding increased to 40% after turning the sound on and adding subtitling.

However, according to these figures, the researcher verified that the speed of the transcription did not give participants time to read and understand the overall story. Therefore, the researcher gave another pilot study formed by seven children aged between six and seven, plus another 16 children aged from seven to ten. Both age groups viewed the cartoon 'Shin-Chan', while the second group was shown the cartoon with subtitles created by using new speed and text selection criteria. Only 2% of participants in the first group understood the cartoon, whereas 65.5% of the second group understand overall.

Ohene-Djan, J Wright, and K Combie Smith (2006) reported that subtitles generally lack the ability to express emotions: happiness, sadness, fear, and comedy. The example of emotional subtitles appeared on a BBC television Tweenies program. Different colours represented each character and their speech. Furthermore, different types of emotion were displayed in a different font. The experiment showed that colourful subtitles appealed to audiences, particularly to children. Moreover, the colours assisted viewers to identify which character was speaking at the time and to encourage audiences to appreciate the emotions of the characters from the television subtitles. Finally, young children learn quickly by the different fonts used.

In summary, subtitling is important for hearing impaired people because written language is a support tool which helps them to understand spoken language and is also useful to describe sound effects and additional information in order to support viewers. This text based approach can be more accessible for people with hearing loss including elderly people who have a hearing difficulty, and who do not rely on sign language. Furthermore, subtitling and captioning also can provide many different languages on the big screen at exhibits or on television. Moreover, offering the different levels of language complexity for people with hearing loss is also necessary because they can choose which best fits their case. Finally, the time spent on reading the subtitles is additional to the time used viewing the images.

2.8.3 Technologies which improve communication for hearing impaired people

Table 2-12 provides a summary of technologies which can improve communication for hearing impaired people. Short Messaging Service (SMS) allows people with and without hearing disabilities to have equal access to information. More freedom is possible when the length of messages is greater than 160 characters. Therefore, email is an alternative way to communicate or share information for anyone which also allows freedom and privacy. The users require access to the Internet to be able to send email and this requires more IT knowledge compared to SMS. Instant messaging (IM) is a real time communication method which users can use to exchange their ideas or make an appointment or even have discussions related to work. IM can decrease discrimination between hearing and hearing impaired people. Social network tools like Facebook or Twitter also allow two way communications which users can use to chat in real time and it is also the way to share public information. It can be another alternative way for deaf and hard of hearing people to gain access to information and share it with friends.

Furthermore, the idea of blogs and wikis are quite similar in term of sharing knowledge but it seems to be that wikis are much more flexible in terms of editing information. These two technologies can be a useful tool for Deaf and hearing impaired people in their access to online information. This is because they can access information by reading text and looking at pictures which are provided on both websites and blogs.

Table 2-12 Technologies to improve communication for hearing impairments

Type	**Examples**
E-mail (Bainbridge, 2004)	Outlook, Gmail, Hotmail, Yahoo
SMS (Harper & Clark, 2002)	WhatsApp, Line, SMS on mobile phone
Instant messaging (Isaacs, Walendowski, Whittaker, Schiano, & Kamm, 2002)	MSN Messenger, QQ, Camfrog
Blog (Winster & Swamynathan, 2010)	Movable Type, Blogger, Word press
Wiki (A3webtech, 2012)	Wikipedia, AboutUs.org, Wikitravel , The Student Room
Social network tools (Wei-Feng & Liu, 2010)	Facebook, Twitter, Hi5, Link2in, Friendster, My Space

2.9 Technologies which assist hearing impaired people in their access to history and culture

In previous times, visitors with hearing loss had to read text from the hard copies of the audio tour script, although now they may not be satisfied carrying a script instead of a mobile device. Hearing impaired people may require video, audio and captioning in their access to information. It may be possible for them to lip read video content, or read the text captions. There are a few technologies which have been developed to assist people with hearing loss in their access to history and culture as detailed in this section. Deaf people who find difficulty with reading captions may prefer sign language and while sign language avatars may offer the future promise of producing cheap, on demand, customisable, extendable and reusable sign language, it is currently more usual to video people for producing sign language.

2.9.1 'The Smart Auslan' technology

Australian Community Exchange (2011) mentions that the National Sports Museum in Melbourne developed 'The Smart Auslan' technology which used QR-Codes to give access to the sign language guide for deaf and hearing impaired visitors. The system is designed to give the opportunity for people with hearing loss to tour a museum like everybody else does with the museum's audio tour. The hearing impaired visitors can access Auslan sign language by scanning a QR-Code. When the QR-Codes are read, the application then plays the appropriate Auslan captioned clip for any exhibit that has an audio component.

2.9.2 The Sign Language Tour

Proctor (2005) asserted there are two examples of using assistive technologies for non-hearing people to access museums. At the Tate Modern Art Gallery, the British Sign Language (BSL) Tour was an adaptation of the multimedia highlights tour. The tour provides an on-demand signing tour with optional subtitles of the displays as an alternative to waiting for a BSL-interpreted gallery talk. The information came from a central server, limitless content could be provided, and could easily be kept up-to-date. The BSL visitors had a high satisfaction (79%) in improving their visit, while only 1% were unsatisfied. Proctor also stated that at the Great Blacks in Wax Museum, the American Sign Language (ASL) tour was using the script of the Voices of History audio tour. The museum found that it was not easy to translate the script into sign language in order to produce an accessible tour. Therefore the museum needed a signing expert to help with the translation in order to create an approved sign language script. The tour also provided captioning for visitors.

The Lázaro Galdiano Museum (2014) provides a Guide app with accessibility options including subtitling and video in Spanish Sign Language for the hearing impaired and audio description for people with visual disabilities, features include zoom, high contrast and screen reader.

2.9.3 Technologies which are used inside and outside museums

Hardware and software are now available to help people with hearing loss to access information in culture and history. The technologies, which are used inside or outside museums, are significantly different because there are different infrastructures and environments. There are various technologies, which have been used as shown in

Table 2-13. From an analysis of these technologies it can be seen that barcodes and infrared can be used inside museums: they require a line of sight between the source and the reader in order to be able to read the data. These two technologies are not so popular at the moment because of their limited range. It seems that Bluetooth has a longer transmission range and it also has a longer capacity. Moreover, Bluetooth is enabled on a variety of handheld devices whereas infrared technologies are becoming less common. However, these three technologies can be disturbed by the weather conditions or by a large number of visitors.

RFID seems to be a popular technology, which many museums apply for tracking locations of objects and for reading the link to an object's details. RFID is a cost-effective technology, which has minimum impact upon the fabric of the objects, and it is possible to receive the signals from a large number of nearby tags at the same time. Furthermore, RFID is used for security at museums in the same way as in department stores.

Augmented reality (AR) has come to be used at museums in order to help visitors to obtain a clearer understanding in art and history by displaying 3D images. AR-technology can also be applied to both indoor and outdoor activities.

However, only a few services are provided for hearing impaired visitors. Museum policies and practices providing sign language, captioning, and subtitling supported by assistive technologies can help remove the barriers to participation. Experience and exhibits can be shared with peers to help people with hearing loss access museums with the same standards as hearing people.

Table 2-13 Technologies which are used inside and outside museums

Technology	Advantages	Disadvantages	Technologies		Benefit for	
			Inside museum	Outside	Museum	Visitor
Barcode	inexpensive	• require a reader • require line of sight • limited range • disturbed by the weather	✓ [1]		✓	✓
QR-code	• contain large amount of data • scan quickly • can read in any orientation even on distorted, or dirty surfaces • inexpensive	require line of sight	✓ [2]		✓	✓
Infrared	can apply to outdoor activities	• require line of sight • require battery life • natural light degrades the signal • require a special reader • limited range • disturbed by the weather	✓ [3]	✓ [3]		✓
RFID	• compact • low cost • maintenance free • long life	require a special reader	✓ [4]	✓		✓
Bluetooth	• does not require line of sight • installed in a wide range of handheld devices	disrupted by atmospheric conditions and number of devices	✓ [3]	✓	✓	✓
Augmented Reality	persuades viewers to engage by superimposing virtual objects on the real environment	• inaccurate position depends on the weather • does not work properly indoors	✓ [5]	✓ [6]		✓
Image recognition	can be used outdoors	time consuming because of complex processing required		✓ [7]		✓
GPS	tracking movement for outdoor activities	short distance		✓ [3]	✓	✓

Source: [1]Tomlin (2008), [2] Australian Community Exchange (2011), [3]Proctor (2005), [4](Yo-Ping, Shan-Shan, & Sandnes, 2011), [5]Wittkamper, Braun, Herbst, and Herling (2007), [6](Archives, 2010), [7]Fritz, Seifert, Luley, Paletta, and Almer (2004)

2.10 Summary of the chapter

A review of interaction frameworks shows none of the frameworks have assisted technology developers to consider all of the possible interactions types that occur at the same time and in the same place although there have been projects concerned with how to use technology to support some of these interactions.

The concepts of accessibility, usability and user experience (UX) highlight a current lack of agreement about whether accessibility means universal design or usability for older and disabled people. The role of accessibility, usability and UX evaluations in the design process were also considered. Universal design can benefit disabled people by increasing their culture, citizenship, democracy, and equality in accessing information. To design for all may not always be possible for all disabilities, designing based on the users' requirements may be sometimes be necessary. However, society cannot ignore the potential offered for people with disabilities even though companies may have to pay more in order to design for all because of the legislation.

Most of the software engineering approaches have not considered disabled people or complex situations. It can result in lack of consideration of the needs of disabled people during the software engineering process. However, there are a few frameworks which focus on helping developers design technology in a complex situation. Although there is a growth of interest in pattern languages within the HCI community, less research has gone into formalising pattern languages for HCI, to make them more usable for computer support.

If hearing impaired people have inadequate access to auditory input, they have less chance to listen to words. As a result, deaf children also do not understand the meaning of words. Becoming readers, deaf children have to learn the mapping between the spoken and written languages. The ways that people with hearing loss use to communicate (listening, lip-reading, and sign language) depend on their levels of hearing and types of hearing loss.

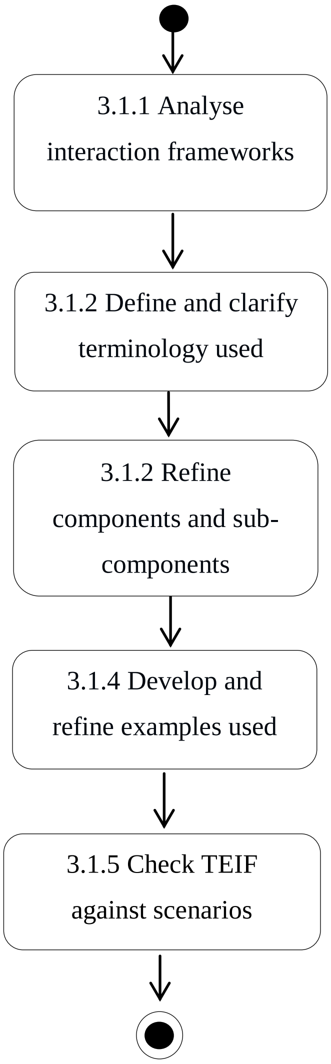
Most Thai museums are local wisdom and small and managed privately or by temples or the local community. The museum owners do not have a large budget compared to the larger modern museums. Few services are provided for hearing impaired visitors. Therefore, museums should take care to ensure their policy and practices provide assistive technologies to help remove the barriers to participation with exhibits and to share experience with peers by providing assistive technologies (e.g. Sign language tour, application for special users). There are different approaches which have to be considered (sign language, captioning) and by combining them with appropriate technologies, it is possible to help people with hearing loss access museums with the same standards as hearing people.

Chapter 3 Technology Enhanced Interaction Framework

This chapter describes the Technology Enhanced Interaction Framework (TEIF) that has been developed based on the main and sub-components identified in Table 3-4 and by adapting and extending the work of Dix (1994) and Gaines (1988) to help developers to design technology to support communication between people and improve interactions between people, technology and objects, particularly in complex situations involving disabled people. The TEIF aims to be a general framework that is designed to be comprehensive and accommodate most situations and scenarios (e.g. it simplifies to be similar to Dix's framework when no objects are involved). The TEIF aims to help developers design technology solutions to complex situations, particularly when disabled people are involved by helping developers think about the user requirements, designing interactions, to meet these requirements and the criteria related to the requirements to evaluate the interactions. Section 3.1 reveals the TEIF development process. Section 3.2 describes terminology used in the TEIF. The main and sub-components of the TEIF are explained and examples are given for each type of interaction in section 3.3. Section 3.4 shows the architecture of the TEIF for each type of interaction. Section 3.5 considers design pattern. Section 3.6 concludes with a summary.

3.1 Development of Technology Enhanced Interaction Framework

This section describes the steps used to develop the TEIF. Figure 3-1 illustrates the main five steps.



- List and summarise dimensions from existing interaction frameworks

- Define and clarify terminology
- Check the terminology in a wide range of scenarios

- Sort dimensions into appropriate components
- Develop new main and sub-components where required

- Develop and refine the examples used in the TEIF
- Explain the examples of the TEIF

- Check TEIF applicability against a wide range of scenarios

Figure 3-1 Development of the Technology Enhanced Interaction Framework Process

3.1.1 Analyse frameworks

The first step in the TEIF development process was to list the existing interaction frameworks as shown in the column headings in Table 3-1 that were based on principles rather than just technology system architectures or solutions and found from the review of literature that included one or more interaction types involving people, technology, and objects. Following this, similar aspects were grouped. This process resulted in six main dimensions: direct communication, interactions, role of interactions, space / time, technology enhancement, and accessibility.

Table 3-1 Summarising a review of frameworks of interactions

	Transactional analysis (Berne, 1964)	Conversational Framework (Laurillard, 1993)	Conversation Analysis (Sacks, 1974)	Interaction Analysis (Flanders, 1960)	Role of Artefacts in Mediated Communication (Vyas et al., 2008)	Computer supported cooperative work - A framework (Dix, 1994)	The Physical Mobile Interaction Framework (PMIF) (Rukzio, 2008)	Designing an electronic guild book for learning engagement in a museum of history (Rukzio, 2008; Sung et al., 2010)	Multimodal Interaction Framework W3C 2003 11, (Larson et al., 2003)	Norman's model of Interaction, (Norman & Draper, 1986)	The Interaction Model, (Abowd & Beale, 1991)	A Ecological Model of the Communication Process (Foulger, 2004)	a time/space matrix to classify synchronous and asynchronous technology (Ellis et al., 1991)	Human Activity Assistive Technology Model, (Cook & Hussey, 1995)	Systems for supporting group learning (Lee et al., 2009)	A Conceptual Framework for Person-Computer Interaction in Distributes Systems, (Gaines, 1988)	Blended Interaction, (Jetter et al., 2012)	Blended Learning (Klink, 2006)	Technology Enhanced Interaction Framework (to be developed)
Direct Communication																			
People-People (P-P)	✓	✓	✓	✓		✓						✓						✓	✓
Interactions																			
People-Technology (P-T)							✓	✓	✓	✓	✓			✓	✓	✓	✓	✓	✓
People-Object (P-O)																			✓
People-technology-people (P-T-P)					✓	✓	✓	✓					✓		✓		✓	✓	✓
People-technology-object (P-T-O)								✓									✓		✓
Role of interactions																			
Presenter-Audience																			✓
Sender-Receiver														✓		✓	✓		✓
Teacher-Student		✓		✓															✓
Consumer-creator												✓							✓
Speaker-Audience								✓					✓						✓
User-system					✓				✓	✓	✓			✓	✓	✓	✓	✓	✓
Peer-peer						✓	✓								✓				✓
No role	✓		✓				✓												✓
Space/Time																			
Same place/ same time	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
Same place/ different time									✓				✓		✓			✓	✓
Same time/ different place									✓				✓					✓	✓
Different time/ different place									✓				✓					✓	✓
Technology enhancement																			
Using technologies					✓	✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
Without technology	✓	✓	✓	✓								✓							✓
Accessibility																			
Consider accessibility														✓					✓

Table 3-1 summarises a review of interaction frameworks and shows that seven frameworks focus on direct communication in the same time and at the same place (P-P), ten frameworks mention about the interaction between people and technology (P-T), eight frameworks focus on using technology to mediate the interaction between people (P-T-P), and two frameworks consider using technology (P-T-O) to enhance the interaction between people and objects (P-O). However, only the Human Activity Assistive Technology Model (HAAT) considers accessibility in the interaction.

The frameworks in Table 3-1 have been assessed against dimensions selected to be comprehensive based on an analysis of the frameworks themselves as well as a wide range of scenarios and technology solutions described in section 3.1.5.

Since no existing framework addresses all of the interactions identified in Table 3-1 the new TEIF has been developed and described in this chapter and has been included in Table 3-1 for comparison to the existing interaction frameworks to show how it addresses all of the interactions.

3.1.2 Define and clarify terminology used

Defining and clarifying terminology used in the TEIF is a crucial process to explain the meaning of terms which are used in this framework. One of the terms which is used in the TEIF is different from the term used in Dix's framework (Figure 2.2). Dix never included a separate technology component in his Framework as it was explicitly for computer supported collaborative working and so all interactions assumed the use of technology. For example he shows person to person direct interaction without an intermediary technology component. Dix used the term 'Artefact' to mean a man-made technology software tool, while in the TEIF the terms both 'Technology' and 'Object' are used instead where 'Object' refers to non-technology objects which can also be natural such as stone. This is shown in Figure 3.2. Moreover, object can have dimensions, properties and content which is human readable (text and pictures) and machine readable (QR code, AR tag, barcode, and RFID tag).

3.1.3 Refine components and sub-components

The TEIF main components and sub-components which were created from the dimensions and sub-dimensions identified from the literature review needed to be refined to be consistent and comprehensive. There are seven main components of the

TEIF: people, objects, technology, interactions and communication, time / place, context, and interaction layer (see detail in Table 3-4).

The changes of main dimensions and sub-dimensions from Table 3-1 to the TEIF main and sub-componets are shown in Table 3-4 as follows:

- The main dimensions and sub-dimensions of direct communication and interactions were grouped into the 'Interactions and Communication' main component of the TEIF. This is because it is difficult to separate actions between communication and interactions. For example, people interact with mobile phones in order to communicate with other people and as both interaction and communication happen at the same time it is better to merge them together into the 'Interactions and Communication' main component.
- The main dimension 'Space / Time' was changed to the TEIF main component 'time / place' in order to make it clearer. The four sub-dimensions (the same place / same time (SP / ST), same place / different time (SP / DT), same time / different place (ST / DP) and different time / different place (DT / DP)) were decreased into two sub-components which are 'Place' and 'Time', and the four sub-dimensions used as examples.
- The 'Role of interactions' main dimension was changed to be a sub-component of the new component called 'People'. This is because people have a role in communication and interactions. 'Accessibility' was also moved under the 'People' component to be another sub-component. The sub-dimensions of the 'Role of interactions' were used as examples in the TEIF.
- The 'Technology enhancement' main dimension was changed to 'Technology' main component. The sub-dimensions 'Using Technologies' and 'Without Technology' were changed to the sub-components 'Electronic' and 'Non-electronic'. Two new sub-components were developed: 'User Interface' and 'Application or Service'.
- Three new main components were developed in the TEIF: 'Objects', 'Context', and 'Interaction Layer'. The 'Objects' main component was developed to make the meaning of objects more comprehensive and consistent so that they can be applied in many situations. As stated in then previous section Dix's framework (Dix, 1994) used the term Artifact and could only be applied to computer supported collaborative working scenarios. Three sub-components were

developed: dimension, property, and content. The 'Context' main component was developed with location, weather condition, signal type and quality, background noise, and lighting as sub-components. Lastly, the 'Interaction Layer' main component was adapted from Gaines (Gaines, 1988) in order to show the essential differences in nature of the other sub-components of the TEIF by categorising them under one or more of the 'Interaction Layer' sub-components of culture, intentionality, knowledge, action, expression, and physical.

3.1.4 Develop and refine examples used

The development of concrete examples used in the TEIF aims to help explain the Framework because some of the new abstract concepts and ideas it introduces may be difficult to understand.

3.1.5 Check components against scenarios

In order to ensure that the TEIF is a general framework which could apply in many situations, a wide range of scenarios and technology solutions were considered during the development process: for example blended learning and technology enhanced interaction in museums. The process showed that the TEIF was suitable for those situations and the new contribution is both a general framework and addresses the specific aspect of using technology enhanced interaction in the same time and at the same place in complex situations particularly when disabled people are involved. The scenarios below are used to check whether the TEIF main components and sub-components can work with multiple scenarios and disabilities. These scenarios were checked againt the TEIF components and subcomponents by a researcher and expert as shown in Tables 3-2 -3-3 which show which aspects of the scenarios relate to which components and sub-components.

a) Tutorial Scenario with hearing impairment

This scenario was developerd by the researcher in order to check all possible types of the interaction in a complex situation when herring impairement involved in a tutorial situation.

"In a tutorial situation at the UK unininversity, a tutor or students can start the conversation by talking or asking some questions. The tutor answers questions by explaining using books, document paper or show some information on the Internet from his computer or mobile phone. The student can also show information to the tutor (e.g. show picture or document file form his mobile phone or laptop). The tutorial can be one to one or group tutorial. Some of students may have disabilities such as low vision, blindness, hearing impairment or deafness in the tutorial. Students who have low vision require appropriate text size and colour (e.g. red or green can be difficult for students with colour vision difficiency).

Students who have hearing disabilities may find that it is difficult to hear and follow the conversation in a tutorial group. Moreover, many students who are born deaf learn Sign Language as their first language, and English is their second language. For this reason, these students will have some of the similar problems with text information as any other international students who have difficulties in understanding the language. The university would like to develop the low cost technology to help impreove this situation.

b) GP Surgery scenario with hearing impairment

This scenario was written based on the true story in PatientPlus articles by a doctor in the UK at GP Surgery to deal with profoundly deaf and other hearing-impaired patients (Patient.co.uk, 2015):

"Anna who is a hearing impaired person with a moderate degree of hearing impairment who uses speech and hearing rather than sign language. She would like to talk to a dentist at her dental surgery in the UK about her painful teeth. She has a problem with booking the appointment as her local dental surgery expects this to be done by telephone, without providing any alternatives. Anna tries to arrange the appointment by telephone but has difficulty understanding the receptionist and therefore, Anna has to visit the dental surgery personally to book the appointment.

At the waiting room in the surgery, Anna has difficulty understanding the receptionists as there is a lot of background noise, and Anna feels embarrassed as a staff members asks her reason for her appointment loudly so that the rest of the room can hear. Anna misses her turn to see the dentist through not hearing her name called. So she has to ask them to tell her personally when it is her turn.

Her difficulties continued in the consultation. Anna cannot lip-read the dentist because he covers his mouth with a mask. The dentist teaches her how to use dental *floss, by showing how to use it but Anna couldn't hear him clearly or even lip-read because the dentist mouth is covered with the mask. The dentist tells her the next appointment date but Anna mishears the actual date because of the lip-reading difficulty. The result is Anna leaves confused about the content of the consultations and as no written information was provided she also misses the next appointment date. The GP surgery would like to improve the service by finding low cost technology to help with this problem."*

c) Segway Tour in Rome scenario with hearing impairment

This scenario was developed by observed by the researchers based on the real situation which took place in a Segway Tour in Rome.

"Becky is a native English speaker who has had a hearing impairment since birth. She wears hearing aids to help her hear more clearly. This is the first time that Becky visits Rome so she has no idea where to visit. Suddenly, she sees a tour with people riding around on two wheeled vehicles called Segways visiting many places in Rome. It looks fun so she decides to join a Segway tour. Before the tour starts the Italian tour guide who speaks English explains and shows everyone how to ride a Segway. There are ten visitors on the same tour as Becky; the rest of visitors have not had any disability. On the tour, visitors have to ride the Segway in single file and keep their hands on the handles for safety. Becky finds it is difficult to hear the tour guide warning the visitors to watch out for the holes or bumps in the ground which can affect the ride because she is in the middle of the line and also because of the Italian tour guide's accent. The first attraction that the tour stops at is the Colosseum, the tour guide explains about the history of the Colosseum which is the same information all the time. Becky misses out some information when the tour guide suddenly changes the topic (e.g. starts talking about when building of the Colossuem started and then changes to talk about where they are going next). It is because she thinks that the tour guild was still talking about the previous topic. Moreover, when the tour guild points to some part of the building and explains the history, Becky finds it is difficult because she finds it difficult to lip-read the Italian tour guide.

While looking at the old buildings the tour guide also displays on her ipad computer simulated recreations of what these old buildings would have looked like in the past via video. It is quite difficult for 10 people to watch the video on the small screen at the same time. Becky finds it is difficult to hear the video from the iPad because it is not amplified and there is background noise from other people and the *noise from vehicles in the nearby street and also difficult to watch the video in the strong lighting. The video does not have captions. Becky asks the tour guide some questions but the tour guilde can't always understand Becky's speech. Becky misses some of the words when the tour guide answers her questions. The tour guide realises the problems which have happened during the tour and reports to the company in order to improve the service. Visitors' satisfactions are very important for the company because there is a very high competition in Segway tours in Rome. The company would like to improve the tour by using technology that can improve communication and interaction during the historical tour."*

d) *Thai Local Museum scenario involing hearing impired people, blind, and physically impaired people*

This scenario was developed based on the interview with the owner of Thai Local Museum (Mr. Suchart Trapsin) while the researcher visited a museum in Thailand. Some information is added to complete the story.

"Suchat Trapsin allocated some parts of his house to become the Museum of Folk Art and Shadow Puppets, in Nakhon Si Thammarat Thailand. There are exhibits of shadow puppets inside the museum, but there is no information provided in text format. This is because Suchat normally explains the history and tradition in Thai by talking to visitors. On Friday afternoon, Chuty (who is local and has been hearing impaired since birth) and her best friends Anna who is blind and Aoo who has a physical impairment requiring the use of a wheelchair, visit the museum. Suchat starts the talk by explaining about the exhibits. Chuty has difficulty hearing the bell when the tour begins. During the talk, Chuty finds that it is very difficult to hear Suchat clearly. Chuty asks Suchat some questions about the exhibits. Suchat answers the questions, but Chuty misses some of the words. While Chuty and her friends are watching the shadow puppet show, Chuty cannot hear the conversation clearly because of the background music which is part of the show. It is also fairly dark which makes lip-reading very difficult for her. Chuty can't easily understand what Suchat is talking about when he points at exhibits around the theatre as she can't watch his lips at the same time as looking at exhibits. Anna finds it difficult to find any exhibits and understand what they are. Aoo can't get access to all parts of the museum because Suchat's house is a Thai traditional house which requires visitors have to climb up a ladder. Suchat would like to have a

technology solution that makes it easier for Chuty and her friends to enjoy the museum."

e) Online shopper with color blindness

This scenario was found on the W3C website about how people with color blindness use the online shopping website (W3C, 2005). The scenario as shown belows:

"Mr. Lee wants to buy some new clothes, appliances, and music. As he frequently does, he is spending an evening shopping online. He has one of the most common visual disabilities for men: color blindness, which in his case means an inability to distinguish between green and red. He has difficulty reading the text on many Web sites. When he first starting using the Web, it seemed to him the text and images on a lot of sites used poor color contrast, since they appeared to use similar shades of brown. He realized that many sites were using colors that were indistinguishable to him because of his red/green color blindness. In some cases the site instructions explained that discounted prices were indicated by red text, but all of the text looked brown to him. In other cases, the required fields on forms were indicated by red text, but again he could not tell which fields had red text."

Table 3-2 Checking scenarios against TEIF components

Main Components	**Sub-components**	**Thai Museums**	**GP Surgery**	**Segway Tour Scenario**	**Tutorial**	**Online shopping**
Interaction Layer	Intentionality	improve communication and interaction	improve communication and interaction	improve communication and interaction	improve communication and interaction	improve communication and interaction
Time / Place Interaction Layer	Time, Place Physical	same time / same place	same time / same place	same time / same place	same time / same place	same time / same place
People Interaction Layer	Role Intentionality	presenter–audience commmunication	presenter–audience communicatio	presenter – audience communication	presenter – audience	No communication only interaction between person and technology (P-T)
People Interaction Layer	Ability / disability Expression	presenter has no disability Audience have disabilities hearing impairment blind physical impairment	presenter has no disability Audience have disabilities hearing impairment	presenter has no disability Audience have disabilities hearing impairment	A presenter has no disability Audience have disabilities hearing impairment low vision, blind	A person has disability Colour blind
People Interaction Layer	Ability / disability Culture	A presenter speaks Thai Audience speak Thai	A presenter speaks Thai Audience speak Thai	A presenter speaks Italian Audience speak English	A presenter speaks English Audience speak English	English speaker
People Objects Interactions and Communication Interaction Layer	Role Dimension Property P-P, P-T, P-O, P-T-P, P-T-O Intentionality Action	P-P, P-O	P-P, P-T-O	P-P, P-O, P-T , P-T-P	P-P, P-T, P-O, P-T-P	P-T
Technology Interaction Layer	Electronic Non-electronic User Interface Signal type and quality Physical	online technology mobile devices	off-line technology mobile devices	off-line technology mobile devices	off-line, online mobile devices non-mobile devices	Online technology mobile devices non-mobile devices
Technology	Application or service	pre-prepare speech captions	spontaneous speech recognition	pre-prepare speech captions	spontaneous speech recognition	web
Objects	Content	neither audio and video	neither audio and video	video	neither audio and video	neither audio and video
Context	Location	indoor	indoor	outdoors	indoor	indoor
Interaction Layer	Culture Physical	low cost solution work with smartphone	low cost solution	no need to be low cost solution	low cost solution	Not mentioned

Table 3-3 Checking scenarios against TEIF components (continued)

Main Components	**Sub-components**	**Thai Museums**	**GP Surgery**	**Segway Tour Scenario**	**Tutorial**	**Online shopping**
Context Interaction Layer	Weather condition Background Noise Lighting Physical	noise, inadequate lighting	noise, distance	noise, distance, (too bright) lighting	did not mention	did not mention

3.2 Terminology

Terminology used in the TEIF is defined as follows:

- *Communication* is the process of passing information from one person to another (Davis, 1977).
- *Technology* is a tool that helps people achieve their purpose.
- *People* means anyone involved in direct communication or interaction with an object, technology, or other people.
- *Object* is real not virtual and anything that is not a technology or a person involved in communication or interaction.
- *Interactions* can be between people and objects (P-O) or people and technology (P-T). People can also use technology to mediate interaction with people (P-T-P) or objects (P-T-O).
- Complex situation is a situation which has the interactions in form of P-P, P-O, P-T, P-T-P and P-T-P, especially when disabled people are involved.

3.3 Main and Sub-Components of Technology Enhanced Interaction Framework

There are seven main components in the TEIF as shown in Table 3-4 which shows the final version of the Framework with a minor changes suggested by the expert review detailed in chapter 7 summarised at the end of this section. People can have roles, abilities, and disabilities. The components ‘Object’ and ‘Technology’ are used in order to extend Dix’s framework to show any type of interaction. Objects are defined as having three sub-components: dimensions, properties, and content. Technology has a cost and can be electronic or non-electronic, online or off-line, and mobile or non-mobile. Furthermore, it may or may not have stored content and may additionally have an interface and be an application or provide a service. Interactions and communication are classified into three groups:

1) Direct Communication:
    - *People to People (P-P)* - People in one-way or two-way communication with people
    - *People to Objects (P-O)* - People can control objects and retrieve information from objects
2) Direct Interaction: *People to Technology (P-T)* - People can control technology and may also be able to use it to store or retrieve information.
3) Technology Mediated Interaction:
    - *People to Technology to People (P-T-P)* – Technology can mediate communication between people.
    - *People to Technology to Objects (P-T-O)* - People can control objects with technology which may use objects to store and retrieve information.

'Time and Place' can be divided into four categories (Ellis et al., 1991a): same time and same place, different time but same place, same time but different place, and different place and different time.

Context can include factors and constraints such as location, signal quality, background noise, lighting, and weather conditions.

Table 3-4 Main and Sub-Components of Technology Enhanced Interaction Framework

Main Component	**Main and Sub-Component of Technology Enhanced Interaction Framework**	
	Sub-component	***Explanations and Examples***
People	Role	A person has a role when communicating with others (e.g. presenter, audience, peer). Roles normally come in pairs such as speaker and audience (e.g. teacher and student or owner and visitor) and peer to peer (e.g. student and student or visitor and visitor).
	Ability / Disability	People have abilities and disabilities which can affect their use of technology or understanding of language and which can lead to communication breakdown (e.g. physical, sensory, language, culture, communication, Information Technology (IT)).
Objects	Dimension	Objects have 2 dimensions (2D) or 3 dimensions (3D), and a 3D object may have a 2D representation.
	Property	Objects have colour, shape, size, and identity
	Content	Objects have content which is human readable (text, pictures) and machine readable (QR code, AR tag, barcode, RFID tag, NFC).
Technology	Electronic	Electronic technology has stored information, is online (e.g. internet, phone network) or offline (e.g. not connected to the internet or phone network), and is mobile (e.g. smartphone) or non-mobile (e.g. desktop computer).
	Non-electronic	Non-electronic technology is used to store information in objects (e.g. writing with a pen on paper) and is mobile (e.g. pen) or non-mobile (e.g. full-size desktop typewriter).
	Usability and Accessibility	People interact with technology through its user interface (e.g. touch screen, keyboard).
	Application or Service	Electronic technology is an application (e.g. dictionary) or a service (e.g. weather forecast).
	Cost	Technology has cost (e.g. of hardware, software, maintenance).
Interactions and Communication	People-People (P-P)	People communicate verbally (speak, listen, ask, answer) and non-verbally (lip-read, smile, touch, sign, gesture, nod). When communicating, people may refer (speak or point) to particular objects or technology – this is known as 'deixis'.
	People-Objects (P-O)	People interact with objects for two main purposes: controlling (e.g. touch, hold or move), and retrieving information (e.g. look, listen, read, in order to get information or construct personal understanding and knowledge).
	People-Technology (P-T)	People control technology (e.g. hold, move, use, type, scan, make image, press, swipe), transmit and store information (e.g. send, save, store, search, retrieve).
	People-Technology-People (P-T-P)	People use technology to transmit information to assist communication with (e.g. send SMS, MMS, email, chat, instant message) other people. Technology is always designed for a purpose by people and so a robotic device triggered by the person walking past it is a P-T-P interaction.
	People-Technology -Objects(P-T-O)	People use technology (e.g. point, move, hold, scan QR codes, scan AR tag, use camera, use compass) to transmit, store, and retrieve information (send, save, store, search, retrieve) to, in, and from objects.
Time / Place	Place	Same and different time and place yield four categories: same time (ST) and same place (SP), different time (DT) and same place (SP), different time (DT) and different place (DP), same time (ST) but different place (DP).
	Time	
Context	Location	Location affects the use of technology (e.g. indoors, outdoors). For example GPS does not work well indoors.
	Weather Condition	Weather condition may affect the use of technology (e.g. rainy, cloudy, sunny, windy, hot, cold, dry, wet). For example, the mobile phone screen doesn't work well in sunshine.
	Signal Type and Quality	Signal type can affect the quality of electronic technology (e.g. broadband, GPS, 3G, 4G).
	Background Noise	Background noise can affect the communication particularly for hearing impaired people (e.g. background music, crowded situation).
	Lighting	Light can affect the interaction (e.g. Inadequate light, too bright).
	Awareness of others' interactions	People can be aware of interactions involving other people
Interaction Layer	Culture	Cultural layer includes countries, traditional, language and gesture (e.g. 'hello' is a normal greeting used in the culture).
	Intentionality	Intention layer involves understanding, purpose and benefit (e.g. the intent is a greeting).
	Knowledge	Knowledge layer involves facts, concepts, procedures, and principles (e.g. how to spell the word 'hello').
	Action	Action layer involves actions and behaviours (e.g. pressing the correct key and not hitting neighbouring keys).
	Expression	Expression layer describes how actions are carried out (e.g. whether action is correct, accurate, and prompt).
	Physical	Physical layer is the lowest layer at which people interact with the physical world (e.g. the button is depressed and so sends the electronic code for the letter to the application).

Gaines' (1988) general framework and Norman's (1986) well established user interface model were both described in chapter 2 section 2.1.2. Interactions and communication in the TEIF may take place at one of the interaction layers of Gaines' framework, which can be related to Norman's model as shown in Table 3-5. This provides further evidence for the value of using Gaines' layers as part of the TEIF.

Table 3-5 Comparing Gaines' framework against Norman's model

Gaines' framework	**Norman's model**
Culture / Intention layers	Establishing the goal
Intention layers	Forming the intention
Knowledge layer	Specifying the action sequence
Action / expression layers	Executing the action
Physical layer	Perceiving the system state
Knowledge layer	Interpreting the system state
Culture/Intention layer	Evaluating the system state with respect to the goals and intentions

Therefore the TEIF layers and explanations have been adapted from Gaines' framework (Gaines, 1988) as follows:

- *Cultural Layer* includes countries, tradition, language, and gesture.
- *Intentionality Layer* involves understanding, purpose and benefit.
- *Knowledge Layer* involves facts, concepts, and principles (Merrill, 2008).
- *Action Layer* involves actions and procedures (Merrill, 2008).
- *Expression Layer* describes how actions are carried out (e.g. correctly or with errors).
- *Physical Layer* is the lowest layer at which people interact with the physical world.

For example, pressing of the letter 'h' on the keyboard when typing 'hello' as a greeting when sending a text message can be thought of as:

- *Cultural Layer*: 'hello' is a normal greeting used in the culture.
- *Intentionality Layer*: the intent is a greeting.
- *Knowledge Layer*: how to spell the word 'hello'
- *Action Layer*: pressing key 'h'
- *Expression Layer*: pressing the correct key and not hitting neighbouring keys

- *Physical Layer*: the button is depressed and so sends the electronic code for the letter to the application.

The relationship between the interaction layer and other sub-components in the TEIF is shown in Table 3-6.

Table 3-6 The relationship between interaction layer and other subcomponents in the TEIF

Main Components	**Sub-components**
People	Role *(Intention Layer)*
	Ability / disability *(Knowledge Layer and Culture Layer and Expression Layer)*
Objects	Dimension *(Physical Layer)*
	Property *(Physical Layer)*
	Content *(Knowledge Layer)*
Technology	Electronic *(Physical Layer)*
	Non-electronic *(Physical Layer)*
	User Interface *(Physical Layer)*
	Application or service *(Intention Layer)*
	Cost *(Culture Layer)*
Interactions and communication	People-People (P-P) *All layers*
	People-Objects (P-O) *All layers*
	People-Technology (P-T) *All layers*
	People-Technology-People (P-T-P) *All layers*
	People-Technology-Objects (P-T-O) *All layers*
Time/Place	Time *(Physical Layer)*
	Place *(Physical Layer)*
Context	Location *(Physical Layer)*
	Weather condition *(Physical Layer)*
	Signal type and quality *(Physical Layer)*
	Background Noise *(Physical Layer)*
	Lighting *(Physical Layer)*
Interaction layer	*Culture*
	Intentionality
	Knowledge
	Action
	Expression
	Physical

As a result of the comments from the three developer experts and Professor Alan Dix the following changes to the original TEIF components were made as shown in Table 3.4.

1) The ‘Objects’ component

Developer expert 1 suggested finding a better word than ‘Objects’ but it has not been possible to find a better word and so the definition and meaning of the word in the TEIF context will be explained in more detail. As the reported discussion with Professor Dix in section 6.3 shows the TEIF has a consistent and clearly defined meaning of the word ‘Objects’ but only a brief explanation was provided for the experts because of time limitation.

2) The ‘Weather Condition’ sub-component

Developer expert 1 found this ‘Oddly Specific’ and so more examples of how weather condition could affect technology interactions have been provided.

3) The ‘Examples’ sub-heading

Developer expert 1 suggested it was unclear what were the examples and what were the explanations and so the sub-heading have been changed to ‘Explanations and examples’.

4) People being aware of other interactions

This aspect has been added as a sub-component to the context component as Professor Dix suggested this might be something worth considering in the TEIF (e.g. between other people or between other people and technology or other people and objects).

5) Identity of an object

The identity of an object has been added to the sub-component ‘Property’ as an example as suggested by Professor Dix.

6) User Perception

An explanation has been provided that as pointed out by Professor Dix, users may have the perception that technology (e.g. a robotic device triggered by the person walking past it) talking to them is a ‘T-P interaction’ whereas the TEIF categorises it as a ‘P-T-P interaction’.

7) TEIF components as index for case based solutions

Professor Dix agreed that the TEIF components could be useful as an index for case based solutions. This aspect will be considered as future work in chapter 11.

8) Instructions

Developer experts 1 and 2 suggested providing more information about the purpose of the TEIF. This participant information was provided through the email but some of the experts appear to have not read this carefully and so the information will be also provided in the start page of the online survey.

3.4 Architecture of the Technology Enhanced Interaction Framework

The overall architecture of the TEIF involves people, technology, and objects and is shown in Figure 3-2. The general Framework covers the use of any technology, which may or may not be electronic; the main difference is that electronic technology can store information. The TEIF extends Dix's framework (Dix, 1994) for Computer Supported Cooperative Work (CSCW) (Figure 2-9) to include interaction with objects as explained in section 3.1.3 and also adds the main component technology.

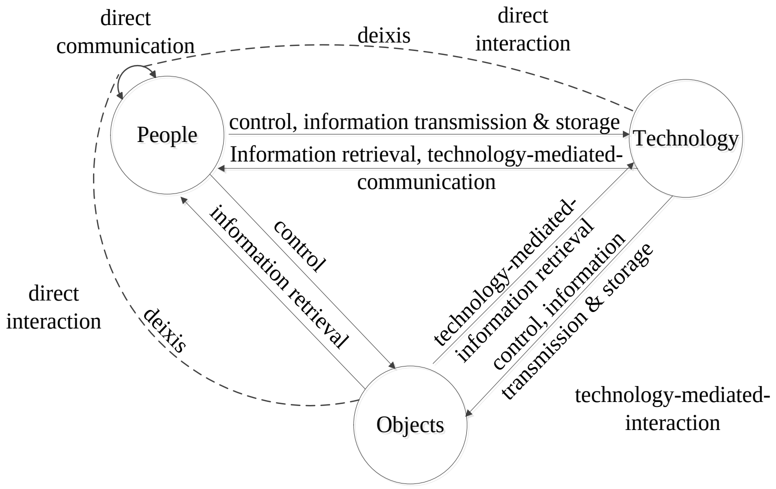


Figure 3-2 The Technology Enhanced Interaction Framework extended from Dix (1994)

The TEIF involves interactions from people to people (P-P), people to objects (P-O), people to technology (P-T), people to technology to people (P-T-P), and people to technology to objects (P-T-O) as follows:

3.4.1 Direct communication

People to People (P-P)

The communication between people and people (Figure 3-3) is a complex subject (Dix, 1994). Berne (1964) identified three roles of parent, adult, and child in his theory of Transactional Analysis. The Conversational Framework developed by Laurillard (Laurillard, 1993) describes how the roles of teachers and students interact in the learning and teaching process. Apart from a role, people have abilities or disabilities which can affect their use of technology or understanding of language and which can lead to communication breakdown. In direct communication people may refer to particular objects and technology – this is known as 'deixis' (Dix, 1994).

An example of direct communication between people is in a classroom at school; the teacher's role is characteristically to provide information, show examples, ask questions, and provide feedback on student answers. A student characteristically undertakes learning activities such as listening, asking and answering questions. However, there may be students who are deaf or blind, who have difficulty in learning or using technology, or international students who have difficulties in understanding a non-native language of instruction.

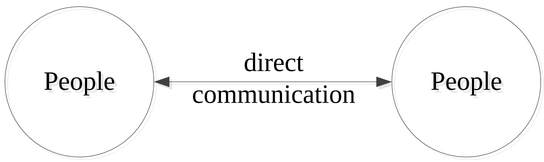


Figure 3-3 Direct Communication between people

3.4.2 Direct Interaction

1) *People to Objects (P-O)*

In direct interaction, people interact with objects (P-O) (Figure 3-4) by pointing, looking, or touching (P-O). There are two main purposes in the interaction between P-O: control, and information retrieval. People control objects by moving, or holding them, and can receive information by looking at or touching them, perhaps while being guided by other people drawing attention to them. For example, a museum guide may point at an exhibit (deixis) when explaining its history to visitors. Blind visitors can touch the object to get information such as shape, size, and weight. In direct interaction, when a person acts upon an object (e.g. moving a piano), the other people may feel the effect of the action, which is called ‘feedthrough’ in Dix’s framework (Dix, 1994, 1997)

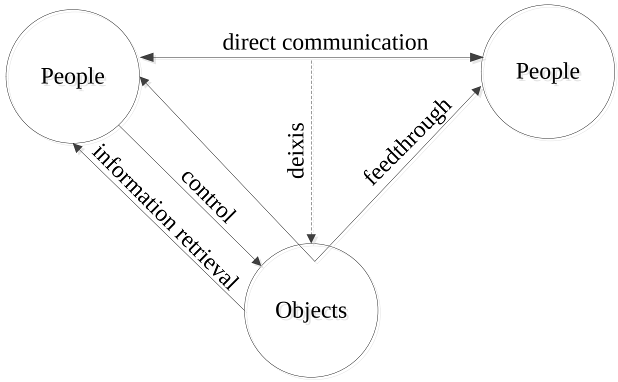


Figure 3-4 The Interaction between people and objects

2) *People to Technology (P-T)*

People can control technology (e.g. hold, move) or store information in technology (e.g save). People can also use the technology to transmit information and retrieve information from technology. The use of technology by people (P-T) is a well-established field of study and information regarding making these interactions more accessible has been discussed in chapter 2 section 2.2.

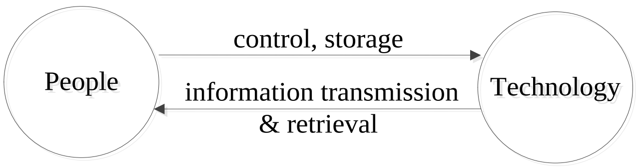


Figure 3-5 The interaction between people and technology

3.4.3 Technology supported communication

1) *People-Technology-People (P-T-P)*

Communication between people and people using technology mediation (P-T-P) (Figure 3-6) usually aims to improve that communication. An example of ‘feedthrough’ is people using their smart phones to communicate to each other by sending SMS or MMS, calling, sending email, sharing information through Bluetooth, or text chatting through mobile applications. An example of 'deixis' is when someone refered to the image they sent (e.g. look at this image).

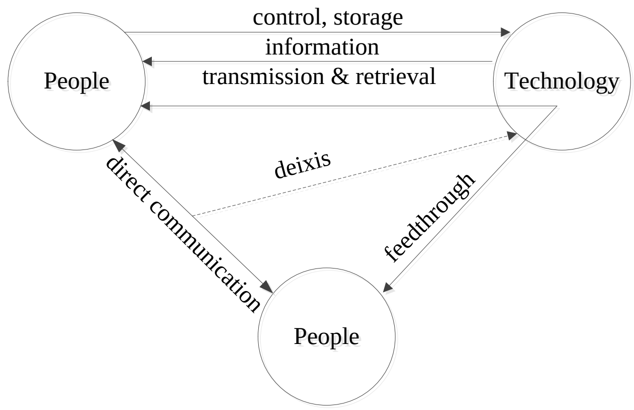


Figure 3-6 The interaction between people to technology to people

2) People-Technology-Objects (P-T-O)

The interaction between people and objects through technology (P-T-O) (Figure 3-7) mediated information retrieval is illustrated by people using (controlling) their mobile phones to take photos of a building or to scan QR codes on the building.

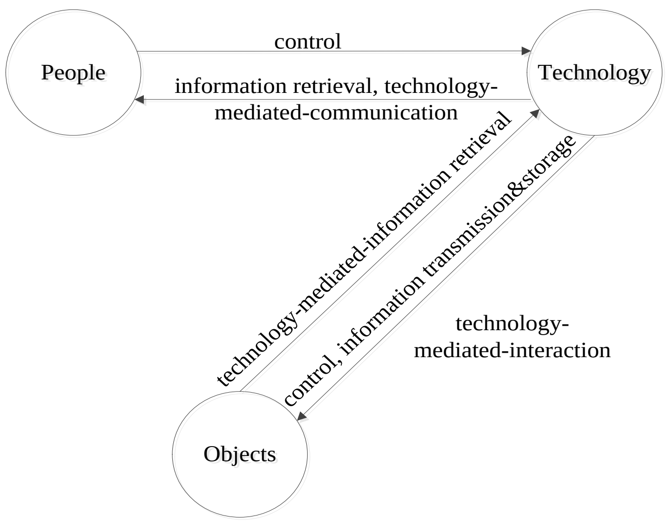


Figure 3-7 The interaction between people to technology to objects

3.5 Summary of the chapter

The TEIF focuses on the development of a general interaction framework to help design technology to support communication between people and improve interactions between people, technology, and objects, particularly in complex situations involving disabled people. The TEIF also addresses the issue that, until now, no existing interaction framework was designed to help technology developers to consider all of the possible interactions that occur at the same time and in the same place. The main and sub-components of the Framework are described and explained and examples are given for each type of interaction. The TEIF Method described in the next chapter has been developed in order to help developers understand and apply the TEIF to scenarios involving people with disabilities.

Chapter 4 Technology Enhanced Interaction Framework Method

The Technology Enhanced Interaction Framework (TEIF) Method has been developed in order to help developers understand and apply the TEIF to help make communication and interaction more accessible for people with disabilities. The TEIF Method does not replace other methods but supports them by providing multiple-choice questions to help identify requirements, the answers to which help provide technology suggestions that support the design stage. The TEIF Interaction Diagram and Use Case Diagram are also provided to help with this stage. The TEIF Method is explained in sections 4.1 – 4.6, while the application of the TEIF Method for the example scenario of a hearing impaired visitor to the Shadow Puppet Museum is also provided in section 4.7 to help understanding of the TEIF Method.

To answer the research questions required the development of multiple-choice questions and technology suggestions necessary to be able to apply the TEIF Method to scenarios involving hearing impaired people. The TEIF Method could in the future be developed into an easy to use expert system that could be applied to scenarios involving people with any disability but this was not feasible within the timescale available for this PhD. This would require many further appropriate multiple-choice questions and technology suggestions to be developed and is therefore discussed in chapter 11.

There was no change to the method following the expert validation and review described in chapters 5-7 and only a few very minor suggested changes to the text used in the example scenario and questions while Chapter 8 explains how the example scenario and questions used for the experiment had to be reduced in length and number due to experiment time constraints.

4.1 TEIF Method Overview

This section describes the steps used in the TEIF Method. Figure 4-1 illustrates the main five steps in the TEIF Method. Developers can go through steps 3 to 5 as many times as required to develop the best solution.

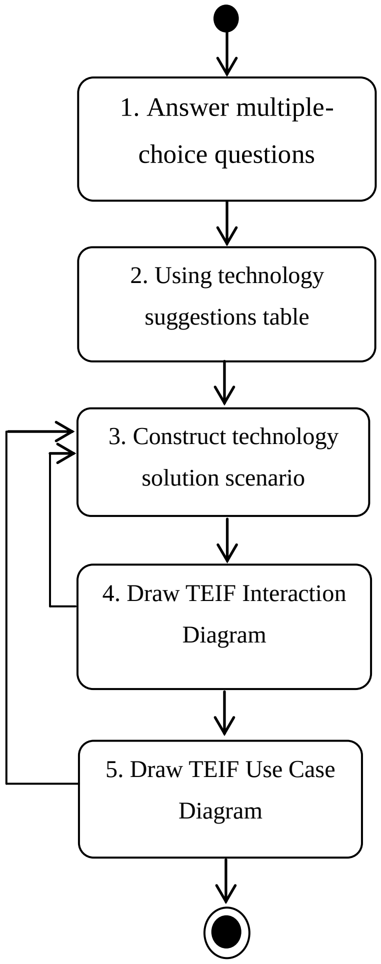
Step 1: developers answer multiple-choice questions for gathering or evaluating requirements which help identify any communication or interaction issues or problems involving hearing impaired people (section 4.2).

Step 2: developers use the technology suggestions table, which is based on answers to the multiple-choice questions, to help in designing or evaluating technology solutions (section 4.3).

Step 3: developers construct a technology solution scenario by using the technology suggestions table to help in designing or evaluating the solution (section 4.4).

Step 4: developers draw the TEIF overview Interaction Diagram showing the interactions between 'People', 'Technology', and 'Objects' to help in designing the technology solution and evaluating how technologies can be best combined (section 4.5).

Step 5: developers draw the TEIF overview Use Case Diagram to help in designing the technology solution, and evaluating how technologies can be best combined by showing the 'location' of interaction activities and the actions of the people and object 'actors' that are required to carry out the related tasks with the technology (section 4.6).



Multiple-choice questions developed based on the TEIF can help developers gather or evaluate requirements.

The technology suggestions can help developers decide which technologies are appropriate to use in designing or evaluating solutions by showing which technologies meet which requirements.

Developers use the technology suggestions table to help in constructing a solution written as a scenario.

The TEIF overview Interaction Diagram illustrates the interactions between ‘People’, ‘Technology’, and ‘Objects’ that address all the requirement issues and so can help developers design, evaluate, and present solutions.

The TEIF overview Use Case Diagram helps developers design and evaluate solutions by showing the actions of the people and object (actors) with the technology and the location but not the detail of the interactions.

Figure 4-1 The steps used in the TEIF Method

4.2 Multiple Choice Questions for Requirements

The TEIF Method helps developers gather or evaluate requirements by using multiple-choice questions which developed based on the TEIF. The questions help identify issues for which a technology solution is required.

Table 4-1 shows the relationship between the example 19 multiple-choice requirement questions for hearing impairment, main components, and sub-components in the TEIF.

Table 4-1 The relationship between requirements, main and sub-components in TEIF

Main Components	Sub-components	Requirement Questions
People	Role	3, 4, 11
	Ability / disability	5, 6, 7, 8, 9, 10
Objects	Dimension	11
	Property	11
	Content	15
Technology	Electronic	12, 13, 19
	Non-electronic	12
	User Interface	12, 13
	Application or service	14
	Cost	18
Interactions and Communication	People-People (P-P)	11
	People-Objects (P-O)	11
	People-Technology (P-T)	11
	People-Technology-People (P-T-P)	11
	People-Technology-Objects (P-T-O)	11
Time/Place	Time	2
	Place	2
Context	Location	16
	Weather condition	17
	Signal type and quality	12
	Background Noise	17
	Lighting	17
Interaction Layer	*Culture*	6, 7, 18
	Intentionality	1, 3, 4, 11
	Knowledge	15
	Action	11
	Expression	5, 8, 9,10
	Physical	2, 12, 13, 16, 17, 19

For example requirement questions ☐ means more than one answer can be chosen and ○ means only one answer can be chosen. The example requirement questions which are shown below only include the one that are related to the correct answer to the scenario provided.

1) What is the main purpose of the technology solution?

☐ a. improve communication and interaction

☐ b. make the service more interesting and exciting

☐ c. improve the service efficiency in terms of time and ease of use

☐ d. improve the storage and retrieval of information

☐ e. make the service more realistic and authentic

☐ f. improve users’ experiences in using the service

2) Where and when does the scenario take place?

○ a. same time / same place

○ b. same time / different place

○ c. different time / same place

○ d. different time / different place

3) What main role do people have in the scenario?

☐ a. presenter - audience (the presenter gives information to the ‘audience’ which could be only one person or many people and so controls the interaction. The audience can ask the presenter questions).

☐ b. peer - peer (any person can give information or ask questions to any other person and therefore no one person controls interaction)

☐ c. no communication between people only interaction with technology or objects

4) How many presenters and audience members are there?

○ a. one presenter – one audience member

○ b. one presenter – many audience members

○ c. many presenters – one audience member

○ d. many presenters – many audience members

5) Does the presenter have a disability?

○ a. Yes

○ b. No

6) What language does the presenter use?

☐ a. English

☐ b. Thai

☐ c. other language

☐ d. I do not know

7) What language does the audience use?

☐ a. English

☐ b. Thai

☐ c. other language

☐ d. I do not know

8) Does the audience have a disability?

○ a. Yes

○ b. No

9) What kind of disability does the audience have?

☐ a. hearing impaired

☐ b. visually impaired

☐ c. physically impaired

☐ d. none

10) What level of hearing loss does the presenter have?

☐ a. mild or moderate hearing loss

☐ b. severe or profound hearing loss

☐ c. I do not know

11) What two interaction types occur in the scenario?

☐ a. people to people

☐ b. people to objects

☐ c. people to technology

☐ d. people to technology to people

☐ e. people to technology to objects

12) What type of technology would be appropriate for the solution to the scenario?

○ a. online technology (Internet)

○ b. off-line technology

○ c. I do not know

13) What type of technology devices would be appropriate for the solution to the scenario?

○ a. mobile devices

○ b. non-mobile devices

○ c. I don't know

14) Has the presenter planned what he wants to say?

○ a. Yes

○ b. No

○ c. I do not know

15) Are audios or videos shown in the scenario?

☐ a. video

☐ b. audio

☐ c. neither

16) Where does the situation take place?

   ○ a. indoors

   ○ b. outdoors

   ○ c. I do not know

17) What are the two main environmental considerations identified that impact the scenario?

   ☐ a. noise (Background noise affects everyone's ability to hear and understand what is said. Noise has even greater impact on deaf and hard of hearing students because it tends to mark or cover over speech.)

   ☐ b. room acoustics (surface (e.g. walls, windows, tile) and objects within every room interact to produce reverberation in response to sound.)

   ☐ c. distance (How far is the audience standing from the presenter? The further a student is from the presenter or sound source, the softer the sound they receive.)

   ☐ d. visual access (How well can the audience see everything that is happening in different locations?)

   ☐ e. lighting (Inadequate lighting or large banks of windows can be challenging for deaf or hard of hearing audience because they cannot see the speakers face well or an interpreter may be located in shadows)

18) Does the customer require a low cost solution?

   ○ a. Yes

   ○ b. No

19) Should the technology solution work on a smart phone?

   ○ a. Yes

   ○ b. No

Tables 4-2 and 4-3 show the answers for three of the scenarios described in section 3.1.5 which demonstrates how the questions can be applied to multiple scenarios.

Table 4-2 Questions and answers 1-10 for three scenarios

Questions	**Thai Local Museum**	**GP Surgery**	**Segway Tour Scenario**
1. What is the main purpose of technology solution?	1a. improve communication and interaction	1a. improve communication and interaction	1a. improve communication and interaction
2) Where and when does the scenario (communication and interaction) take place?	2a. same time / same place	2a. same time / same place	2a. same time / same place
3) What main role do people have in the scenario?	3a. presenter – audience	3a. presenter – audience	3a. presenter – audience
4) How many presenters and audience members are there?	4b. one presenter – many audience members	4a. one presenter – one audience member	4b. one presenter – many audience members
5) Does the presenter have a disability?	5b. No	5b. No	5b. No
6) What language does the presenter use?	6b. presenters speaks Thai	6b. presenters speaks Thai	6c. presenter speaks other languages ….Italian….
7) What language does the audience use?	7b. audience speak Thai	7b. audience speak Thai	7a. audience speak English
8) Does the audience have a disability?	8a. Yes	8a. Yes	8a. Yes
9) What kind of disability does the audience have?	9a. hearing impaired	9a. hearing impaired	9a. hearing impaired
10) What level of hearing loss does the presenter have?	10c. I don't know	10c. I don't know	10c. I don't know

Table 4-3 Questions and answers 11-19 for three scenarios

Questions	Thai Local Museum	GP Surgery	Segway Tour Scenario
11) What two interaction types occur in the scenario? What kinds of interaction types occur in the scenario?	11a. people to people , b. people to objects	11a. people to people , d. people to technology to people (Anna booked the appointment by telephone)	11a. people to people, b. people to objects (presenter points at the old building) (visitors control Segway), c. people to technology (presenter interacts with an iPad), d. people to technology to people (presenter shows video on the iPad)
12) What type of technology would be appropriate for the solution to the scenario?	12a. online technology	12 b. off-line technology	12 b. off-line technology
13) What type of technology devices would be appropriate for the solution to the scenario?	13a. mobile devices	13a. mobile devices	13a. mobile devices
14) Has the presenter planned what he wants to say?	14a. pre-prepare speech	14.b No	14a. Yes (presenter speaks pre-prepare speech)
15) Are audios or videos shown in the scenario?	15c. neither	15c. neither	15b. video
16) Where does the situation take place?	16a. indoor	16a. indoor	16b. outdoors
17) What are the two main environmental considerations identified that impact the scenario?	17a. noise, e. inadequate lighting	17a. noise, b. distance	17a. noise, b. distance, c. (too bright) lighting
18) Does the customer require a low cost solution?	18a. low cost solution	18a. low cost solution	18b. no
19) Should the technology solution work on a smart phone?	19a. work with smartphones	19c. I don’t know	19c. I don’t know

4.3 Technology Suggestions Table for Thai Local Museum Scenario

Technology suggestions and descriptions are provided in a table with indications of how they meet the requirements and 12 of these technology suggestions are shown in Table 4-4 to Table 4-7 while an additional 10 are shown in Appendix A. The technology suggestions are based upon an analysis of answers to the requirement questions. Note that the column furthest to the right (Total score) shows the number of scenario requirements met by each technology suggestion. Ticks (indicating the requirement is met by the suggested technology) and crosses (indicating the requirement is not met by the suggested technology) are also shown in Table 4-4 to Table 4-7. The online version uses tooltips to display the explanations for the ticks or crosses. The paper version of the explanations for the mobile web are shown in Table 4-8 while a complete table of all these explanations is provided in Appendix B.

The technology suggestions table can be used to help identify one or more technologies than can be used for the solution by ensuring any combination of technologies used for the solution addresses all the requirement issues (i.e. all the issues have at least one tick in their column). For example, Suchat would like to use online technology indoors which is reflected in the answers to questions 12 and 16. He also would like to use Chuty's and her parents' smartphones to keep his costs low, which is shown in the answers to questions 13, 18, and 19. Many technologies may meet a requirement: for example, all of the technology suggestions shown in Table 4-4 to 4-5 improve communication which is the requirement expressed in the answer to requirement question 1. The technology suggestions in the table are listed in order of total score.

If different combinations of technologies can be used to meet all the requirements then the developer can use requirement priorities and how well the technologies meet requirements to help evaluate the best solution. For example, while the highest scoring technology is the mobile web site, which addresses all of the problems and requirements, the highest scoring technology might not always be the chosen solution as the final decision about any technologies to implement would depend on their cost and prioritisation of the relative importance of requirements. Since the TEIF Method is not used in isolation and developers will have learnt about other software development methods and requirements prioritisation through their undergraduate or postgraduate courses, the TEIF Method provides information to help with such prioritisation rather than introducing a new prioritisation method.

Further possible future development of the Technology Suggestion Table will be explained in chapter 11.

Table 4-4 Technology Suggestion Table (1-3)

Technology suggestions	Explanation	**Which requirements the technology meets**																
		1a.improve communication	2a.same time/ same place	3a.presenter-audience	6b. speaker speaks Thai	7b. presenter speaks Thai	9a. hearing impaired	11a. people – people	11b. people - objects	12a.online technology	13a.mobile devices	14a.pre-prepared speech	16a. indoor	17a. noise	17e.inadequate lighting	18a. low cost solution	19a. work with smart phones	Total Score
1. Mobile web site	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network. For more information about basic guideline mobile web practice : http://www.w3.org/TR/mobile-bp/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
2.Pre-prepared caption/subtitle	Captions are text versions of the spoken word. Captions allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. More information about captions see: http://webaim.org/techniques/captions/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
3. Frequently asked questions (FAQ)	FAQ are listed questions and answers, all supposed to be commonly asked in some context, and pertaining to a particular topic. It is very useful for the presenter who communicates with hearing impaired people because they can send the pre-prepared answers to the audience in case the questions that they ask match the FQA. For more information about FAQ see: http://en.wikipedia.org/wiki/FAQ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16

Table 4-5 Technology Suggestion Table (4-6)

Technology suggestions	Explanation	Which requirements the technology meets																
		1a.improve communication	2a.same time/ same place	3a.presenter-audience	6b. speaker speaks Thai	7b. presenter speaks Thai	9a. hearing impaired	11a. people – people	11b. people - objects	12a.online technology	13a.mobile devices	14a.pre-prepared speech	16a. indoor	17a. noise	17e.inadequate lighting	18a. low cost solution	19a. work with smart phones	Total Score
4. Quick Response Code (QR-code)	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special scanner to scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information. For more information about QR codes see: http://www.whatisaqrcode.co.uk/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
5. Instant messaging	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Instant_messaging	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	15
6. Short Message Service (SMS)	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Short_Message_Service	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15

Table 4-6 Technology Suggestion Table (7-9)

Technology suggestions	Explanation	**Which requirements the technology meets**																
		1a.improve communication	2a.same time/ same place	3a.presenter-audience	6b. speaker speaks Thai	7b. presenter speaks Thai	9a. hearing impaired	11a. people – people	11b. people - objects	12a.online technology	13a.mobile devices	14a.pre-prepared speech	16a. indoor	17a. noise	17e.inadequate lighting	18a. low cost solution	19a. work with smart phones	Total Score
7. Vibrating alert	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone. For more information about vibrating alert see: http://en.wikipedia.org/wiki/Vibrating_alert	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
8. Barcode	Barcodes originally require a special reader to access them but later scanners and interpretive software became available on smartphone devices. There needs to be line of sight between the barcode and the reader. For more information about barcodes see: http://www.britannica.com/EBchecked/topic/52455/bar-code	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	15
9. Radio frequency identification (RFID)	RFID is a radio technology which can be read by an RFID receiver automatically with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can’t determine which item the user is browsing. The RFID tags are clearly to show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content. For more information about RFID see: http://cdn.intechopen.com/pdfs/31056/InTech-Using_rfid_nfc_and_qr_code_in_mobile_phones_to_link_the_physical_and_the_digital_world.pdf	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	×	×	14

Table 4-7 Technology Suggestion Table (13-14)

Technology suggestions	Explanation	Which requirements the technology meets																
		1a.improve communication	2a.same time/ same place	3a.presenter-audience	6b. speaker speaks Thai	7b. presenter speaks Thai	9a. hearing impaired	11a. people – people	11b. people - objects	12a.online technology	13a.mobile devices	14a.pre-prepared speech	16a. indoor	17a. noise	17e.inadequate lighting	18a. low cost solution	19a. work with smart phones	Total Score
13. Speech recognition	The captioning is performed by an operator, using an electronic stenotype keyboard or more often, speech recognition revoicing by human operating using speech recognition software to transcribe into text. No training required for users. Speech recognition can help clarify missing words but sometimes make errors. If there is noise or some other sound in the room, the number of errors will increase. Speak recognition works best if the microphone is close to the user (e.g. in a phone or if the user is wearing a microphone). More distance microphones will tend to increase the number of errors. For more information about live captions see guideline 1.2.4 Captions (Live) –W3C: http://www.w3.org/TR/UNDERSTANDING-WCAG20/media-equiv-real-time-captions.html	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×	13
14. Flashing light	A flashing light alert gets attention of hearing impaired people normally only used for room lights as need to get attention whether person is looking. Normally used for room lighting only off-line. High cost wireless systems are becoming available.	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	✓	×	13
15. Infrared Systems	These systems utilize light waves to transmit sound from the transmitter to a special light sensitive receiver which can be mobile. There must be a clear line of connection between the transmitter and receiver so that the light signal is not interrupted. These systems can be sensitive to external light sources or interfering objects. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about Infrared see:: http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx	✓	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	✓	×	×	12

Table 4-8 Explanation for Mobile Web Technology

Mobile Website	Explanations
1a improve communication	displays captions
2a. same time / same place	People control and read captions.
3a. presenter –audience	Presenter controls captions.
6b. speaker speaks Thai	can display in Thai
7b. audience speak Thai	can display in Thai
9a. Audience have hearing impairments	can read captions
11a. people to people	control and read captions
11b. people to objects	display information from QR-codes
12a. online technology	works online
13a. mobile devices	works on mobile devices
14a. presenter planned what to say	displays captions
16a. indoors	works indoors
17a. noise	displays captions
17e. inadequate lighting	can read in the dark
18a. low cost solution	low cost and uses audience devices
19a. work on smartphone	works on smartphones

To develop the technology suggestions (Table 4-4 to 4-5), an extensive review was conducted of technologies and their potential uses for hearing impaired people as well people with other disabilities.

4.4 Technology Solution Scenario for Thai Museum Example

The technology solution scenario describes how the technologies selected from the technology suggestions table meets the requirements. This can be revisited to find the best solution through an iterative process involving evaluation with the help of the TEIF overview Interaction Diagram and Use Case Diagram. To help developers understand how to apply the TEIF Method, an example technology solution scenario is provided (section 4.7.3) with an explanation of how this was developed (section 4.7.6).

4.5 TEIF Interaction Diagram

The TEIF Interaction Diagram shown in Figure 3-2 to Figure 3-7 (chapter 3) can be used to help developers evaluate how technologies can be best combined to create a solution. There are various potential ways of visualising and drawing this combination and the suggested way is for the circles representing ‘People’, ‘Technology’, and ‘Objects’ in Figure 3-2 to Figure 3-7 to be redrawn as rectangles to save space and the connections between them annotated with the relevant actions numbered to show a typical sequence. An example of using this approach for the Thai museum example scenario is shown in Figure 4-3.

4.6 Use Case Diagram

To help developers understand, evaluate and check the scenario solution against the requirements, a Use Case Diagram can be used (Stevens & Pooley, 2006).

Figure 4-2 shows the relationship between the Interaction Diagram and the Use Case Diagram. Actors can be particular people or people's roles or objects. The Use Case Diagram shows the actions of the actors on the technology that are required to carry out the related tasks. To help developers understand how to apply this in the TEIF Method, an example Use Case Diagram is provided (section 4.7.5).

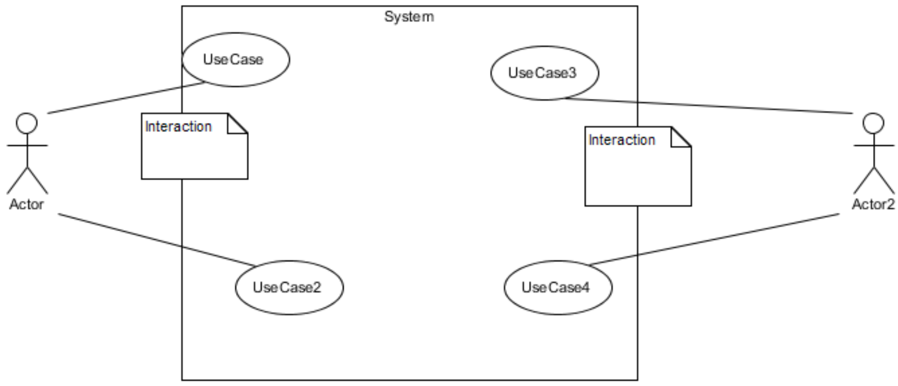


Figure 4-2 Relationship between Interaction Diagram and Use Case Diagram

4.7 Examples to illustrate the TEIF Method

To help developers understand how to apply the TEIF Method, an example scenario involving a hearing impaired visitor to the Shadow Puppet Museum (section 4.7.1), is provided along with example explanations for the 'correct' answers to the 19 example requirement questions (section 4.7.2) and a technology solution for the example scenario (section 4.7.3), example Interaction Diagram (section 4.7.4), example Use Case Diagram (section 4.7.5), and explanations for the choice of technology solution (section 4.7.6).

4.7.1 Thai Local Museum Example Scenario

In order to explain how the TEIF can be applied, the following example scenario is provided which shows problems faced by the visitors, the museum's owner and suggests requirements for a technology solution.

'Suchat Trapsin allocated some parts of his house to become the Museum of Folk Art and Shadow Puppets, in Thailand. There are exhibits of shadow puppets inside the museum, but there is no information provided in text format. This is because Suchat normally explains the history and tradition in Thai by talking to visitors. He presents the same information in the same order every time.

On Friday afternoon, Chuty (who has been hearing impaired since birth) and her parents (who have some hearing loss due to their age), who are local people, visit the museum. Suchat starts the talk by explaining about the exhibits. During the talk, Chuty and her parents find that it is very difficult to hear Suchat clearly. Chuty asks Suchat some questions about the exhibits. Suchat answers the questions, but Chuty misses some of the words. While Chuty and her parents are watching the shadow puppet show, they also cannot hear the conversation clearly because of the background music which is part of the show. It is also fairly dark which makes lip-reading very difficult for them.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him. There is good Wi-Fi at the museum so he would like to use Chuty's and her parents' smartphones to keep his costs low.'

4.7.2 Example Answers and Explanations for Thai Local Museum Scenario

To show how the TEIF Method helps gather, identify or evaluate requirements from developers, the following answers and explanations based on the scenario are provided:

1) What is the main purpose of the technology solution?

   Answer: a improve communication

   Explanation: Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him.

2) Where and when does the scenario take place?

   Answer: a. same time / same place

   Explanation: Suchat, Chuty and her parents are in the same place (The Museum of Folk Art and Shadow Puppets, Thailand) and at the same time (Friday afternoon).

3) What main role do people have in the scenario?

   Answer: a. presenter - audience

   Explanation: the 'presenter' (Suchat) talks to the 'audience' (Chuty and her parents) and the audience ask the presenter questions.

4) How many presenters and audience members are there?

   Answer: b. one presenter – many audience members

   Explanation: Suchat is a person who gives the information (one presenter) to Chuty and her parents (many audience members).

5) Does the presenter have a disability?

   Answer: b. No

   Explanation: Suchat doesn't have any disability.

6) What language does the presenter use?

   Answer: b. Thai

   Explanation: Suchat talks to Chuty and her parents in Thai.

7) What language does the audience use?

   Answer: b. Thai

   Explanation: Chuty and her parents are local people who live in Thailand.

8) Does the audience have a disability?

   Answer: a. Yes

   Explanation: Chuty and her parents have a disability.

9) What kind of disability does the audience have?

   Answer: a. hearing impaired

   Explanation: Chuty has had hearing impairment at birth and her parents have hearing loss due to their age.

10) What level of hearing loss does the presenter have?

    Answer: c. I don't know

    Explanation: There is no detailed information about the level of hearing loss of audience member in the scenario.

11) What two interaction types occur in the scenario?

    Answer: a. people to people and b. people to objects

    Explanation: Suchat communicates with Chuty and her parents (people - people) and Chuty and her parents watch the shadow puppet show (people - objects).

12) What type of technology would be appropriate for the solution to the scenario?

    Answer: a. online technology (Internet)

    Explanation: There is good Wi-Fi at the museum and Suchat would like to use Chuty's and her parents' smartphones.

13) What type of technology devices would be appropriate for the solution to the scenario?

    Answer: a. mobile devices

    Explanation: Suchat would like to use Chuty's and her parents' smartphones.

14) Has the presenter planned what he wants to say?

    Answer: a. Yes

    Explanation: Suchat has already prepared what to talk to the visitors about (pre-prepared speech).

15) Are audios or videos shown in the scenario?

    Answer: c. neither

    Explanation: There is no audio or video information to be shown in the scenario. The music is just a background sound.

16) Where does the situation take place?

    Answer: a. indoors

    Explanation: Inside the museum **(**the Museum of Folk Art and Shadow Puppets**)**.

17) What are the two main environmental considerations identified that impact the scenario?

    Answer: a. noise and e. lighting

    Explanation: Chuty and her parents cannot hear the conversation clearly because of the music background, which is part of the show. It is also fairly dark which makes lip-reading very difficult.

18) Does the customer require a low cost solution?

    Answer: a. Yes

    Explanation: Suchat would like to use Chuty's and her parents' smartphones to keep his costs low.

19) Should the technology solution work on a smart phone?

    Answer: a. Yes

    Explanation: Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him using their smartphones.

4.7.3 Example Thai Local Museum Scenario Technology Solution

To help developers understand how to use the technology suggestions, an example solution is provided that incorporates some of the technology suggestions shown in Tables 4-2 to 4-5. The numbers below link to the technology suggestions, which are used in this example scenario technology solution.

'The technology developer has decided based on the TEIF Method's suggestions and discussions with their client Suchat to make available a mobile web site (1) with which Chuty and her parents can use their smart phones to enhance the visit. There is a specific function called live functionality which assists Chuty and her parents to communicate with Suchat. Chuty and her parents go to the mobile website (1) and enable the function before the tour starts. The function allows Suchat to notify Chuty and her parents when the tour begins and change the topics by pressing the 'start' button on his mobile phone. Chuty and her parents' phones vibrate (7) at the same time to notify them of this, and as Suchat starts speaking the pre-prepared summary captions (2) for the first topic, appear on their smartphones. As the captions (2) are presented on the mobile website (1), the words are highlighted in a sentence, allowing her to follow the conversation. Suchat can also notify Chuty and her parents that the topic is changing by sending a message (6) to the server causing the captions to automatically change on the mobile website (1).

Sometimes Chuty can't catch all of the conversation but she can pick out keywords through lip reading and hearing. Moreover, she can search for text by using automatic speech recognition (13) of keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour. So she can scroll up and down to find the conversation.

When Suchat shows the shadow puppet, he uses his mobile phone to select and indicate the captions (2) of the show that he is currently performing. Chuty and her parents then can enjoy the show by watching the shadow puppet and they also can read the captions when they need to on their smartphones.

During the tour, Chuty asks some questions by typing instant messages (5) on her smartphone which Suchat answers supported by selecting pre-prepared caption answers to frequently asked questions (3) or by typing the answers (5) on his smartphone. When Chuty asks questions about the exhibits, to help Chuty understand Suchat's answers she can use the further information displayed on her smartphone browser through the links from the QR codes (4) on the exhibits.'

4.7.4 *Example Thai Local Museum Interaction Diagram*

The Interaction Diagrams shown in chapter 3, Figure 3-2 to Figure 3-7, have been used to evaluate how technologies can be best combined to create a technology solution for the example scenario that can also help understand the scenario solution's interactions. The circles representing 'People' (e.g. Suchat, Chuty and parents), 'Technologies' (e.g. Chuty and Parents Mobile phones, Suchat's Mobile Phone, Mobile Web) and 'Objects' (e.g. Poster and Exhibits) in Figure 3-2 to Figure 3-7 have been redrawn as rectangles in Figure 4-3 to save space and the connections between them have been annotated with the relevant actions numbered to show a typical sequence.

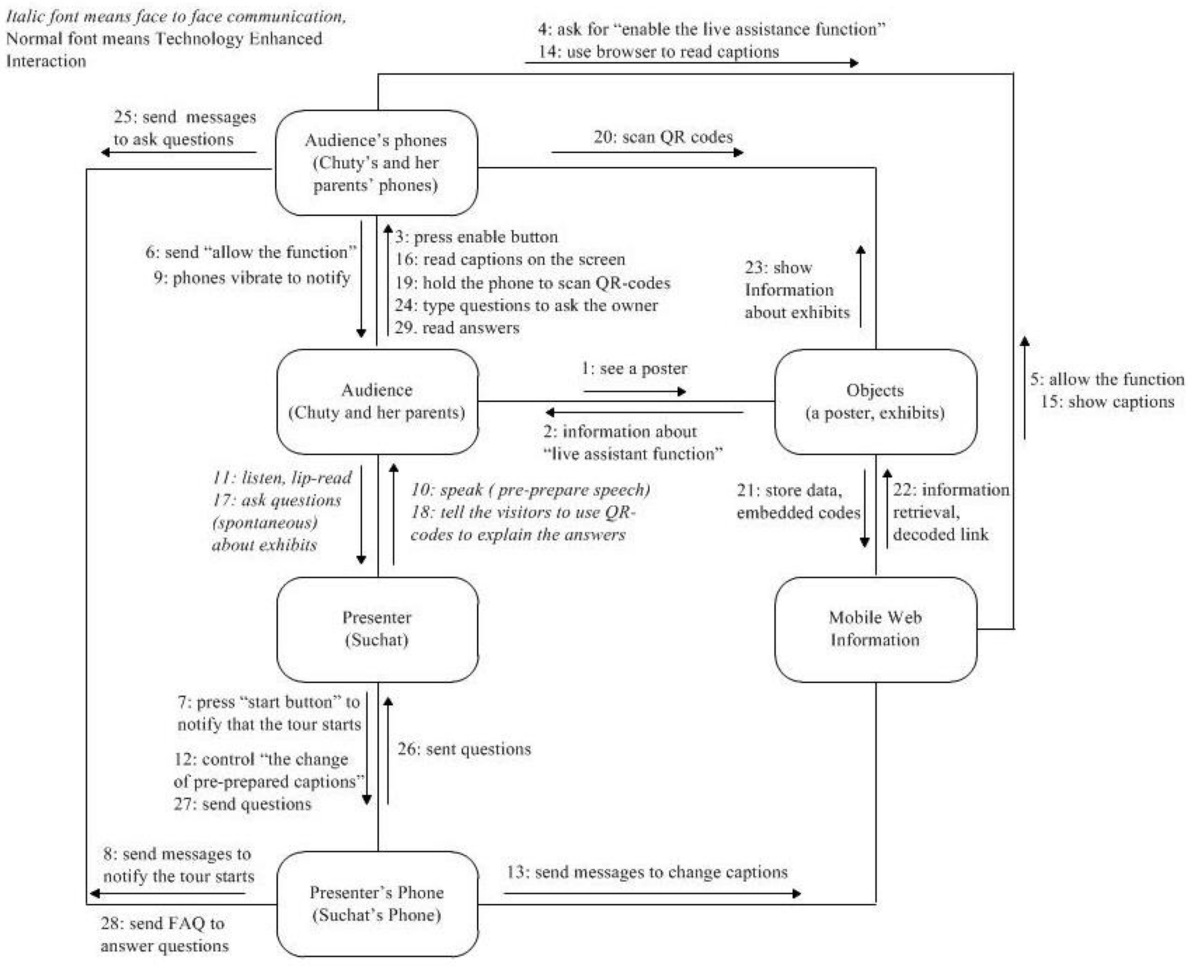


Figure 4-3 TEIF Overall Interaction Diagram

4.7.5 Example Use Case Diagram

The Use Case Diagram for the Thai Local Museum example scenario is presented in Figure 4-4.

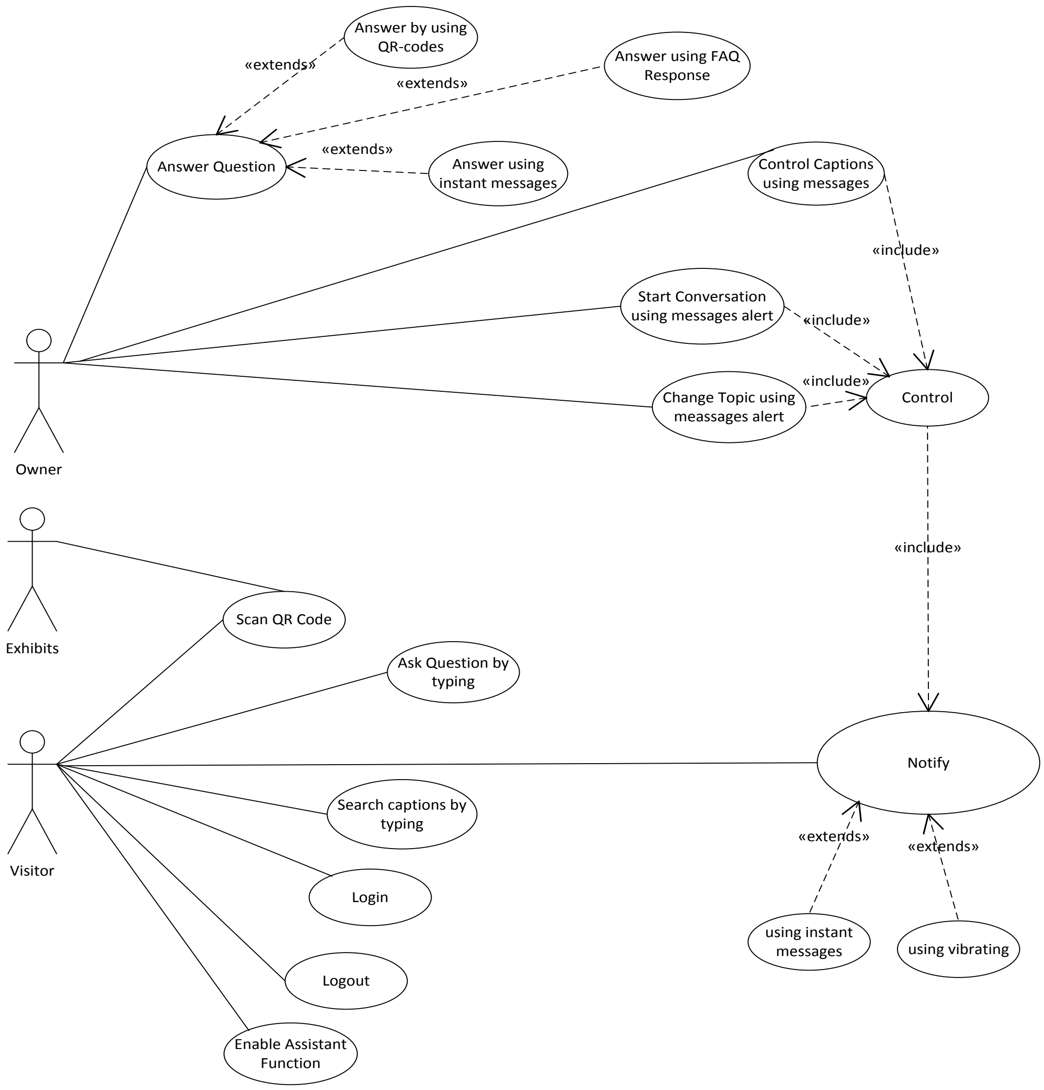


Figure 4-4 Example of Use Case Diagram

4.7.6 Example Explanation of how the TEIF Method helped decide on the solution

From the Scenario Technology Solution, Suchat has a role in the communication which is important because he can control technology to send an instant message to Chuty and her parents' phones to make them vibrate to let Chuty and her parents know when the conversation starts. The technology solution selected to enable this is instant messaging which was chosen over SMS. Instant messaging is suggested because it is free of cost using wireless and smartphones (Harper & Clark, 2002; Isaacs et al., 2002; Sheng & Xu, 2010). Moreover, it can also vibrate Chuty's and her parents' smartphones which is better than turning lights in the room on and off to notify them as this may not be noticeable in sunlight.

Captions can be of value to everybody, especially people with no useful hearing, and were selected as the solution of choice (Bain et al., 2005; Benjamins, 2008; Cambra, 2008; Iglesias et al., 2014; Wald, 2010). Thai speech recognition is not very accurate for spontaneous speech (Suebvisai et al., 2005) and therefore as Suchat already knows what he plans to say the best solution is pre-prepared summary captions.

As he presents his talk Suchat controls the changing pre-prepared captions on the mobile website using his smartphone. He has an application on his phone that can send a message to the webserver to display the next caption on the webpage that Chuty and her parents are looking at. This solution was chosen over using a pre-prepared captioned video as that would not have supported live face to face communication and interaction between Suchat and his visitors.

Chuty and her parents ask spontaneous questions about some of the exhibits in the museum. Suchat will not have been able to pre-prepare the order of the captions. In this case, Suchat can introduce machine readable QR codes. QR codes were selected rather than other possible approaches (e.g. barcodes, RFID tags, image recognition, typing a code number) because they are simple, cheap, quick and work with smartphones using free software to provide a link to information on a mobile website (Australian Community Exchange, 2011).

4.8 Case Based Design Solutions / Patterns

The TEIF Method could also be used as an index to identify previous solutions for similar scenarios that could help support developers in their design of new solutions. Solutions could be scored against scenario requirements as shown in

Table 4-9 in a similar way to the technology suggestions as shown in Tables 4-2 to 4-5.

For instance, if four solutions have previously been designed for similar scenarios to the scenario example shown in section 4.7.1 above then the TEIF Method would be able to show a new developer how closely these previous solutions met the requirements of the new scenario. For example a developer can immediately see that the designed technology solution 3 has the closest similarity to the new scenario with a score of 12 requirements met.

Table 4-9 Case Based Design Solutions

Designed Technology Solution	1a.improve	2a.same time/ same place	3a.presenter-audience	6b. speaker speaks Thai	7b. presenter speaks Thai	9a. hearing impaired	11a. people – people	11b. people - objects	12a.online technology	13a.mobile devices	14a.pre-prepared speech	16a. Indoor	17a. noise	17e.inadequate lighting	18a. low cost solution	19a. work with smart	Total Score
3	✓	✓	✓	x	x	✓	✓	✓	✓	✓	✓	x	✓	x	✓	✓	12
4	✓	✓	✓	✓	✓	x	✓	✓	x	X	✓	x	✓	x	✓	x	10
2	✓	✓	✓	x	x	✓	✓	x	x	✓	✓	x	✓	x	✓	x	9
1	✓	✓	x	x	x	x	✓	✓	x	x	x	✓	x	✓	✓	x	7

4.9 Summary of the chapter

The TEIF Method has been developed in order to help developers understand and apply the TEIF. There are two essential parts to applying the TEIF Method. Firstly, using multiple-choice questions, in order to help gather or evaluate the requirements. Secondly, based on the answers to the questions, technology suggestions are provided to help developers design or evaluate a technology solution with the help of the TEIF Interaction Diagram and Use Case Diagram. An example is also provided to help developers understand how to apply the TEIF Method and this includes a scenario, multiple-choice questions with answers and explanations, a scenario technology solution, an Interaction Diagram, a Use Case Diagram and an explanation why particular technologies rather than others were selected for the designing of the technology solution. There is also the potential for using the TEIF Method as an index for finding relevant previous design solutions that could help developers design new solutions to similar scenarios.

Chapter 5 Framework and Method Validation and Review Methodology

This chapter describes the research methodology that has been used for review and validation of the TEIF and TEIF Method. Section 5.1 explains the triangulation method used for gathering data for the evaluation methodology which consists of information from theory and existing frameworks, expert validation (section 5.2.1) and expert review (section 5.2.2). The methodology for choosing the experts is discussed in section 5.2.3. Section 5.3 discusses research methods. Section 5.4 presents the design of the questionnaires while the piloting of the questionnaire is discussed in section 5.5. Finally, section 5.6 summarises this chapter.

5.1 Triangulation

Triangulation is a technique which is used in both quantitative and qualitative research studies. The aim of using triangulation in qualitative research is to ensure the validity and credibility of the results (Altrichter, Feldman, & Posch, 2008; Cohen, 2000; O'Donoghue & K., 2003). There are four basic types of triangulation (Denzin, 1970):

- Data triangulation: involves different time, social situations, and variety of people
- Investigator triangulation: using multiple researchers in an investigation

- Theory triangulation: using more than one theoretical scheme in the interpretation of data
- Methodological triangulation: using more than one method for gathering data, such as interviews, questionnaires, and documents

In this thesis, methodological triangulation is concerned with the using of more than one method for gathering data in evaluation methods to help in validating the TEIF and TEIF Method. The methodological triangulation is based on theory and existing frameworks, expert validation and expert review, and user evaluation as shown in Figure 5-1.

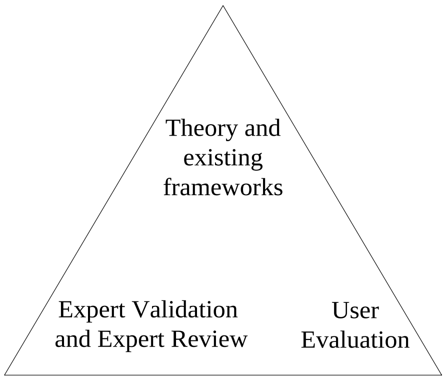


Figure 5-1 Triangulation Diagram

The TEIF described in chapter 3 was developed based on an understanding of the existing interaction frameworks and theories. Evaluation of the TEIF and TEIF Method was undertaken using a system built around isurvey (The Online Survey of The University of Southampton: www.isurvey.soton.ac.uk) and structured to help the users understand how to use the TEIF Method to apply the TEIF. Experts reviewed and validated the TEIF and TEIF Method by answering the online questionnaire and discussing it afterwards.

The theory and existing frameworks have already been discussed in chapter 2. This chapter will discuss expert validation and expert review which were used in obtaining data in this study and the user evaluation will be discussed in chapter 8. Investigator triangulation using two groups of three experts was used in this study for both validation and review and is explained in sections 5.2 and 5.3.

5.2 Validation, Reliability, and Review

The experts were required to validate (section 5.2.1) and review (section 5.2.2) the TEIF and TEIF Method before the TEIF Method was evaluated with developers. While it might be more usual to first validate and review a framework, and then develop a method for applying the framework in this case after discussion with a few experts it was decided that it would help the experts to understand the purpose and value of the TEIF by also providing them with the TEIF Method to apply the Framework. It was understood that any changes required for the TEIF might also require changes to the TEIF Method.

5.2.1 Validation and Reliability

Validation is an important process particularly when a measure is being developed which operationalises the concept as the researcher intended (Sapsford & Jupp, 1996; Scaife, 2004). Validity confirms the truth or accuracy of an instrument to measure the construct in the context of the concepts being studied (Polit & Beck, 2006). Asking a group of experts to validate the concept at an early stage provides useful feedback on the quality of a newly developed concept. Without the validation, untested data may need revision in a future study (Coombes, 2001).

The purpose of using expert validation to validate the TEIF is that there is no other interaction framework which addresses the new concept of designing using technology to enhance the interaction between people, technology, and objects in face to face situations particularly in a complex situation when disabled people are involved. Therefore, the TEIF and its content are new and need to be validated in order to check whether they are correct and clear. This approach will also result in saving time after the implementation stage by not have to redo anything that was not well thought out.

The validation and review of the TEIF and TEIF Method was considered by two groups: developer experts and accessibility experts. The experts were asked for their agreements on the content of the TEIF and TEIF Method. For example, there were closed question which asked experts whether they agreed or disagreed with the components of the TEIF or whether they agreed with the technology suggestions which are based on the issues from the scenario.

Reliability measures the consistency of the instrument. The example used in a test or procedure should produce similar results under constant conditions on all occasions. Checking reliability normally comes at the question wording and piloting stage. If the reliability is strong it does not necessarily mean it is also valid, but if an item is unreliable, then it must also lack validity (Bell, 2010; Coombes, 2001). Olson (2010) suggests that 'some variation in expert ratings can be controlled by standardising the task given to the expert, but that other variation cannot be easily controlled without specific selection of experts (e.g., that related to experience or background knowledge)'. Investigator triangulation using three experts in each group with similar experience or background knowledge increases the reliability of the TEIF and TEIF Method, and is explained further in section 5.2.3.

5.2.2 Expert Review

An expert review is a process asking the opinions, suggestions, feedback or comments from experts. For example, subject matter experts are asked for checking content of questionnaires, sensitivity / threat of information request or appropriateness of wording and terminology of items (Ramirez, 2002).

In this study, the groups of experts were asked to review the TEIF and TEIF Method in slightly different ways. The developer experts were focused on the reviewing of the main and sub-components of the TEIF. Examples of the questions they were asked are whether the instructions, descriptions and explanations are clear, what is missing, and whether they had other comments. Only the developer experts were consulted about the Interaction Diagram and Use Case Diagram and whether they are useful in designing the technology solution to the scenario. Both developer and accessibility expert groups were asked to check whether the scenario, requirement questions, multiple choices, suggested answers and the explanation of the answers were correct, sensible and understandable. Moreover, questions about the example of designing the scenario technology solution and the explanation for choosing the technologies also were asked to both expert groups. However, the accessibility experts were focused on checking the technology suggestions and the explanations of the ticks and crosses in the tables and were also asked their opinion and suggestions to improve the content.

5.2.3 *Selection of Experts*

In this study, two groups of expert were chosen to look at different aspects of validation and reviewing the TEIF and TEIF Method. According to Coombes (2001), the measurement of the instrument can usually be repeated by a different researcher with a different respondent. The measurement of the questionnaire should be the same no matter who does the measuring. Therefore, three experts were chosen for each group so that if there was disagreement among the group a majority decision could be used.

The first group of experts chosen for the validation and review were three 'developer experts' selected for their development expertise and with a Computer Science background and over five years experience. This group focused on validation and review of the TEIF and TEIF Method which consisted of: a scenario, requirement questions, Interaction Diagram, Use Case diagram, and the technology suggestions that were used in the example scenario solution.

The second group of experts chosen for the validation and review were three 'accessibility experts' and were selected for their extensive understanding and experience in working in this area for at least five years. This group focused on validating and reviewing the accessibility aspects of the TEIF Method (only the scenario, technology suggestions and example solution). They were given more technology suggestions to validate and review than the developer experts.

5.3 Research Method

The possible methods that could have been used in validating and reviewing the TEIF and TEIF Method are compared in Table 5-1. In this study, the combination of online questionnaire on the University's isurvey system and interviewing were chosen for the expert validation and expert review. This is because the experts need some time to complete the questionnaire. They can choose their preferred time and place and they also can stop and return to the questionnaire whenever they want. Using the online questionnaire helps experts to see the prototype of the system so they can give more suggestions or comments about how to design the layout of the system. However, it might result in confusion between validating or reviewing the questionnaire and the system. Therefore, in the analysis of the results it was important to note whether the comments were about the system or the TEIF and TEIF Method. For example, in the pilot test respondents gave comments about the slow response of the isurvey system, which is not an issue about the content. The online questionnaire makes it easy to analyse the data and read the comments compared to the paper based system but does not help when the expert requires clarification of the questions or misunderstands some points. Therefore, the study also used the interview methods to discuss with the experts about any unclear information and Professor Alan Dix and Professor Brian R Gaines were also contacted to comment on the TEIF through interview.

Table 5-1 Comparing Research Methods

Research Methods	Advantages	Disadvantages
Paper based questionnaire	1) Easy to navigate 2) Can access the questionnaire anytime anyplace 3) Easy to correct 4) Respondents have time to consider their questionnaire (Brace, 2008). 5) They can leave the questionnaire while they go away to check information (Brace, 2008).	1) Cannot read handwriting 2) Fixed space for comments 3) The experts have to return the questionnaire. 4) A researcher has to send the questionnaire by post if the experts are not in same place. 5) The experts cannot ask if they do not understand. 6) Cannot stop respondents from reading through all of the questions before responding (Brace, 2008)
Electronic document questionnaire	1) Easy to read comments 2) No worry about spacing 3) Respondents have time to consider their questionnaire (Brace, 2008). 4) They can leave the questionnaire while they go away to check information (Brace, 2008).	1) The experts have to return it. 2) The experts cannot ask if they don't understand. 3) Cannot stop respondents from reading through all of the questions before responding (Brace, 2008)
Online Questionnaire on survey system	1) Easy to reach respondents (Coombes, 2001) 2) Respondents can stop for a break whenever they want and return later (Brace, 2008) 3) Respondents can see a prototype system. 4) Online – questionnaire can be designed to have visual appeal (e.g. feedback logic and tooltips) (Brace, 2008) 5) Easy to read comments 6) No worry about spacing 7) Automated analysis 8) More effective with sensitive issues (Basi, 1999; Kellner, 2004) involving the respondents more (Brace, 2008) 9) The questions are presented in the sequence that the researcher wants the respondents to see (Brace, 2008).	1) Limited by online survey system features 2) Takes time to learn to build survey online 3) Experts can get confused that the online survey tool is the system they are validating/reviewing 4) Not having the opportunity to clarify questions or to repair misunderstanding (Brace, 2008). 5) There will be a bias towards the technically able person (Coombes, 2001).
Build tool on website and ask about it on survey system	1) Less confusing what is being validated / reviewed by separating the framework tool and the survey tool 2) More flexible design features than survey tool (e.g. drag and drop graphical interface) 3) Online – questionnaire can be designed to have visual appeal (e.g. feedback logic and tooltips) (Brace, 2008). 4) Involving the respondents more (Brace, 2008)	1) Easier if questions asked at the end of using the tool. Otherwise have to switch between screens. 2) Takes time (but sometimes time to learn survey tool can be longer)
Interview	1) Allow clarification of ambiguity (Leung, 2001). 2) Allow participation by illiterate people (Leung, 2001) 3) No worry about returning questionnaire	1) Respondents might be hesitant in commenting face to face 2) Pressure of interviewer presence while they are reading 3) Cannot stop for a break whenever they want 4) Has to be same time same place arranged time and place

5.4 Designing Questionnaires

When designing the questionnaires the researcher also needs to be aware of the advantages and limitations of different question types, to be sure to select the question type that elicits the information that the researcher needs and wants to know from the respondents. When designing questionnaires the researcher also needs to consider the time required for respondents to take part in the survey and ensure the most efficient use of questions (Coombes, 2001).

5.4.1 Selecting Question Type

For the evaluation of the TEIF and TEIF Method, the combination of closed questions and open questions were chosen. The advantages and disadvantages of these types of question are compared in Table 5-2.

Table 5-2 Comparing Question Type

Question Type	Advantages	Disadvantages
Closed question	1) Include all possible answers (e.g. multiple choice questions, scale questions). 2) Easy and quick to fill in (Leung, 2001) 3) Useful for greater numbers of respondents to generate statistic in quantitative research (Leung, 2001),(Coombes, 2001) 4) Easy to report results (Leung, 2001)	1) Can suggest ideas that the respondent would not have 2) Clerical mistakes or marking the wrong response is possible 3) Respondents can be frustrated because their desired answer is not a choice
Open question	1) Allow respondents answers in their own words (Coombes, 2001). 2) Respondents can explain their answer (Coombes, 2001). 3) Can be richer, longer and more revealing (Brace, 2008)	1) Comparisons and statistical analysis become difficult 2) A greater amount of respondent time, thought, and effort is necessary (Coombes, 2001)

For the validation of the TEIF and TEIF Method, a set of closed questions were provided, with single and multiple answers boxes to select from in the scenario, questions and answers section. Moreover, the closed questions were also used in other sections to find out the respondents' agreement. The reason that this combination method was chosen was that if only open questions were provided, if the respondents left the text box blank, it would be very difficult to analyse the data because it would be uncertain what it exactly meant. It might mean that they do not understand the questions or they may think the information is correct and have no comment and so leave the text boxes blank. Also, asking the respondents' agreement is more suitable in the form of a closed question because it saves time for the expert respondents to answer the questions and also saves time for the researcher to analyse the data as well.

5.4.2 Constructing Questionnaires

Once having selected the question types, the wording and structure of questions also needs to be considered. Questions should be kept short and simple. Grouping the questions into specific topics makes it easier to understand and follow. Layout and spacing is important as a cluttered questionnaire is less likely to be answered. Ideally, each question should measure different qualities, the responses between any two items should not be very strongly correlated and non-response rate should be low (Leung, 2001).

The questionnaires were constructed to make the best used of the experts' time and expertise as shown in Table 5-3. The developer experts focused on the TEIF and use of the TEIF Method whereas the accessibility experts focused on reviewing the accessibility aspects of the TEIF Method. The printed online questionnaires are shown in Appendix C (Developer experts), and Appendix D (Accessibility experts), and details will be explained in section 5.4.2.1 and 5.4.2.2.

Table 5-3 Comparison of Questionnaire Structures

Questionnaire Section	Developer Expert	Accessibility Expert
Technology Enhanced Interaction Framework	Yes	No
TEIF Method		
Scenario, requirement questions and answers	Yes	Yes
Technology Suggestions	Yes (Only suggestions used in solution)	Yes (More suggestions, reviewing the accessibility aspects)
Scenario Technology Solution	Yes	Yes
The Mobile Web Interactions	Yes	No
The Use Case Diagram	Yes	No
Chosen Solution and Explanations	Yes	Yes

5.4.2.1 Developer Expert Questionnaire

There were seven sections provided for the developer experts to validate and review:

1) The TEIF: in this section the aim of the open question was asking the responders about whether they thought the instructions, explanation, and example were clear.
2) The TEIF Method consisting of six sections:
   a) *Evaluating the scenario, requirement questions and answers*: this section was designed to get the requirements in designing technology from the developers. The requirement questions and multiple choice answers were built based on the TEIF to help the developers to think about the problems

and interactions which will occur in the example scenario about designing technology when disabled people are involved. The questions asked of the participants in this section were about whether they understood the questions and multiple choice answers provided, did they think any important information was missing and were the explanations clear.

b) *The Technology Suggestions*: this section shows the list of technologies, which are used in the solution to the example scenario. The technology suggestions are shown in a table with ticks and crosses and explanations about how those technologies are related to the answers to the requirement questions. The questions asked in this section were about whether the descriptions were clear and did they agree with the ticks or crosses and the explanations. The numbers of technology suggestions shown to the developer experts were limited to only those used in the scenario technology solution. This was done in order to enable them to spend the maximum amount of time validating and reviewing the TEIF Method rather than the specific details of assistive technologies which is not their speciality.

c) *The Scenario Technology Solution*: this is the example of designing technology in order to show how to use the TEIF Method by following the requirements, and technology suggestions and explanations. The open questions were asked to get some feedback about the design and usefulness in understanding the TEIF Method.

d) *The Mobile Web Interactions*: the Interaction Diagram shows the process in communication and interaction between people, technology, and objects based on the scenario technology solution to help users understand the interaction process. Questions were asked in this section about whether the Interaction Diagram was useful for them and how could the Interaction Diagram be improved.

e) *The Use Case Diagram*: this is similar to the Interaction Diagram but concentrated on helping developers to design the solution following the scenario technology suggestions. The questions asked in this section are similar to the ones about the Mobile Web Interactions Diagram.

f) Chosen Solution and Explanations: this section explains why certain technologies were chosen in designing the scenario solution rather than the other possible technologies in the suggestions tables.

5.4.2.2 Accessibility Expert Questionnaire

There were four sections provided for the accessibility experts to validate and review the accessibility aspects of the TEIF Method:

1) Evaluating the scenario, requirement questions and answers: this section was presented to show the steps in gathering, identifying or evaluating information and led to the next section that the researcher needed the accessibility expert to validate and review. The questions asked in this section were the same as for the developer experts.

2) The Technology Suggestions showed more lists of technologies and required the accessibility experts to validate and review the descriptions and explanations of the technologies and whether they were correct and related to the scenario example requirements.

3) The Scenario Technology Solution: the content and questions presented to both groups of experts were the same. The aim of presenting this information in this section to the accessibility experts was to show the example of how the developers would use the technology suggestions in designing the technology solution.

4) The Chosen Solution and Explanations: the content and questions presented to both groups of experts were the same. This section explains why certain technologies were chosen in designing the scenario solution rather than the other possible technologies in the suggestions tables.

5.4.3 Selecting Contact Method

Table 5-4 compares possible ways to contact the respondents to take part in the online survey in the study. E-mail and personal contact were chosen in this study. Four experts were asked face to face to take part in the survey because they work in the same place as the researcher. The other two experts work in different departments therefore they were asked to take part in the survey by email. This is because of the limitation of place and time. After agreeing, personal invitations were sent to all the experts through their email, and the experts were asked to read the participant sheet (Appendix C (Developer Experts), Appendix D (Accessibility Experts)) which includes the objective of the survey and what was expected of them.

Table 5-4 Comparison of Contact Method

Contact Method	**Advantages**	**Disadvantages**
E-mail	1) Can be used to contact large numbers of people at a low cost 2) Good way to reach the respondents who are in different places 3) Convenient for respondents' who can answer when they have time 4) Respondents can be directed to the site following a survey link (Brace, 2008)	1) Not flexible to answer the E-mail as required the Internet connection 2) Take longer to complete the invitation than telephone or personal contact
Telephone	1) Quick method 2) More flexible as researcher can explain about the survey 3) Response rate tends to be higher than E-mail	1) Cost per respondent high 2) May need to re-contact in case the respondents don't answer the phone 3) Need to know their phone number
Personal contact	1) Researcher can hold respondents' attention and are available to clarify the survey. 2) Personal invitation can show actual questionnaire or survey and observe their reactions	1) Take time if the respondents are in the different places 2) Have to visit them again in case they are not in the place

5.5 Piloting the questionnaire

Hulley (2007) stated that a pilot study is 'a small-scale preliminary study that aims to evaluate feasibility, time, cost, and effect size in order to predict an appropriate sample size and improve upon the study design prior to performance of a full-scale research project'.

Having constructed the questionnaire, it was important to pilot it before giving it to experts to validate and review as it is impossible even for an experienced questionnaire designer to get a questionnaire completely right the first time. Questionnaires must be piloted on a small scale sample of people characteristic of those in the survey (Leung, 2001).

To pilot the validation and review of the TEIF and TEIF Method, one experienced accessibility expert and two experienced developers took the online questionnaire through isurvey. The original pilot surveys are available at: https://www.isurvey.soton.ac.uk/6481 (Developer Experts) and https://www.isurvey.soton.ac.uk/6332 (Accessibility Expert).

In addition to answering the questions in the validation and review survey they were asked how much time they required to complete the survey and for any other suggestions they had for improving the questionnaire. Based on their responses changes were made to improve the questions, response times, and layout as explained in the next chapter.

5.6 Summary of the chapter

This chapter explains the research methodology that has been used for validation and review of the TEIF and TEIF Method. Methodological triangulation was used for gathering information from theory and existing frameworks, while experts were asked to validate and review the TEIF and TEIF Method. An accessibility expert and two developer experts were asked to undertake the pilot study. Three experts were developer experts, the other three were accessibility experts. The groups of experts were asked to validate and review the TEIF and TEIF Method in slightly different ways via the online survey (isurvey). The three developer experts focused on the Framework and Interaction Diagram and Use Case Diagram, whereas the three accessibility experts were asked to check the descriptions and explanations of the technology suggestions. The next chapter discusses the findings of the expert validation and review.

Chapter 6 Analysis of the Findings of Expert Validation and Review

This chapter describes the findings of expert validation and review of the TEIF and TEIF Method. Section 6.1 shows the findings from the pilot study which was used to improve the quality of the study before asking the experts to complete it. There were three pilot participants who took part in the online questionnaire (isurvey). Two participants took the questionnaire, which was developed for developer experts. Another participant took the questionnaire which was developed for accessibility experts. Six experts were selected to validate and review the TEIF and TEIF Method, and were divided into two groups, developer experts and accessibility experts. There were three experts in each group. The findings of expert validation and review are reported in section 6.2 and where both groups of expert have been asked the same question their responses are combined (i.e. treated as six experts). If the majority of experts answered ‘Yes’ to the questions this was considered as a successful validation. Brian Gains replied to the email invitation stating he was pleased that his framework was helpful but he was now retired. Alan Dix agreed to discuss the TEIF and TEIF Method and section 6.3 presents the result of the discussion. Section 6.4 summarises the chapter.

6.1 Pilot Study Findings

After analysing the data collected from the pilot study which is provided in Appendix E changes were made to the survey. There were two main categories of changes to the pilot study: content and the isurvey system as summarised in Table 6-1 (questionnaire for developer experts) and Table 6.2 (questionnaire for accessibility experts). The pilot study participants confirmed the changes satisfied all the issues they had identified. The updated version of the surveys after the pilot study are available at: https://www.isurvey.soton.ac.uk/6291 (Developer experts) and https://www.isurvey.soton.ac.uk/6577 (Accessibility experts).

Table 6-1 Pilot Study Finding for developer expert questionnaire

Category of changes	**What was changed?**	**Result of changes**
Content		
rewrite the instructions	1) Scenario section 2) Technology suggestions section	make it clearer
rewrite the descriptions	1) Technology suggestions section 2) Scenario technology solution section 3) Chosen solution and explanations section	make it clearer
add explanation of the technology suggestion tables	Technology Suggestions Section: Table 1, 2, 3, 4 and 5	help respondents understand why technologies have ticks or crosses in cells corresponding to requirements
improve content	1) Framework Section: role 2) Scenario Section: scenario, requirement questions (question number 1, 3, 9,10,11) multiple choices (answers of question number 1, 3,10,11) and the explanations of answers 3) Technology Suggestions: Table 1, 2, 3, 4 and 5 4) Scenario technology suggestions section 5) Mobile Web Interactions section 6) Chosen solution and explanations	make it clear and understandable without assuming knowledge
isurvey System		
change the image tables to html tables	1) Framework section 2) Technology suggestions section: Table 1, 2, 3, 4 and 5	make the table accessible, now can copy the content in order to make change, can link to the websites were provided, can provide explanations in tooltip
remove the logic and always display comment box and question	1) Framework Section 2) Scenario Section 3) Technology Suggestions Section 4) Mobile Web Interactions Diagram Section 5) Use case Diagram Section 6) Scenario Technology Solution 7) Chosen Solution and Explanations	isurvey processing was slow therefore logic did not display question before user moved on to next question and processing icon at the top of page which was out of view unless scroll up

The participant who did the piloting questionnaire for accessibility experts suggested the changes as shown in Table 6.2. The first participant had spent 1 hour and 15 minutes and the second participant had spent 1 hour and 22 minutes to complete the online questionnaire which was developed for developer experts. One piloting participant took 1 hour 30 minutes to complete the online questionnaire which was developed for accessibility experts.

Table 6-2 Pilot Study Finding for accessibility expert questionnaire

Category of changes	What was changed?	Result of changes
Content		
spelling and grammar mistakes	1) Scenario Section 2) Technology Suggestions Section, Table 1, 2, 3 and 4 3) Scenario Technology Solution Section 4) Mobile Web Interactions Section 5) Chosen Solution and Explanations Section	make it correct and more understandable
isurvey System		
Choice, force entry to move on or just reminder	1) TEIF Section 2) Scenario Section 3) Technology Suggestions Section 4) Mobile Web Interactions Diagram Section 5) Use case Diagram Section 6) Scenario Technology Solution 7) Chosen Solution and Explanations	remind the respondents to provide the answer but allow blank entry

6.2 Expert Validation and Review Findings

The questionnaires designed for both groups of experts were different as described in Table 5-3. The full detail of the experts' responses are presented in Appendix F.

6.2.1 The Technology Enhanced Interaction Framework

Only developer experts were asked to validate and review the TEIF table. There were three validation questions that experts were asked and three review questions and the results of validation as shown in Table 6-3 and the results of review in Table 6-4. As shown in Table 6-3, the TEIF table was successfully validated.

Table 6-3 Experts validating TEIF table

Questions	% of experts answering 'Yes'	Successful validation
1. Are the instructions clear?	67%	Yes
3. Are the examples and explanations clear?	100%	Yes
5. Do you agree with the main and sub-components of the framework?	100%	Yes

As shown in Table 6-4, the only improvement suggested by the majority of experts was providing more information for the instructions.

Table 6-4 Percent of experts commenting on the aspects of the TEIF table

Categories	Instructions	Examples and explanations	Components
Grammar/spelling	0%	33%	0%
Layout/presentation	0%	0%	33%
More information	67%	0%	0%
Change component name	N/A	33%	33%

6.2.2 The Example of TEIF Method

6.2.2.1 The Example Scenario, Questions, and Answers

All experts were asked to read the scenario and answer the requirement questions (developed based on TEIF) based on the scenario. After that the provided answers and explanations appeared. The questions asked in this section can be divided into three main parts as follows:

Part 1: Instructions

All the developer experts agreed that the instructions of the scenario, questions, and answers are clear, while two accessibility experts disagreed (Table 6-5) by giving reasons that they are unclear what 'instructions' refer to and suggested more information was required to clarify what analysis of the scenario was wanted (Table 6-6).

Table 6-5 Experts validating the instructions of the scenario, questions, and answers

Questions	% of experts answering 'Yes'	Successful validation
1. Are the instructions clear?	67%	Yes

Table 6-6 Percent of experts commenting on the instructions of the scenario, questions, and answers

Categories	Instructions
Grammar /spelling	0%
Layout /presentation	0%
More information	50%

Part 2: Requirement questions, Multiple Choices Answers, and Explanations

There were 19 requirement questions with multiple choices, answers and explanations that both groups of experts were asked to review and comment on. Most of the comments were about providing re-wording or further information (Table 6-7).

Table 6-7 Percent of experts commenting on aspects of requirement questions and multiple choices answers, and explanations

Categories	**Comments on Question and Multiple choices**	**Comments on Answers and explanations**
Grammar/spelling/re-wording	68%	26%
Layout/presentation	16%	0%
More information	0%	53%
Change multiple choices options	16%	N/A
Disagree with answers	N/A	16%

Part 3: Questions and Multiple Choices Answers, and Explanations

As shown in Table 6-8, the experts confirmed nothing was missing and that having the requirement numbers next to the sub-components did not help the majority of experts.

Table 6-8 Experts validating associated question to Part 2

Questions	**% of experts answering 'Yes'**	**Successful validation**
60. Was it helpful to have the requirement numbers next to the sub-components in the Technology Enhanced Interaction Framework table shown in the previous section?	33%	No
62. Are there any questions, requirements, components or sub-components missing that would be relevant to the scenario?	0%	Yes

Table 6-9 shows that 33% of the experts made suggestions for improvements in the scenario in layout and information, while Table 6-10 shows that 33% thought the requirement number should be in the scenario.

Table 6-9 Percent of experts commenting on question 61

	61. How can the scenario be improved to make it easier to answer the questions?
Layout/presentation	33%
More information	33%

Table 6-10 Percent of experts commenting on question 62

Categories	62. Is there a better way to show the relationship between the Technology Enhanced Interaction Framework and the requirement questions?
Put requirement numbers into the scenario	33%

6.2.2.2 Technology Suggestion Tables

The technology suggestion tables were successfully validated (Table 6-11). One accessibility expert did not have time to go through the ticks. Therefore this answer to question 3 had not been counted. There were four tables of technology suggestions for the accessibility experts and three tables for developer experts. An accessibility expert only answered ‘No’ to question 3 for ‘Technology Suggestion Table 3’ (Appendix F). One developer expert only answered ‘No’ to question 3 in Technology Suggestion Table 2 (Appendix F). The main comments were about the re-wording as shown in Table 6-12.

Table 6-11 Experts validating technology suggestion tables

Questions	% of experts answering ‘Yes’	Successful validation
1. Are the description of the technologies table clear?	67%	Yes
3. Do you agree that the ticks correctly identify the requirements met	60%	Yes

Table 6-12 Percent of experts commenting on technology suggestion tables

Categories	2. How can the descriptions of the technologies be improved?	4. How can the ticks of the technology suggestions be improved?
Grammar/spelling/re-wording	67%	N/A
Remove link to Wikipedia	N/A	17%
More information	0%	17%
Don’t understand people-object column	N/A	17%

6.2.2.3 Example of Scenario Technology Solution

The Scenario Technology Solution was successfully validated (Table 6-13) with 50% of the experts suggesting some grammar/spelling/re-wording changes Table 6-14.

Table 6-13 Experts validating scenario technology solution

Questions	% of experts answering 'Yes'	Successful validation
1. Is the scenario solution clearly described?	83%	Yes
3. Does the solution meet the scenario requirements?	67%	Yes

Table 6-14 Percent of experts commenting on Scenario Technology Solution

Categories	2. How can the scenario solution description be improved?	4. How can the solution be improved?
Grammar/spelling/re-wording	17%	0
Changes to solution	N/A	50%

6.2.2.4 Example of Mobile Web Interaction Diagram

The Mobile Web Interaction Diagram was successfully validated (Table 6-15) with many suggestions for improvements (Table 6-16).

Table 6-15 Experts validating the Mobile Web Interaction Diagram

Questions	% of experts answering 'Yes'	Successful validation
1. Does the Mobile Web Interactions diagram help understand the scenario solution?	100%	Yes

Table 6-16 Percent of experts commenting on Mobile Web Interaction Diagram

Categories	2. How can the Mobile Web Interactions be improved?
Explain the numbering of actions	67%
Re-order the numbering of actions	33%

6.2.2.5 Example of Use Case Diagram

The Use Case Diagram was successfully validated (Table 6-17) with only one improvement suggested (Table 6-18).

Table 6-17 Experts validating the Use Case Diagram

Questions	% of experts answering 'Yes'	Successful validation
1. Does the Use Case Diagram help understand the scenario solution?	100%	Yes

Table 6-18 Percent of experts commenting on the Use Case Diagram

Categories	2. How can the Mobile Web Interactions be improved?
Add login and logout functions	33%

6.2.2.6 Chosen Solution and Explanations

The Chosen Solution and Explanations were successfully validated (Table 6-19) with a few improvements suggested (Table 6-20).

Table 6-19 Experts validating the Chosen Solution and Explanations

Questions	% of experts answering 'Yes'	Successful validation
1. Is the explanation of how the solution was derived from the suggestions easy to understand?	100%	Yes
3. Do you agree that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people?	83%	Yes

Table 6-20 Percent of experts commenting on the Chosen Solution and Explanations

Categories	2. How can the explanation be improved?	4. How can the framework with associated questions and suggestions be improved?
More information	17%	0%
Break TEIF into easy small step	0%	17%
Layout/presentation	0%	17%

6.3 Result of the interview with Professor Dix

Professor Alan Dix from the University of Birmingham agreed to discuss the TEIF and TEIF Method. A summary of his comments and suggestions on the TEIF and TEIF Method were as follows:

Comments on TEIF

- People being aware of other interactions might be something worth considering in the TEIF (e.g. between other people or between other people and technology or other people and objects).
- How did the TEIF handle tangible interfaces which are object mediated interactions with technology (P-O-T)? It was explained to Professor Dix that the TEIF defines something used in this way as a tool as 'technology' rather than an 'Object' and the TEIF was very careful to define terms consistently, whereas Professor Dix's CSCW framework used the terms

'object', 'artefact', 'tool' and 'technology' interchangeably. Professor Dix acknowledged that the TEIF was more careful in this respect than his CSCW framework.

- Should a property of an object include the identity of an object?
- The TEIF components could be useful as an index for case based solutions or patterns.
- Users may have the perception that technology (e.g. a robotic device triggered by the person walking past it) talking to them is a T-P whereas the TEIF categorises it as a P-T-P interaction.

Comment on TEIF Method

- In the technology suggestions table rate how well a technology meets the requirement rather than just showing a tick or cross.

6.4 Summary of the chapter

An accessibility expert and two developer experts were asked to undertake the pilot study of the validation and review. The three pilot study participants spent around 1 hour and 30 minutes to complete the online questionnaires and made suggestions and comments on content and the isurvey system. Changes were made following the suggestions and comments. The pilot study participants were satisfied with all the changes. The TEIF was successfully validated by the developer experts and the TEIF Method was successfully validated by the developer experts and the accessibility experts. The experts made suggestions for improvement to both the content and the system and their answers and suggestions are discussed in the next chapter. Professor Alan Dix agreed to comment on the TEIF and TEIF Method through a face to face interview. He suggested awareness of other people's interactions might be of value as might the perspective of users that technology talking to them is a T-P interaction while TEIF categorises it as a P-T-P interaction. The way the TEIF dealt with tangible interfaces was discussed as well as using TEIF components as an index for case based solutions. The next chapter discusses the findings of the expert validation and review.

Chapter 7 Discussion of the Findings of Expert Validation and Review

This chapter discusses the findings of the expert validation and review of the TEIF and TEIF Methods presented in chapter 6. Where both groups of expert have been asked the same question their responses have been combined (i.e. treated as six experts). If the majority of experts answered ‘Yes’ to a question this was considered as a successful validation.

7.1 The Technology Enhanced Interaction Framework

As shown in Table 6-3, the TEIF table was successfully validated but as a result of the comments from the three developer experts and Professor Alan Dix the following changes to the TEIF components were made as shown in Table 7-1.

1) The ‘Objects’ component

   Developer expert 1 suggested finding a better word than ‘Objects’ but it has not been possible to find a better word and so the definition and meaning of the word in the TEIF context will be explained in more detail. As the reported discussion with Professor Dix in section 6.3 shows the TEIF has a consistent and clearly defined meaning of the word ‘Objects’ but only a brief explanation was provided for the experts because of time limitation.

2) The ‘Weather Condition’ sub-component

   Developer expert 1 found this ‘Oddly Specific’ and so more examples of how weather condition could affect technology interactions have been provided.

3) The ‘Examples’ sub-heading

   Developer expert 1 suggested it was unclear what were the examples and what were the explanations and so the sub-heading have been changed to ‘Explanations and examples’.

4) People being aware of other interactions

   This aspect has been added as a sub-component to the context component as Professor Dix suggested this might be something worth considering in the TEIF (e.g. between other people or between other people and technology or other people and objects).

5) Identity of an object

   The identity of an object has been added to the sub-component ‘Property’ as an example as suggested by Professor Dix.

6) User Perception

   An explanation has been provided that as pointed out by Professor Dix, users may have the perception that technology (e.g. a robotic device triggered by the person walking past it) talking to them is a ‘T-P interaction’ whereas the TEIF categorises it as a ‘P-T-P interaction’.

7) TEIF components as index for case based solutions

   Professor Dix agreed that the TEIF components could be useful as an index for case based solutions. This aspect will be considered as future work in chapter 11.

8) Instructions

   Developer experts 1 and 2 suggested providing more information about the purpose of the TEIF. This participant information was provided through the email but some of the experts appear to have not read this carefully and so the information will be also provided in the start page of the online survey.

Table 7-1 The final version of TEIF

Main Component	Main and Sub-Component of Technology Enhanced Interaction Framework	
	Sub-component	***Explanations and Examples***
People	Role	A person has a role when communicating with others (e.g. presenter, audience, peer). Roles normally come in pairs such as speaker and audience (e.g. teacher and student or owner and visitor) and peer to peer (e.g. student and student or visitor and visitor).
	Ability / Disability	People have abilities and disabilities which can affect their use of technology or understanding of language and which can lead to communication breakdown (e.g. physical, sensory, language, culture, communication, Information Technology (IT)).
Objects	Dimension	Objects have 2 dimensions (2D) or 3 dimensions (3D), and a 3D object may have a 2D representation.
	Property	Objects have colour, shape, size, and identity
	Content	Objects have content which is human readable (text, pictures) and machine readable (QR code, AR tag, barcode, RFID tag, NFC).
Technology	Electronic	Electronic technology has stored information, is online (e.g. internet, phone network) or offline (e.g. not connected to the internet or phone network), and is mobile (e.g. smartphone) or non-mobile (e.g. desktop computer).
	Non-electronic	Non-electronic technology is used to store information in objects (e.g. writing with a pen on paper) and is mobile (e.g. pen) or non-mobile (e.g. full-size desktop typewriter).
	Usability and Accessibility	People interact with technology through its user interface (e.g. touch screen, keyboard).
	Application or Service	Electronic technology is an application (e.g. dictionary) or a service (e.g. weather forecast).
	Cost	Technology has cost (e.g. of hardware, software, maintenance).
Interactions and Communication	People-People (P-P)	People communicate verbally (speak, listen, ask, answer) and non-verbally (lip-read, smile, touch, sign, gesture, nod). When communicating, people may refer (speak or point) to particular objects or technology – this is known as 'deixis'.
	People-Objects (P-O)	People interact with objects for two main purposes: controlling (e.g. touch, hold or move), and retrieving information (e.g. look, listen, read, in order to get information or construct personal understanding and knowledge).
	People-Technology (P-T)	People control technology (e.g. hold, move, use, type, scan, make image, press, swipe), transmit and store information (e.g. send, save, store, search, retrieve).
	People-Technology-People (P-T-P)	People use technology to transmit information to assist communication with (e.g. send SMS, MMS, email, chat, instant message) other people. Technology is always designed for a purpose by people and so a robotic device triggered by the person walking past it is a P-T-P interaction.
	People-Technology -Objects(P-T-O)	People use technology (e.g. point, move, hold, scan QR codes, scan AR tag, use camera, use compass) to transmit, store, and retrieve information (send, save, store, search, retrieve) to, in, and from objects.
Time / Place	Place	Same and different time and place yield four categories: same time (ST) and same place (SP), different time (DT) and same place (SP), different time (DT) and different place (DP), same time (ST) but different place (DP).
	Time	
Context	Location	Location affects the use of technology (e.g. indoors, outdoors). For example GPS does not work well indoors.
	Weather Condition	Weather condition may affect the use of technology (e.g. rainy, cloudy, sunny, windy, hot, cold, dry, wet). For example, the mobile phone screen doesn't work well in sunshine.
	Signal Type and Quality	Signal type can affect the quality of electronic technology (e.g. broadband, GPS, 3G, 4G).
	Background Noise	Background noise can affect the communication particularly for hearing impaired people (e.g. background music, crowded situation).
	Lighting	Light can affect the interaction (e.g. Inadequate light, too bright).
	Awareness of others' interactions	People can be aware of interactions involving other people
Interaction Layer	Culture	Cultural layer includes countries, traditional, language and gesture (e.g. 'hello' is a normal greeting used in the culture).
	Intentionality	Intention layer involves understanding, purpose and benefit (e.g. the intent is a greeting).
	Knowledge	Knowledge layer involves facts, concepts, procedures, and principles (e.g. how to spell the word 'hello').
	Action	Action layer involves actions and behaviours (e.g. pressing the correct key and not hitting neighbouring keys).
	Expression	Expression layer describes how actions are carried out (e.g. whether action is correct, accurate, and prompt).
	Physical	Physical layer is the lowest layer at which people interact with the physical world (e.g. the button is depressed and so sends the electronic code for the letter to the application).

7.2 The Examples of TEIF Method

7.2.1 The Scenario, Questions, and Answers

Developer expert 1 and accessibility experts 1 and 2 wanted more detail in order to be able to answer requirement questions. This detail will be added into the scenario.

Part 1: Instructions in the scenario, questions, and answers section

Accessibility experts 1 and 2 were unclear what 'instructions' referred to. Therefore the wording will be changed to clarify this.

Part 2: Requirement questions and multiple choices Answers, and Explanations

1) Grammar / spelling / re-wording

There were many suggestions for improving the wording of the questions, multiple choices, answers and explanations and these will be used to improve this section.

2) Change multiple choices options and answers

Accessibility experts 1 and 2 and developer expert 2 found it unclear why choice 'f' was not also a correct answer to requirement question 1 and so choice 'f' will be removed because this is not related to the components of the TEIF.

Developer expert 1 suggested another choice 'd' mobile and non-mobile devices' to requirement question 13 even though the scenario stated a mobile was required and therefore the scenario wording will be improved to make this even clearer.

Regarding requirement question 18, three experts (developer expert 1 and accessibility experts 1 and 2) stated there is no explanation why the low cost solution is required and another expert suggested there might be a lower cost technology than smartphones. To address this more explanation will be added into the scenario.

Part 3: Questions, associated questions and multiple choices answers, and explanations

There were no questions, requirements, components or sub-components missing that would be relevant to the scenario.

Having the requirement numbers next to the sub-components did not help the majority of experts. The TEIF is used to inform the method and processes but knowing the relationship between the requirements and the sub-components is not necessary to follow the method and processes. It is also difficult to move between the sections on isurvey to refer to the requirement numbers. Developer expert 1 suggested putting the requirement numbers in the scenario but this would interrupt the flow of the scenario narrative. To address this issue the relationship will be explained more clearly and a way to make it easier to move between sections will be investigated.

7.2.2 Technology Suggestion Table

The technology suggestion tables were successfully validated. The problem the experts had with the time required to validate all the information will not be a problem with the users evaluation because it will only refer to a few technologies. The required grammar / spelling / re-wording changes will be made. Links to sources other than Wikipedia will be investigated. The problem one expert had understanding the 'P-O' column should be removed by the more detailed explanations that will be provided in the TEIF as already described in section 6.2.1.

Professor Dix's idea of the technology suggestions table rating how well a technology meets the requirement rather than just showing a tick or cross had been considered when the TEIF was being developed but it was decided that this could be a refinement for future work after completion of the PhD.

7.2.3 Example Scenario Technology Solution

The example 'Scenario Technology Solution' was successfully validated. The required grammar / spelling / re-wording changes will be made and the solution improved following the suggestions made. For example, it will be made clear that Chuty does not speak using Thai speech recognition at the same time as Suchat is talking.

7.2.4 Example Mobile Web Interaction Diagram

The example 'Mobile Web Interaction Diagram' was successfully validated. The numbering and re-ordering of actions will be improved following the suggestions made. For example, presenting concurrent as well as sequential actions.

7.2.5 Example Use Case Diagram

The example 'Use Case Diagram' was successfully validated.

7.2.6 Chosen Solution and Explanations

The example 'Chosen Solution and Explanations' were successfully validated. As suggested by the experts more information will be provided, the layout / presentation will be improved and the TEIF Method will be broken down into easier smaller steps.

7.3 Summary of the chapter

Professor Alan Dix and the three developer experts chosen to review and validate the TEIF and TEIF Method based on their expertise and experiences successfully validated the TEIF and TEIF Method. The three accessibility experts chosen to review and validate only the TEIF Method based on their expertise and experiences successfully validated the TEIF Method. Changes made to TEIF table in response to expert's suggestions were: change 'Examples' TEIF heading to 'Explanations and examples'; add People being aware of other interactions as sub-component to the context component; add identity of an object to the sub-component 'Property'; explain perception that P-T-P interactions are T-P interactions; consider TEIF components as index for case based solutions. These issues are discussed further in the next chapter, which describes the rationale and approach for the user evaluation of the TEIF Method.

Potential changes in response to expert's suggestions about the TEIF Method are: more information and improve grammar / spelling / re-wording and layout / presentation; remove question 1 choice 'f'; explain relationship between requirements and sub-components; investigate easier movement between sections; improve numbering and re-ordering of actions in the example 'Mobile Web Interaction Diagram'; present the TEIF Method in easier smaller steps.

Chapter 8 User Evaluation Methodology

8.1 Introduction

The two research questions that have already been answered in the work undertaken so far are:

Research question 1: Can the TEIF be developed regarding disabled people interacting with people, technologies, and objects?

Research question 2: Can the TEIF Method be developed building on this TEIF to help design technology solutions for disabled people interacting with people, technologies, and objects?

This development of the TEIF was described in chapter 3 based on the existing frameworks, theories and principles described in chapter 2 and used to provide a technology solution to the example scenario of hearing impaired visitors visiting a local privately managed Thai museum. The TEIF is a general interaction framework to help design technological support for communication between people and interactions between people, technology, and objects, particularly in complex situations involving disabled people.

The TEIF Method has been developed in order to help developers understand and apply the TEIF in real situations and consists of: a scenario; requirement questions, answers, and explanation to evaluate requirements; technology suggestions based on the answers from the requirement questions; a scenario technology solution; Interaction Diagram; Use Case Diagram; and the explanation of the technology solution. There is also the potential for presenting similar design solutions to help developers in designing solutions to similar scenarios.

The results of the expert validation and review by Professor Alan Dix and three developer experts and three accessibility experts following the methodology explained in chapter 5 were analysed and presented in chapter 6. The validation and review supported the view that the TEIF and TEIF Method could help developers design technology solutions in complex situations when disabled people are involved. Changes to the TEIF based on the expert review were discussed in chapter 7. Chapter 8 explains an experimental design methodology for the user evaluation of the TEIF Method in order to answer the remaining research questions.

Research question 3: Can developers use the TEIF Method to help with the software development process when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.1: Can developers use the TEIF Method to help with evaluating requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.2: Can developers use the TEIF Method to help with evaluating technology solutions when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.3: Can developers use the TEIF Method to help with gathering requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.4: Can developers use the TEIF Method to help with designing technology solutions to interactions for disabled people with people, technologies, and objects?

Research question 4: In what ways does the TEIF Method help developers?

Sub research question 4.1: Does the TEIF Method help to improve awareness of interaction issues involving hearing impaired people?

Sub research question 4.2: Does the TEIF Method help to improve understanding of how environment context affects interaction when hearing impaired people are involved?

Sub research question 4.3: Does the technology suggestions table in the TEIF Method help identify technology solutions to interaction problems involving hearing impaired people?

Sub research question 4.4: Is using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the Method?

Possible ways in which the developers might evaluate the TEIF Method were considered before the final decision was taken on the approach to be used.

Section 8.2 discusses user evaluation methodology issues. Section 8.3 discusses possible user evaluation experimental design approaches. Section 8.4 discusses paper based or computer based methods. Section 8.5 identifies issues in evaluating the TEIF Method support for requirements. Section 8.6 describes studies on requirements using an experimental approach. Section 8.7 considers the advantages and disadvantages of evaluating or gathering requirements in the experiment. Section 8.8 presents the rationale for the approach chosen. Section 8.9 discusses rank ordering or rating solutions for the technology solution experimental task. Section 8.10 and section 8.11 respectively describe how the research questions 3 and 4 regarding the TEIF Method can be answered. Section 8.12 describes the pilot studies and their findings while section 8.13 explains the experimental design. Section 8.14 explains statistical terms and tests used. A summary of the chapter is given in section 8.15.

8.2 User Evaluation Methodology Issues

A literature review showed that while there have been many studies concerned with methods for evaluating software designs, few studies addressed ways to evaluate software design methods. Kitchenham (1996) described types of evaluation for evaluating a tool, a method, and a generic method which is one of a series of notes based on the DTI-backed DESMET project. These were experiments, case studies, surveys, qualitative screening, qualitative effects analysis, and benchmarking. The project concluded that for evaluating generic methods, ‘Qualitative Effects Analysis (A subjective assessment of the quantitative effect based on expert opinion) is likely to be appropriate because any quantitative evaluation would be based on a specific instantiation of the generic method’.

Therefore while the results of a quantitative experimental evaluation can provide strong evidence the conclusions are not generalisable and it would be possible to also use a qualitative generalisable questionnaire.

A case study evaluation is not appropriate as the requirement questions and technology suggestions table need extending further if the TEIF Method is to be applied for all disabilities and scenarios.

The TEIF Method is not designed to replace other software design methods but support them and so any comparison between only using the TEIF Method and using an established software design method would not be appropriate. Any comparison should therefore compare another software design method used alongside the TEIF Method with that software design method used without the TEIF Method.

A review of the literature provided little clear information about what would be commonly used and well understood methods, and indeed Barry and Lang (2003) found that 25% of the organisations and engineers surveyed do not use any method, while 76% of those that use a 'method' mainly use their proprietary 'in house' methods.

This lack of any clear 'best method' is supported by the recent research by Moyo, Peeps, Soganile, Dzawo, and Madzima (2013) who reviewed systems development methodology selection frameworks and investigated the consistency between methods practitioners claim to use to select software development methodologies and the methods they actually use in one organisation over a period of two years and found that changes in the projects' characteristics (e.g. an experienced expert resigns) could result in changes in methodology. They compared developmental approaches (lens to view everything through) with methods, models (arrangement of activities) and techniques (details of implementation). Twenty five percent of judgments on methodology characteristics were found to be inconsistent, with practitioners recommending methodologies over others they evaluated as superior.

It would therefore appear sensible to allow users to choose whatever method they prefer to use in any comparison with the TEIF Method.

Hooper (2010) developed 'Teasing Apart, Piecing Together (TAPT)' as a software engineering design process for analysing and redesigning experiences and evaluated it with a comparative evaluation with a 'scenario' method of its use by software engineers, an expert review of the outputs of that evaluation and case studies of its use by professionals. The expert review of artefacts addressed the possibility of bias in participants' self-assessments, while the case studies examined TAPT's use in a more realistic field environment than the controlled lab based comparative experiments. Evidence from the expert review suggested that participants should have been given an opportunity to familiarise themselves with new methods through a 'trial run'. The comparative evaluation suggested that TAPT might be best used with a complementary method such as 'scenarios'. Experts preferred artefacts produced with Unstructured Discussion compared to TAPT or 'scenarios' perhaps due to the fact that the structure of the artefacts produced by those methods was removed to help ensure the expert could not identify the method. Possible improvements to TAPT based on the feedback included encouraging practitioners to indicate in designs where they have included key effects from analyses.

Case study participants found TAPT and scenarios to be complementary methods. One participant used TAPT as an evaluative tool, and reported finding the process helpful for better understanding the product he evaluated. Others applied TAPT to facets of an experience or to a list of project requirements. Hooper drew the analogy with Computer Scientists using parts of Unified Modelling Language (UML) best suited to the task at hand rather than as a rigid process and in a similar way parts of TAPT most appropriate to the problem being tackled can be used in an agile way.

While TAPT focuses on user experiences of technology rather than the TEIF Method focus of the accessibility of interactions the following lessons learned regarding evaluation of methods appear relevant to TEIF Method evaluation methodology:

- Participants should be given an opportunity to familiarise themselves with new methods.
- Methodological aspects in the structure of artefacts should not be removed before expert evaluation.
- Key effects from analyses should be shown in designs.
- Users can use parts of a method in an agile way.
- The method may be useful alongside other methods rather than replacing other methods.
- Aspects of the design method may also be valuable as an evaluation method.

Eccles and Wigfield (2002) considered that there are four components of value in an activity: the personal value of doing well on an activity (attainment value), subjective interest or enjoyment of performing an activity (intrinsic value), the extent to which activity completion is perceived to facilitate current or future goals (utility value), and the negative aspects of engaging in an given activity such as anxiety happiness and fear of failure (cost).

Guay et al. (2010) stated that there are two types of motivation: intrinsic motivation which refers to motivation that is animated by personal enjoyment, interest, or pleasure and is usually contrasted with extrinsic motivation, which is manipulated by reinforcement contingencies. Normally, extrinsic motivations are rewards (e.g. money or award) for showing the desired behavior, and the threat of punishment when misbehaving. An extrinsic motivator seems to be competition because it encourages the performer to win and compete others. It is not simply to enjoy the intrinsic rewards of the activity. A cheering crowd and the desire to win a trophy are also extrinsic incentives.

In order to engage the participants to become interested and engaged in a task which involves spending a lot of time thinking about and understanding a new idea, both intrinsic and extrinsic motivation and Interaction Design components need to be considered. Psomas (2007) reported that Interaction Design plays an important role in improving user experiences, particularly in conceptualising design, which matches user expectations and standards of User Interface patterns and components.

Therefore consideration needs to be given regarding the motivation and design of the experiment and this is considered in the next section which presents alternative possible experimental designs that take into account the issues that have been discussed.

8.3 Possible User Evaluation Experimental Design Approaches

Eight possible ways in which the developers might evaluate the TEIF Method were considered in detail before finally deciding on the approach to be used. The approaches are described and their advantages and disadvantages are summarised in Table 8-1 and Table 8-2.

Table 8-1 The advantages and disadvantages of user evaluation approaches 1-7

Approaches	Main Advantages	Main Disadvantages
Approach 1 • Developers read and understand TEIF Method • Self-evaluate	• Least time spent by participants	• May be difficult to motivate and engage developers solely through reading and answering questions • Users may find it difficult to evaluate TEIF Method just by reading and answering questions
Approach 2 • Developers read scenario and design solution • Developers read and understand TEIF Method • Self-evaluate	• Less time for participants than 3 and 4 • Developers may find designing more enjoyable than just reading and answering questions as in 1	• More time spent by participants than 1 • Requires expert evaluation of solutions • Requires expert evaluation of solutions
Approach 3 • Developers read scenario and design solution • Developers read and understand TEIF Method • Developers design solution again • Self-evaluate	• Less time spent by participants than 4 • Developers may find it easier to evaluate the method than in 1 and 2 by comparing their designs • Developers may find it more enjoyable and motivating and engaging than 2 by actually trying to improve their original design solution	• More time spent by participants than 1 and 2 • Difficult to identify the learning effect of already having designed a solution to the scenario • Requires expert evaluation of solutions
Approach 4 • Developers read scenario and design solution • Developers read and understand TEIF Method • Developers design solution again • Developers build solution • Disabled person or expert understanding needs of disabled person evaluation	• Developers may find it more enjoyable to design and develop and test and evaluate a real solution with disabled people • Developing a working technology solution and evaluating it with disabled users provides greater face validity to the evaluation	• Most time for participants as will spend much time to design and build the software • Requires expert evaluation of solutions
Approach 5 • Developers read scenario A and design solution A • Developers read and understand TEIF Method and suggested solution A • Developers read scenario B and design solution B using TEIF Method • Self-evaluate	• Developers may find it easier to evaluate the method than in 1 and 2 by comparing their designs • Developers may find it more enjoyable and motivating and engaging than 2 by actually trying to improve their original design solution • Can balance the order effect by giving one scenario first to half the developers and the other scenario first to the other half	• Participants spend more time than 1 and 2 and 3 • Requires expert evaluation of solutions • Requires expert evaluation of solutions

Table 8-2 The advantages and disadvantages of user evaluation approaches 7-8

Approach	Main Advantages	Main Disadvantages
Approach 6 • Developers read scenario A and design solution A • Developers read & understand TEIF and suggested solution A • Developers read scenario B and design solution B using TEIF Method and example solutions (e.g. A, C, D, E) • Developers add their solutions • Self-evaluate	• Developers may find it more enjoyable and motivating and engaging than 2 or 3 or 5 by using TEIF Method with patterns to design a new solution to a new scenario. • Developers may find it more motivating than other approaches by being part of helping their peers in designing technology and will be able to see the value of the TEIF Method for helping build a large number of patterns.	• Participants spend more time than 1 and 2 and 3 and 5 • Requires expert evaluation of solutions
Approach 7 • Developers interview 'client' to gather requirements and evaluate three provided solutions A, B, C • 1st group of developers use their preferred method • 2nd group of developers use TEIF Method • Both groups also self-evaluate	• Face validity of gathering requirements through interview • Evaluating solutions easier to assess than designing solutions	• Participants need interviewing skills • Participants don't actually design solution
Approach 8 • Developers evaluate requirements from interview transcript and evaluate three provided solutions A, B, C • One group of developers use their own method • Another group of developers use TEIF Method • Both groups also self-evaluate	• Evaluating requirements easier for participants than interviewing • Evaluating solutions easier to assess than designing solutions	• Participants do not actually gather requirements or design solutions

Approach 1: Ask the developers to look at the TEIF Method, and then ask them to answer the questions about whether the TEIF Method could help them to design the technology solution in a complex situation when disabled people are involved.

Approach 2: Ask the developers to design the technology solutions based on the example scenario provided with the TEIF Method, but without using TEIF Method. Then, as with approach 1 above, show them the TEIF Method and technology solutions, and ask them to answer the questions about whether the TEIF Method could help them to design the technology solution in a complex situation when disabled people are involved.

Approach 3: Ask the developers to design two technology solutions based on the example scenario provided, with the TEIF Method, the first without using the TEIF Method (i.e. as with approach 2 above), and the second with using the TEIF Method and technology solutions. Then ask the developers to answer the questions about whether the TEIF Method helps them to design the technology solution in a complex situation when disabled people are involved.

Approach 4: Ask the developers to design the technology solutions based on the example scenario provided with and without the TEIF Method (i.e. similar to approach 3). Then, ask them to build the software based on their design and test it with the disabled people in the real situation. After that, ask the disabled people whether the software helps them to improve their interaction or not.

Approach 5: Ask the developers to design two technology solutions for two different scenarios. The first without using the TEIF Method but then being shown the TEIF Method and suggested solution for that example scenario (i.e. as with approach 2 above), the second, with using the TEIF Method. Then, ask the developers to answer the questions about whether the TEIF Method helps them to design the technology solution in a complex situation when disabled people are involved.

Approach 6: Ask the developers to design two technology solutions for two different scenarios A and B, scenario A without using the TEIF Method but then being shown the TEIF Method and suggested solution for that example scenario (i.e. as with approach 2 above). Then, they design a solution to scenario B with using the TEIF Method including a case based solution table (similar to

Table 4-9) with solution patterns A, B, C scored by requirements (patterns A, B, C have been created for

Table 8-1. with corresponding different scenarios, solutions and requirements scores). The developers then add their solution to the use case solution table to help understand how the design solutions table is created. It would be possible to have the next developer participants have access to this solution and give them a slightly different scenario F. Then, ask the developers to answer the questions about whether the TEIF Method helps them to design the technology solution in a complex situation when disabled people are involved.

Approach 7: Ask the developers to act as an interviewer while an actor takes the role of the client in order to gather requirements and evaluate three provided solutions A, B, C. The first group of developers uses their own method, while the second group uses the TEIF Method in interviewing the client in order to gather requirements. Then, ask the developers in both groups to answer the questions about whether the TEIF Method helps them to gather requirements by using interview technique.

Approach 8: Ask the developers to evaluate requirements from an interview transcript. Then, ask them to evaluate three provided solutions A, B, C. The first group uses their own method in evaluating requirements and evaluating solutions A, B, C, while the second group uses the TEIF Method. Then, ask the developers in both groups to answer the questions about whether the TEIF Method helps them to evaluate requirements and evaluate solutions.

Some initial exploratory investigations were carried out to finalise the selected approach and these are discussed in sections 8.4 to 8.7.

8.4 Paper Based or Computer Based Method

Lim, Pangam, Periyasami, and Aneja (2006) stated that an important issue that can arise when users evaluate a new idea or concept using a prototype system is that they evaluate the system rather than the idea. Using a low fidelity prototype (e.g. paper) rather than a high fidelity prototype (e.g. a functioning website) can sometimes help the user focus on the idea rather than the system. However, some users may find it more difficult to evaluate the potential of an abstract concept or idea than a concrete product.

The decision was taken to use paper based scenarios and questions because it was easier for participants to refer back to information and also underline and annotate the scenario. Also the experiment was carried out in a face to face situation with the researcher so the researcher was in control by passing the next document to the participant. The face to face situation also allowed the researcher to ensure the participant engaged with the experimental tasks. The technology suggestions table was provided both on paper and on a computer screen so that the participants could refer to the explanations of the ticks and crosses in the tooltips which was faster for them than using explanations cross referenced in another table.

8.5 Issues in Evaluating TEIF Method Support for Requirements

There are alternative sources concerning software engineering requirements processes such as Volere Requirements Specification Template (Robertson & Robertson, 2014), and IEEE Recommended Practice for Software Requirements Specifications (IEEE, 1998), but they do not provide sufficient details for gathering or identifying the requirements for making interactions accessible. The TEIF Method does not aim to replace other approaches to gathering and identifying requirements but support this process with regard to the requirements for making interactions accessible.

Scenarios for the user evaluation experiment can be artificially constructed or taken from the real world. Scenarios taken from the real world have high face validity but may not provide the best scenario for the experiment. An artificially constructed scenario can provide the best scenario for the experiment but has low face validity. Slightly modifying a real world scenario for the experiment can combine the advantages of both approaches.

Three ways to gather and identify requirements in the experimental situation are a simulated interview, automated interview, and document inspection and the main advantages and disadvantages of each are shown in Table 8-3.

Table 8-3 Requirements Gathering or Evaluating Approaches

Approach	**Gathering/ Evaluating**	**Advantages**	**Disadvantages**
Simulated Interview (participants interview researcher or actor role playing 'client')	Gathering	• High face validity as with a real interview the interviewer can ask the client to clarify any unclear information (Leung, 2001). • Allows participation by people who have difficulty with reading or writing (Leung, 2001).	• The predisposition, experience, understanding, and bias of the interviewer influence the information obtained (Young, 2002). • The need for the use of actors to remove bias of researcher acting as interviewee • Reliability issues of how to consistently answer questions that are 'off script' • Can't stop for a break whenever they want • Need to arrange a suitable time and place
Automated simulated interview	Evaluating and gathering	• Selecting from list of questions which have built in answers make the interview process more reliable. The use of context-free questions by the interviewer helps avoid prejudicing the response (Young, 2002).	• Low face validity and need to put into questions many 'distractors' as otherwise requirement questions are too obvious
Document inspection	Evaluating or gathering	• High reliability as all effective requirements are mentioned in the document. • The use of context-free questions to consider helps avoid prejudicing the response (Young, 2002).	• Need to add many 'distractors' into document as otherwise requirement information is too obvious

Following this review, it can be seen that a simulated interview has high face validity but is difficult to do reliably without bias, while an automated simulated interview has lower face validity but more reliability. Document inspection can be reliably used for the experiment, if the requirements are not too obvious. Some small experimental design studies to decide on the best way to evaluate the TEIF Method for requirements were undertaken and are described in section 8.6.

8.6 Studies on requirements experimental approach

To answer sub research question 3.1 and 3.3, it was necessary to conduct some initial studies in order to refine the design of the experimental approach. The first initial study involved three participants (software engineers) conducting face to face interviews with the researcher playing the role of the client in order to investigate whether they could gather and identify requirements in this 'realistic' way (approach 7). The participants found this task very difficult as they said they had not had experience of interviewing before.

An investigation into developing an automated simulation interview was conducted. An automated simulation interview requires the development of a large number of possible realistic questions with corresponding answers so that 'distractor' questions make it difficult for participants to guess the correct questions to ask to gather the requirements. Such a corpus of questions and answers does not exist and so would require recording and transcribing developers conducting lots of interviews. However as discussed in the previous paragraph, it was not possible to find developers with these skills.

The researcher decided therefore that a different approach using a written document explaining the scenario was required for the task of evaluating or gathering requirements. The next initial study was therefore about how to present the information in the participants' preferred style. This was because they needed to spend some time on reading and understanding the scenario in order to apply the TEIF Method experimental steps and tasks and needed to look at the scenario up to seven times.

Yao (2011) found that using an interview transcript with direct speech was more realistic and engaging than a descriptive document using indirect speech. The researcher therefore developed two styles of presenting the scenario information: *A: 'report'* and *B: 'interview transcript'* extracts of which are given below. Full details are provided in Appendix G.

A. Report style:

'Chuty is a very successful Thai businesswoman in her 30s who has lived in Thailand all her life and only speaks Thai. She became hearing impaired in her twenties and depends completely on her hearing aids and lip-reading. She speaks clearly and Suchat has no problem understanding her'.

B. Interview transcript:

Interviewer: 'Could you please tell me about your recent visitor?'

Suchat: 'Chuty is a very successful Thai businesswoman in her 30s who has lived in Thailand all her life and only speaks Thai. She became hearing impaired in her twenties and depends completely on her hearing aids and lip-reading. She speaks clearly and I had no problem understanding her'.

Twelve participants were asked to give their opinions in this study. Most of the participants (eight out of twelve) preferred the interview transcript to the report so the interview transcript was chosen to be used in the experiment. Examples of participants' comments on the pilot include:

- 'B style easy to read and clearer to understand'
- 'I would prefer reading B, with more line space between what Chuty says and what the Interviewer says. B currently has more distractions because of the bold type. Currently I find A easier to read.'
- 'In order to prepare content for readers, the style-B is better because it does not have a lot of content that will make a reader so tired and boring. Reading question and answer is more fun than many sentences in the paragraphs'.

The results of the experiment supported Yao's research findings and so it was decided to use the interview transcript rather than a report style of document for the experiment as it was more realistic and engaging.

8.7 Evaluating Requirements or Gathering Requirements

The advantages and disadvantages of requiring participants to gather requirements or evaluate requirements were considered.

If the experiment required participants to gather requirements, judgements of these requirements could only be made by experts who might be influenced by the written style, grammar, spelling and general writing skills of the participants. Trials with a few developers also showed that they found the task of gathering and writing out requirements difficult and very time consuming.

It was therefore decided to present an evaluation task instead where developers would be asked to select the best ten requirements from a long list of possible requirements to reduce the probability of selecting the ten best requirements by chance. So that experts would not be required to judge which were the best ten, only ten of the requirements presented fitted exactly with the information presented in the transcript, the other possible requirements assumed information that was not provided in the transcript.

Six participants were asked to undertake the evaluate requirements task in order to get iterative feedback to improve the task. The electronic files (transcript of interview and task with 28 possible requirements) were sent to participants through emails. The improvements to the requirements task as a result of the pilot were clearer explanations, re-ordering the position of the requirements in the list, and adding one more requirement to the list so that 29 possible requirements would be provided.

8.8 Rationale for Approach Chosen

After considering the research evidence and investigation results it was decides that approach number 8 was the best experimental approach. The rationale for choosing approach 8 was that it was easier to design the experiment with:

- Evaluating technology solutions rather than designing technology solutions due to:
    - Developers use different ways to present their designs (e.g. UML, sketches etc.) and these are difficult to compare and evaluate.
    - Time limitation: designing a technology solution can take many hours and it is difficult to get ethics approval for an experiment that takes many hours and also difficult to motivate participants to spend this amount of time.
    - Need experts to evaluate the designs and this would require them to spend a great deal of their valuable time and also different experts might disagree in their judgements
- Having participants each use only one scenario and one method rather than two scenarios and two methods due to the limited time available.
- Three solutions were used rather than two to reduce the probability of selecting requirements by chance and also allows solutions with both large and small differences in ratings to be used.
- Two independent groups were used rather than one group using both methods to reduce the learning effect.

Full details of the experimental materials used in the experiment are given in the Appendix H (TEIF Method) and Appendix I (Other Methods).

8.9 Rank Ordering or Rating Solutions

It was possible to either ask participants to rank solutions or to rate solutions. While ranking has the benefit of simplicity and producing a clear ‘best’ solution, rating was chosen as it allows more sensible statistical analysis to be undertaken while still allowing the solutions to be ranked.

A rating scale from 0 to 10 was selected rather than a five point scale as this would for example allow solution A to be rated five points higher than solution B, while solution B could still be rated five points higher than solution C. Also, if solution A is slightly better than solution B, which is slightly better than solution C, which is still thought to be quite good, then a five point scale would only allow A=5, B=4, C=3, which would not give C a ‘quite good’ rating whereas the larger scale allows ratings to be A=10, B =9, C =8.

Sub research question 3.2 was explored using three different approaches investigating whether:

a: the TEIF Method helps developers select the best design solution(s) more often than the Other Methods

b: the TEIF Method helps developers rate solutions closer to the experts’ ratings than the Other Methods?

c: the TEIF Method helps rate differences (amount and direction) between solutions closer to experts’ difference scores than the Other Methods?

8.10 Questionnaire to Help Answer Research Question 3

As the experiment only involved evaluating requirements and technology solution designs and did not involve gathering requirements or designing technology solutions and also the experiment only involved requirements and solutions for a scenario involving a hearing impaired visitor, a questionnaire was used for finding out the participants’ views on the value of the TEIF Method for requirements gathering, solution design, and other disabilities in order to be able to answer all the sub research questions.

Question 10 focused on gathering requirements for hearing impaired people: ‘You would find the TEIF Method you used for the evaluate requirements task helpful to gather requirements for technology solutions to interaction problems involving hearing impaired people'.

Question 11 focused on designing technology solutions for hearing impaired people: 'You would find the TEIF Method you used for evaluate technology solution task helpful for designing technology solutions to interaction problems involving hearing impaired people'.

Question 13 focused on gathering requirements for disabled people: 'If information was also provided about other disabilities you would find the TEIF Method helpful in gathering requirements for technology solutions to interaction problems involving disabled people'.

Question 14 focussed on designing technology solutions for disabled people: 'If information was also provided about other disabilities you would find the TEIF Method helpful for designing technology solutions to interaction problems involving disabled people'.

8.11 Questions Asked to Participants to Help Answer Research Question 4

To help answer this research question the sub research questions were explored through questionnaire responses and also any difficulties the participants had with the TEIF Method steps were analysed.

Question 5 focused on awareness of interaction issues: 'The TEIF Method helped to improve your awareness of interaction issues involving hearing impaired people'.

Question 6 focused on environment context: 'The TEIF Method helped to improve your understanding of how environment context affects interaction when hearing impaired people are involved'.

Question 7 focused on the technology suggestions table: 'The TEIF Method technology suggestions table helped you to identify technology solutions to issues involving hearing impaired people'.

Question 12: focused on the whole and parts of the TEIF Method: 'You would find using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the part of the TEIF Method you used for evaluate technology solution task'.

Further questions were asked about the TEIF Method steps, to see how the steps helped developers use the TEIF Method. These questions are explained below. (see Appendix H for the full details).

Step 1 identified 5 interaction types P-P, P-T, P-O, P-T-P, and P-T-O

Purpose: Check whether they can identify these types

After participants finished the step, the correct answers and explanations (Appendix H) were given when participants got the wrong answers in order to ensure they understood the terms of the interaction types.

Step 2 analysed how interactions are affected by hearing impairment

Purpose: This is the part of the TEIF Method that helps analyse interaction issues affected by hearing impairment.

Participants read the interview transcript and answered the 13 multiple choice questions about it. To help ensure they engaged with the transcript they were also asked to underline the words in the transcript that helped with each answer and write the number of question and answer choice they selected above the underlined words on the interview transcript sheet.

Step 3 identified questions-answers related to requirements

Purpose: This is the part of the TEIF Method that helps analyse how the interaction issues relate to requirements.

Participants used answers to question to analyse the best ten requirements for a technology solution that solves the disability related problems identified from the interview transcript by putting a tick in the appropriate table cell when the answer in that column was related to the requirement in that row.

Step 4 identified which technologies met each requirement

Purpose: This is the part of the TEIF Method that helps analyse how possible technologies relate to requirements.

Participants identified all the technologies from the technology suggestions table which could be used to meet each of the ten requirements.

8.12 Experiment Pilot Studies

In order to obtain ethics approval, it was required that participants were able to complete the experiment in less than 90 minutes. The TEIF Method was cut down by not showing the Interaction Diagram and Use Case Diagram or explanation for a technology solution. Requirement questions were reduced to 13, and the scenario and technology suggestions table were both shortened.

Eight participants, English native speakers and non-native speakers, were mixed equally between two groups. To pilot the tasks and steps four participants were asked to use the TEIF Method while the other four were asked to use their preferred other methods.

All participants were Software Engineers and PhD students in Computer Science at the Southampton University selected through personal invitations and able to spare up to an hour and a half to go through the TEIF Method and process and provide constructive feedback.

Participants were asked to do the tasks independently and only if an instruction was found to be unclear, did the researcher explain the instruction. The process for the pilot study was that the individual participant sat down with the researcher and completed and applied the TEIF Method steps to do the evaluating requirement task and technology solution task. In this pilot study, the participants were also asked to complete a questionnaire after the experiment (Appendix H). The intention of this final pilot was to gather data on how much time would be required working on the tasks and to gain feedback on the materials and questionnaire design.

Issues found in the pilot study included:

- An English native speaker spent less time (approximately 60 minutes) than non-native speaker (approximately 90 minutes).
- Some non-native English speakers needed clarification of some of words in the interview transcript. So, the researcher developed a glossary in order to clarify these words (e.g. shadow puppet, spontaneous speech).
- The instructions for some of the tasks needed improving e.g. most participants found that step 3 was not clear and so needed clarifying.
- Sign language video was missing from the technology suggestion table.
- The transcript of the interview needed improving by explaining more clearly
- The transcript needed shortening due to the limitation of time
- More ‘distraction’ text was inserted in order to make it more realistic and more difficult to identify the requirements
- Unclear requirements needed improvements to be clearer

- Insert blank lines between each instruction rather than combining in one paragraph
- Asking participants in the Other Method group for their opinion and feedback about the TEIF Method and steps after the researcher showed the TEIF Method to the Other Method group at the end of the experiment
- Separate into two separate sections the evaluation of how the TEIF Method helped in the experiment from how the TEIF Method might help them in the future in order to be clearer and less confusing

8.13 Experimental Design

The purpose of this study was to evaluate a new software engineering method that can help technology developers who are not accessibility experts design technology solutions to interaction issues encountered by disabled people. The process took between one hour and one hour and a half. An expected sample size for the experiment was 36, which divided into two groups (18 participants in each group), using the given values of:

- effect size : 1 – This represent a relatively large effect size
- alpha error probability: 0.05 – normal conventon
- power: 0.8 - normal conventon
- test family: t test – two independent mea
- tails : two – is appropriate when a difference in any direction is expected (it could be higher or lower)
- number of group : 2
- statistic test : means: difference between two independent means (two groups)

The thirty-six participants were asked in person or by email to take part in the experiment. They were divided into two equal independent groups of 18 participants, four English native speakers and 14 non-native English speakers in each group (see Table 8-4). The first group of the participant used the TEIF Method consisting of four steps to complete the evaluating requirement task and evaluating technology solution task. The second group of participants used their preferred other methods to complete both tasks.

Table 8-4 English native speakers and non-native English speakers in each group

English Speaker	TEIF Method	Other Methods
Native	4	4
Non-native	14	14
Total	18	18

For the evaluating requirement task, participants selected the best ten requirements from the twenty-nine requirements provided for a technology solution to the disability related problems they identified from the interview transcript.

The ten correct requirements with their numbering were:

- Requirement 1: The technology solution should help hearing impaired visitors in the audience understand the owner present information.
- Requirement 4: The technology solution should help hearing-impaired visitors understand conversation in background music.
- Requirement 8: The technology solution should help notify hearing impaired visitors when the tour starts.
- Requirement 11: The technology solution should help visitors to not miss information when the owner points to exhibits.
- Requirement 14: The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.
- Requirement 17: The technology solution should help visitors to understand the shadow puppet show in the dark.
- Requirement 21: The technology solution should work with pre-prepared speech from the owner to the visitors.
- Requirement 24: The technology solution should work with spontaneous speech between the owner and the visitors.
- Requirement 25: The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).
- Requirement 28: The technology solution should work with Thai language.

The nineteen incorrect requirements with their numbering were:

- Requirement 2: The technology solution should help provide sign language for hearing impaired visitors.

- Requirement 3: The technology solution should improve mobile phone signal for hearing impaired visitors.
- Requirement 5: The technology solution should work with hearing impaired people who use sign language.
- Requirement 6: The technology solution should enable hearing impaired visitors to ask the owner questions.
- Requirement 7: The technology solution should help wheelchair users in the museum.
- Requirement 9: The technology solution should help blind visitors to the museum.
- Requirement 10: The technology solution should keep disabled visitors dry by not having to walk between buildings.
- Requirement 12: The technology solution should help find parking facilities for disabled visitors.
- Requirement 13: The technology solution should improve GPS reception for hearing impaired visitors.
- Requirement 15: The technology solution should help the owner make more profit.
- Requirement 16: The technology solution should improve catering for disabled visitors.
- Requirement 18: The technology solution should help hearing impaired visitor's friends email them to discuss the shadow puppet museum.
- Requirement 19: The technology solution should improve Wi-Fi facilities for hearing impaired visitors.
- Requirement 20: The technology solution should reduce costs of shadow puppet souvenirs for disabled visitors.
- Requirement 22: The technology solution should improve toilet facilities for disabled visitors
- Requirement 23: The technology solution should help find nearest toilet facilities for disabled visitors.
- Requirement 26: The technology solution should improve parking facilities for disabled visitors.
- Requirement 27: The technology solution should help find nearest food outlet for disabled visitors.

- Requirement 29: The technology solution should help hearing impaired visitors email friends to discuss the shadow puppet museum.

The order of the three technology solutions A, B, C were presented in the evaluating technology suggestion task was balanced so that three participants in each group were asked to rate the solutions for each of the six orders as shown in Table 8-5.

Table 8-5 Solution order for experiment in each group

Solution order	**TEIF Method**	**Other Methods**
A, B, C	3	3
A, C, B	3	3
B, A, C	3	3
B, C, A	3	3
C, A, B	3	3
C, B, A	3	3

8.13.1 TEIF Method Group

This group undertook the steps, tasks and questionnaire in the following order (The full details and material are provided in Appendix H):

Step 1: The eighteen participants in the TEIF Method group were asked to match interaction types to five given situations. The researcher checked the answers and, for any wrong answers, the answers were shown and explained to them, in order to make sure all participants understood the TEIF interaction types before moving to step 2.

Step 2: The participants were asked to read a transcript of an interview and answer multiple choice questions that analysed how interactions were affected by hearing impairment. They were asked to underline the words in the transcript sheet that helped them with each answer.

Step 3: The participants were asked to identify the issues from step 2, that were related to the 29 requirements.

Task: Evaluating Requirement

The participants were asked to select the best ten requirements for a technology solution to the disability related problems they identified from the interview transcript and underline the keywords of each answer on the transcript sheet.

Step 4: The technology suggestion table was provided in both online and paper versions to identify which technologies met which issues. The advantage of the onlinr version was that the participants could refer to the explanations of ticks and crosses provided in tooltips, whereas the paper version was easier to underline or make notes on. The participants were asked to use the technology suggestions table to identify which technologies were appropriate for each of the ten requirements.

Task: Evaluating Technology Solution

The participants were asked to give ratings between 0 and 10 for how well each of the three solutions (A, B, C) provided met each of the ten requirements, using the technology suggestion table, and were asked to underline the words on the solution sheets that helped them with their ratings.

Task: Questionnaire

The participants were asked about background information, rate the clarity of explanation of TEIF Method steps, evaluate whether and how the TEIF Method helped in the experiment, imagine how the TEIF Method might help in the future, and any other comments about the usefulness or value of the TEIF Method.

8.13.2 Other Methods Group

The full details and material used by the Other Methods group are provided in Appendix I. The three tasks were:

Task Evaluating Requirement:

The participants were asked to select the best ten requirements for a technology solution to the disability related problems they identified from the interview transcript and underline the keywords of each answer on the transcript sheet.

Task Evaluating Technology Solution:

The participants were asked to give ratings between 0 and 10 for how well each of the three solutions (A, B, C) provided met each of the ten requirements and were asked to underline the words on the solution sheets that helped them with their ratings. To assist them with this task they were provided with a modified version of the paper based technology suggestion table that was provided for the

TEIF Method group that only contained descriptions of the technologies, without any ticks, crosses, or explanations.

Task Questionnaire:

The participants were asked to give background information, rate the clarity of explanation of TEIF Method steps, evaluate whether and how the TEIF Method helped imagine how the TEIF Method might help in the future, and any other comments about the usefulness or value of the TEIF Method.

8.14 Statistical Tests Used

The statistical terms and tests used are described in Appendix J. The results in chapter 9 present the statistical tests in detail for each of the part of the research.

The mean values in some tables are the same, for example, Table 9-71 and Table 9-163 because they use the same raw data, the difference between the tables being the estimate of error variance. Ideally, estimates of error variance are pooled from the variance of the raw data, but such pooling was not feasible when analysing simple effect using multivariate analysis in SPSS. The slight differences in statistical significance were of no consequence for the interpretation and discussion of the results as all significant differences remained significant and all non-significant differences remained non-significant.

8.15 Summary

Following completion of the expert validation and review of the TEIF and the TEIF Method, a mixed methods approach using a quantitative experimental evaluation and a qualitative questionnaire informed by a pilot study was used to evaluate the TEIF Method. Thirty-six participants were divided into two equal independent groups of 18 participants. The first group of the participants used the TEIF Method while the second group of participants used their preferred the Other Methods. Both groups answered a questionnaire at the end of the experiment. The experiment cut down the TEIF Method by not showing the Interaction Diagram and Use Case Diagram or explanation for a technology solution. Requirement questions were reduced to 13, and the scenario and technology suggestions table were both shortened. Paper based scenarios and questions were used because it was easier for participants to refer back to information and also underline and annotate the scenario. The technology suggestions table was also, however, provided on a computer screen so that the participants could refer to the explanations of the ticks and crosses in the tooltips which was faster for them than using explanations cross referenced in another table on paper. The experiment was carried out in a face to face situation with the researcher so the researcher was in control by passing the appropriate document to the participant and ensuring the participant engaged with the experimental tasks.

Chapter 9 Experimental Results

This chapter reports the statistical analysis and results for the experiments to help answer research questions 3 and 4. Section 9.1 reports the analysis and results on participants' profiles while section 9.2 presents the analysis and results for the TEIF Method. Section 9.3 reports the evaluate requirements task analysis and results which helps answer research question 3.1. Section 9.4 presents the evaluate technology solutions task analysis and results which helps answer research question 3.2. Section 9.5 reports the analysis and results for the questions asked to participants following their completion of the experimental tasks and this helps answer research questions 3.3, 3.4, and 4 as well as providing further evidence for research questions 3.1 and 3.2. Figure 9-1 shows an overview of all the analyses undertaken and the sections of this chapter in which they are reported.

A brief summary and discussion of the results is presented at the beginning of this chapter to help the reader while the full details of the results are presented in this chapter while a more detailed discussion is presented in the next chapter.

- *Sub research question 3.1: Can developers use the TEIF Method to help with evaluating requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?*

The mean number of correct requirements was significantly higher for participants using the TEIF Method than the Other Methods (Sections 9.3 and 10.3.1). More participants in the TEIF Method group selected each correct requirement than the Other Methods group (section 9-3, and 10.3.1). Both the results of the evaluate requirement task of the experiment (section 9.3) and the questionnaire question 8 (the TEIF Method helped evaluate requirements: section 9.5.1) were in agreement with this finding.

○ *Sub research question 3.2: Can developers use the TEIF Method to help with evaluating technology solutions when designing technology solutions to interactions for disabled people with people, technologies, and objects?*

Approach A: Investigated whether the TEIF Method helped developers select the best technology solution(s) more often than the Other Methods. The paired t test and the chi-square test were used for this investigation. The results showed that the TEIF Method did not help developers select the exclusive best design solution(s) significantly more often than the Other Methods but it did help them select a solution significantly more often than the Other Methods that was not worse than a solution rated best by the experts (Sections 9.4.2 and 10.3.2). Participants were not explicitly asked to select the best solution(s) but were asked to rate the three solutions on a scale from 0-10. This required each participant to make 30 ratings. The researcher observed that participants found this a difficult task as they had to read and analyse each solution for each of the ten requirements. Therefore testing whether the participants rated the same solution highest as the solution the experts rated highest and also requiring the participants to rate the same solutions equally high as the experts was probably too strict a test of whether the TEIF Methods helped them select the best solution.

Approach B: Investigated whether the TEIF Method helped developers rate technology solutions closer to the experts' ratings than the Other Methods.

The results showed that The TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A but not for solutions B and C, and this applied similarly to each requirement (Sections 9.4.3.2 and 10.3.2). As the technology suggestions table only showed ticks and crosses for technologies these gave only a binary indication and so this was more help to the reader for very good or very bad solutions that would be given very high or very low ratings rather than solutions that would be in the middle of a 10 point rating scale. While the experimental result shows that the TEIF Method helps with solution A, the questionnaire results for question 9 (section 9.5.2) showed that the participants thought that the TEIF Method had helped them evaluate the solutions (mean rating = 4.28).

Approach C: Investigated whether the TEIF Method helped rate differences (measure amount and direction) between technology solutions closer to experts' difference scores than the Other Methods (Sections 9.4.3.3 and 10.3.2).

Differential A-B: The results showed that the TEIF Method helped differentiation between solutions to be closer to experts' differentiation than the Other Methods for differential A-B for requirement 8 on measures amount and direction but not for other requirements (Sections 9.4.3.3.1 and 10.3.2.1). The expert differential A-B for requirement 8 was 10 which was larger than the expert differential A-B for any other requirements. This may account for the significant results involving requirement 8 (Figure 9-26 and Figure 9-27) and for the lack of significance for the other requirements.

Differential A-C

The results showed that the TEIF Method did not help differentiation between solutions A and C to be closer to experts' differentiation than the Other Methods (Sections 9.4.3.3.2 and 10.3.2.2). Requirement 1 was selected by the greatest number of participants in the TEIF group in the requirement task and so perhaps participants understood this requirement the best. As the TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A, this might help in also rating the differential A-C closer than the Other Methods, but the lack of significant findings for eight of the requirements and the results suggested that in general, there is no differential effect between the TEIF Method or the Other Methods.

Differential B-C

The results showed that the TEIF Method helped differentiation between solutions B and C to be closer to experts' differentiation than the Other Methods on both measures amount and direction for requirements 8 and 28 (Sections 9.4.3.3.3 and 10.3.2.3).

The expert differential B-C for requirement 8 was 10 which was larger than the expert differential B-C for any other requirement. The expert differential B-C for requirement 28 was 0 and was the only expert differential of 0 for B-C for any requirement where both solution B and C were rated 10. Requirement 28 was selected by the lowest number of participants in the Other Methods group in evaluating requirement task. This might help explain why the TEIF Method helped for these requirements.

○ *Sub research question 3.3: Can developers use the TEIF Method to help with gathering requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?*

The results in section 9.5.4 showed the participants thought that the TEIF Method would also help with gathering requirements for technology solutions to interaction problems involving hearing impaired people (mean rating = 4.53), and for other disabled people (mean rating = 4.47). On the rating scale between 1 and 5, with 3 as the neutral point, a rating of around 4.5 suggests a very strong opinion of the value of the TEIF Method in gathering requirements for hearing impairments as well as other disabilities.

○ *Sub research question 3.4: Can developers use the TEIF Method to help with designing technology solutions to interactions for disabled people with people, technologies, and objects?*

The results showed that the participants thought that the TEIF Method would help designing technology solutions to interaction problems involving hearing impaired people (question 11, mean rating = 4.39), and if information was provided for other disabled people (question 12, mean rating = 4.56). On the rating scale between 1 and 5, with 3 as the neutral point, a rating of around 4.4 to 4.5 suggests a very strong opinion of the value of the TEIF Method in designing technology suggestions for hearing impairments as well as other disabilities.

○ *Sub research question 4.1: Does the TEIF Method help to improve awareness of interaction issues involving hearing impaired people?*

A one-sample t-test was used to analyse the results of question number 5. Participants thought that the TEIF Method helped improve a developer's awareness of interaction issues involving hearing impaired people (mean rating = 4.44) (Sections 9.5.3 and 10.4.1). On the rating scale between 1 and 5, a rating of between 4 and 5 suggests a strong opinion of the value of the TEIF

Method to help a developer’s awareness of interaction issues involving hearing impaired people.

- *Sub research question 4.2: Does the TEIF Method help to improve understanding of how environment context affects interaction when hearing impaired people are involved?*

A one-sample t-test was used to analyse the results of question number 6 (section 9.5.3). Participants thought that the TEIF Method helped to improve understanding of how environment context affects interaction when hearing impaired people are involved (mean rating = 4.44) (Sections 9.5.3 and 10.4.2). On the rating scale between 1 and 5, a rating of around 4 suggests a strong opinion of the value of the TEIF Method help a developer’s improve understanding of how environment context affects interaction when hearing impaired people are involved. The result from the multiple choice questions (section 9.2.2) showed 100% understood the impact of background noise, 72% understood the importance of visual access to speaker face, 67% understood the effect on distances on the level of sound, but only 18% understood the importance of hard surface and reverberation. Although, the scenario mentioned that the shadow puppet theatre was made of wood perhaps the participants may not have thought that the museum was also made from wood.

- *Sub research question 4.3: Does the technology suggestions table in the TEIF Method help identify technology solutions to interaction problems involving hearing impaired people?*

  A one-sample t-test was used to analyse the results of question number 7 (section 9.5.3). Participants thought that the technology suggestions table in the TEIF Method helped with identifying technology solutions to interaction problems involving hearing impaired people (mean rating = 4.44) (Sections 9.5.3 and 10.4.3). On the rating scale between 1 and 5, a rating of around 4 suggests a strong opinion of the value of the TEIF Method helping identify technology solutions to interaction problems involving hearing impaired people.

- *Sub research question 4.4: Is using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the Method?*

A one-sample t-test was used to analyse the results of question number 12 (section 9.5.4). Participants thought that using the whole TEIF Method would be more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the method (mean rating = 4.56, sections 9.5.4 and 10.4.4). On the rating scale between 1 and 5, a rating of around 4.5 suggests a very strong opinion of the value of using the whole TEIF Method for designing technology solutions compared to just using the technology suggestions table part of the TEIF Method.

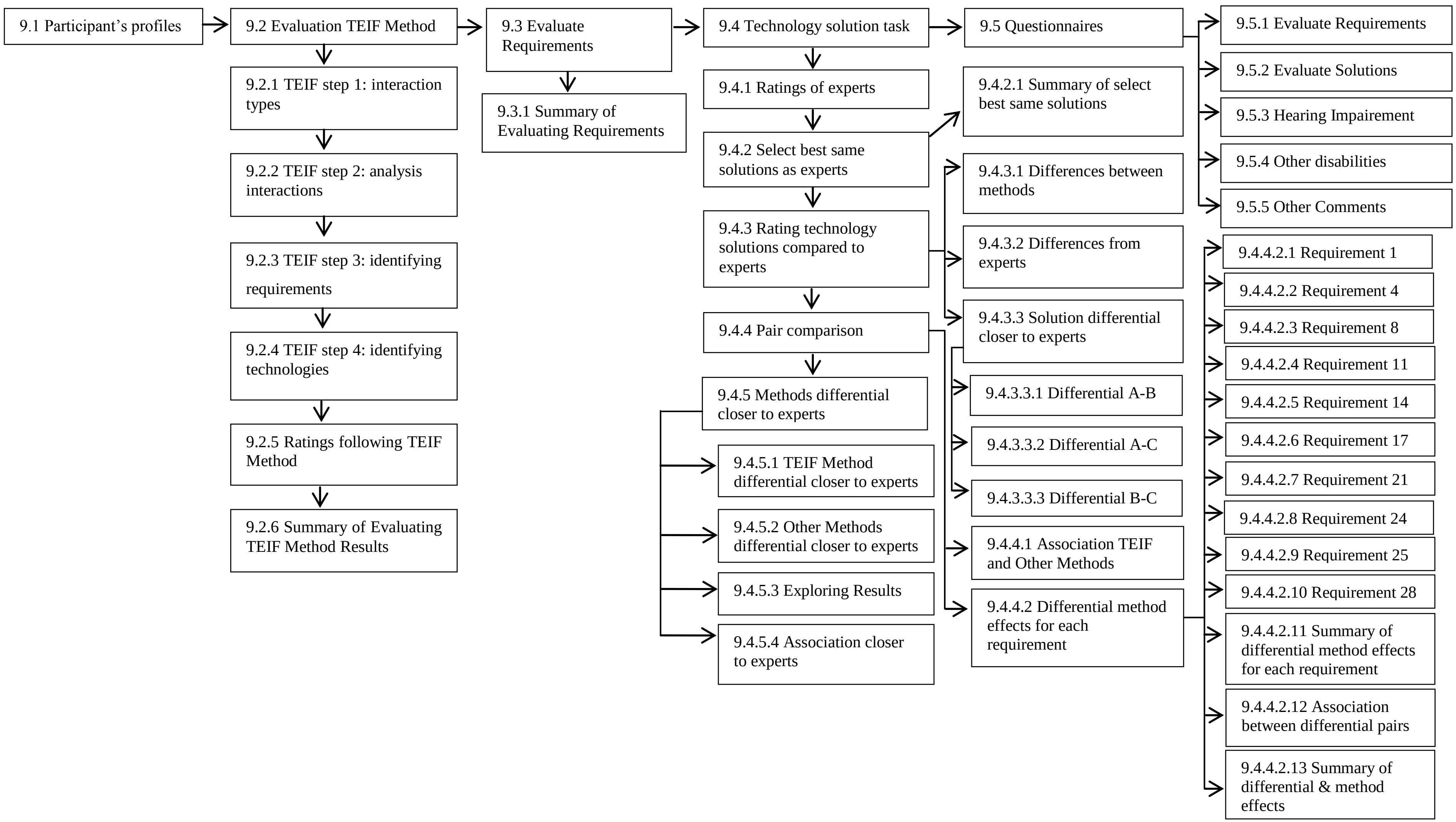


Figure 9-1 Overview of analyses undertaken

9.1 Participants' profiles

There were thirty-six participants who participated in this user evaluation for both experiment and questionnaire. They were separated into two groups: the TEIF Method group and the Other Methods group as shown in Table 9-1. There were both native and non-native English speakers: 22.2% (eight participants) were native English speakers and 77.8 % (28 participants) were non-native English speakers as shown in Table 9-2. All participants who were involved in this user evaluation were technology developers with a computing related qualification at degree level with a range of experiences in designing software as shown in Table 9-3 and illustrated in Figure 9-2. Less than 20% had experiences in designing technology solutions for disabled people as shown in Table 9-4. None were accessibility experts.

Participants' Experiences included:

- Working on research for autistic people
- ATbar : desktop accessibility toolbar
- Use semantic web and open data to help disabilities to find the accessible facilities around
- Designing disability solution for Malaysian government
- Hand and Arm recognition applications
- An HCI module in the second year of degree

Table 9-1 Number of participants in groups

Method	Frequency	Percent
TEIF	18	50
Other	18	50
Total	36	100

Table 9-2 Number of English speakers in groups

Method	English Speakers	Frequency	Percent
TEIF	Native	4	11.1
	Non-native	14	38.9
Other	Native	4	11.1
	Non-native	14	38.9
	Total	36	100

Table 9-3 Number of years experience in designing software

Years experience		Frequency	Percent
	.00	1	2.8
	1.00	5	13.9
	1.50	1	2.8
	2.00	4	11.1
	3.00	6	16.7
	4.00	5	13.9
Value	5.00	4	11.1
	7.00	2	5.6
	8.00	2	5.6
	9.00	1	2.8
	10.00	4	11.1
	12.00	1	2.8
	Total	36	100

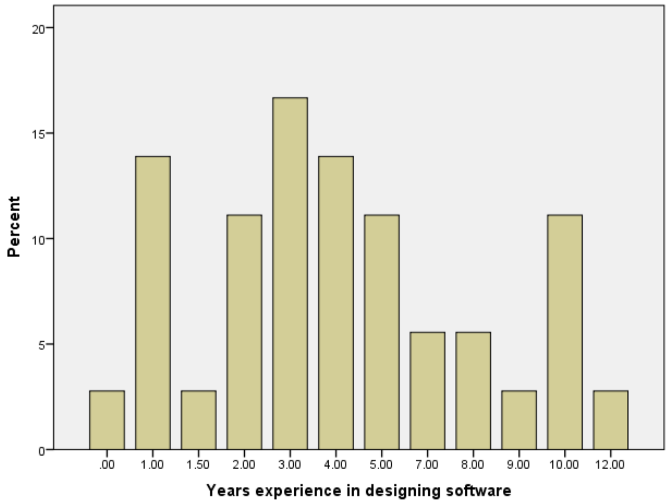


Figure 9-2 Profile graph of years experience in designing software

Table 9-4 Number of participants having experiences in designing technology solutions for disabled people

Experiences in designing technology solutions for disabled people	Frequency	Percent
No	29	80.6
Yes	7	19.4
Total	36	100

An independent samples t-test was conducted in order to check whether experiences in designing software and experiences in designing technology solutions for disabled people were significantly different between the TEIF Method group and the Other Methods group.

Table 9-5 shows mean years experience in designing software and designing technology solutions for disabled people. There was no significant difference between the two groups for the number of years of practical experience designing software and experience in designing technology solutions for disabled people as shown in Table 9-6 and illustrates in Figure 9-3.

Table 9-5 Group Statistics of experience

Experiences	Method	N	Mean	Std. Deviation	Std. Error Mean
Design software	TEIF	18	4.89	3.01	.723
	Others	18	4.19	3.44	.812
Design technology solutions for disabled people	TEIF	18	.222	.428	.101
	Others	18	.167	.383	.09

Table 9-6 Independent samples test of experiences

Experiences		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Design software	Equal variances assumed	.028	.867	639	4	.527	.694	1.09	-1.51	2.90
	Equal variances not assumed			639	33.6	.527	.694	1.09	-1.52	2.90
Design technology solutions for disabled people	Equal variances assumed	.681	.415	410	34	.684	.056	.135	-.220	.330
	Equal variances not assumed			410	33.6	.684	.056	.135	-.220	.330

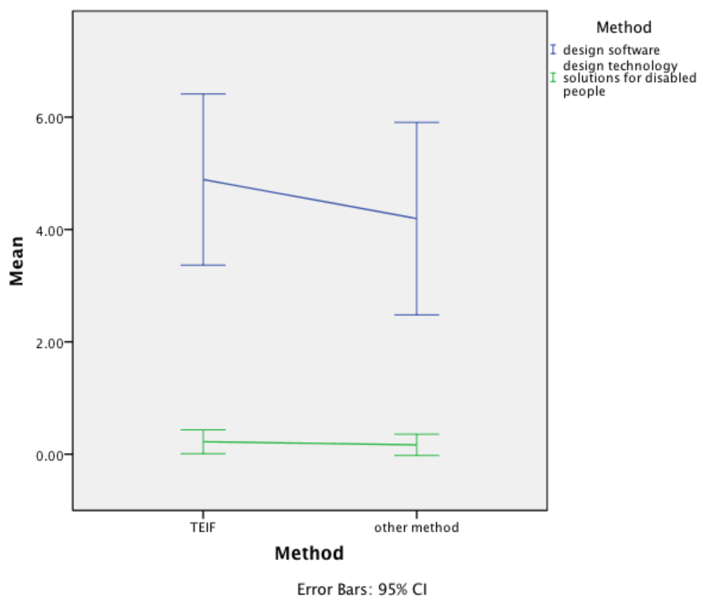


Figure 9-3 Profiles graph of mean experiences in designing software and designing technology solutions for disabled people

9.2 Evaluation of TEIF Method

There were eighteen participants who used the TEIF Method to do the experimental tasks. The four TEIF Method steps' materials are shown in Appendix H. The results from the four steps were as follows:

9.2.1 Step 1: Identify interaction types

The interaction types: P-P, P-O, and P-T-P were selected correctly by 100 % of participants, whereas the interaction types: P-T and P-T-O were selected correctly by 94 % of participants as shown in Table 9-7.

Table 9-7 Number of participates who selected the right answers on step 1

Interaction Type	**Statement**	**Number of participants who selected the right answer**	**Percent of participants who selected the right answer**
P-P	D. Suchat gave a museum tour by explaining about the museum in Thai and Chuty asked him some questions.	18	100
P-O	E. Chuty touches the puppets in order to feel the leather.	18	100
P-T	B. Chuty uses GPS to navigate to the museum.	17	94
P-T-P	A. Suchat rang the tiny metal bell to let Chuty know when the tour started.	18	100
P-T-O	C. Chuty uses her mobile phone to scan QR-codes on an object to get further information.	17	94

9.2.2 Step 2: Analyse how interactions are affected by hearing impairment

There were thirteen questions in step 2 which participants had to complete. The questions were linked back to the TEIF which helped participants analyse how interactions are affected by hearing impairment. The results of step 2 are shown in

Table 9-8 and illustrated in Figure 9-4 as follows:

- The answer numbers 1a, 2b, 3a, 5b, 10a, and 12a were selected correctly by 100 % of participants.
- The answer numbers 4a, 6b, 7a, 8a, 9a and 13a were selected correctly by 94 % of participants.
- The answer numbers 11a was selected correctly by 89 % of participants.
- The answer numbers 12c was selected correctly by 78 % of participants.

- The answer numbers 12b and 10d were selected correctly by 72 %of participants.
- The answer number 10c was selected correctly by 67 % of participants.
- The answer number 10b was selected correctly by only 28 %of participants.

Table 9-8 Number of participants who selected the right answers on TEIF Method step 2

Question	**Answer**	**Number of participants who selected the right answer**	**Percent of participants who selected the right answer**
1) What main role did people have in the scenario?	1a : presenter - audience	18	100
2) Did the presenter have a disability?	2b: no	18	100
3) Did any of the audience have a disability?	3a: yes	18	100
4) What kind of disability did any of the audience have?	4a: hearing impaired	17	94
5) What language did the owner and the disabled visitor speak in their interactions?	5b: Thai	18	100
6) Did the hearing impaired person use sign language?	6b: yes	17	94
7) Did the hearing impaired person wear hearing aids?	7a: yes	17	94
8) Did the hearing impaired person use lip-reading?	8a: yes	17	94
9) Is cost an issue for a solution?	9a: yes	17	94
10) Which environmental considerations may have impacted the interactions with the disabled person in the transcript?	10a: Background noise	18	100
	10b: Hard surfaces	5	28
	10c: distance	12	67
	10d: Visual access	13	72
11) What 'types' of speech did the presenter use?	11a: prepared or rehearsed speech	16	89
	11b: spontaneous speech	10	56
12) How could the disability have affected actions and reactions in the People to People (P-P) interactions with the disabled person?	12a: quiet speech and background noise	18	100
	12b: lip reader needed to look away from the speaker's lips/face	13	72
	12c: speaker's mouth/face and lip-readers' eyes were blocked	14	78
13) How did disability affect the actions and reactions in the People to Technology (P-T-P) interactions in the transcript?	13a: difficult to hear notification	17	94
Mean	**16.3**		
Standard Deviation	**2.08**		

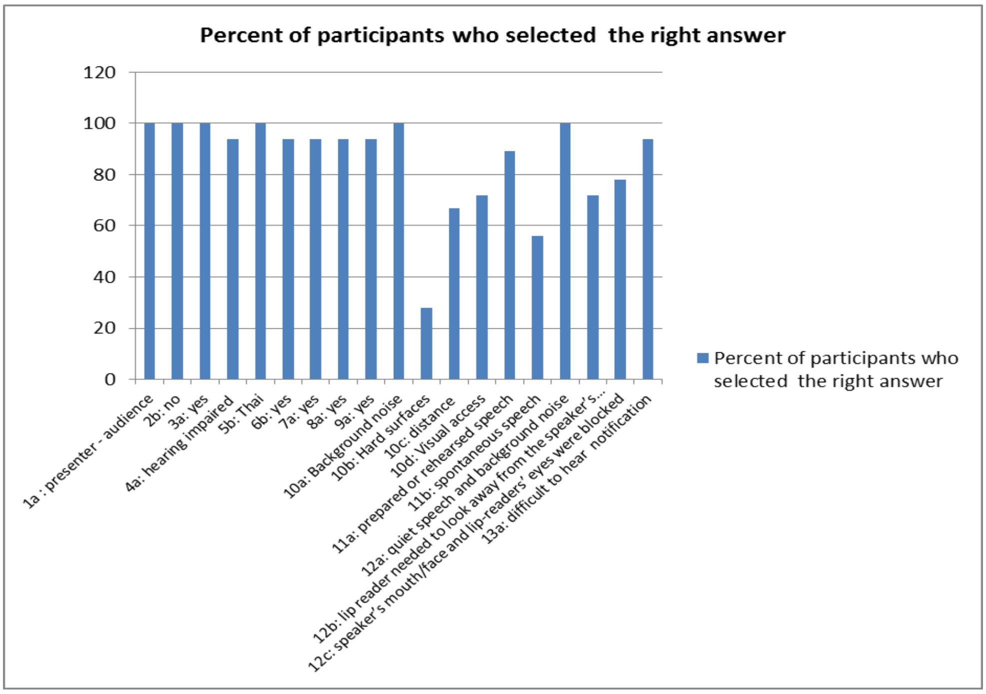


Figure 9-4 Percent of participants who selected the right answers in TEIF step 2

9.2.3 Step 3: Identify requirements

In step 3 participants had to match ten question-answers with twenty-nine provided requirements and select only the best ten requirements for a technology solution that solves the disability related problems identified from the interview transcript. The results of step 3 are shown in Table 9-9 and illustrated in Figure 9-5 as follows:

- Requirements 1 and 11 were selected correctly by 67% of participants.
- Requirement 4 was selected correctly by 100% of participants.
- Requirement 14 was selected correctly by 89% of participants.
- Requirement 21 was selected correctly by 83% of participants.
- Requirements 24 and 28 were selected correctly by 94% of participants.

Table 9-9 Number of participants who selected the right answers on step 3

Requirement number	Number of participates who selected the right answer	Percent of participates who selected the right answer
1. help hearing impaired visitors in the audience understand the owner present information	12	67
4. help hearing impaired visitors understand conversation in background music	18	100
8. help notify hearing impaired visitors that the tour starts	14	78
11. help visitors to not miss information when the owner points to exhibits	12	67
14. work with hearing impaired visitors who wear hearing aid and use lip-reading	16	89
17. help visitors to understand the shadow puppet show in the dark	14	78
21. work with pre-prepared speech from the owner to the visitors	15	83
24. work with spontaneous speech between the owner and the visitors	17	94
25. keep costs low by working with existing Wi-Fi and visitors' smartphones	14	78
28. work in Thai language	17	94
Mean for all items	**14.9**	
Standard Deviation	**2.80**	

Figure 9-5 Percent of participants who selected the right answers in step 3

9.2.4 Step 4: Identifying which technologies meet each requirement

The technology suggestion table, which consisted of eleven technologies with descriptions, ticks and crosses, and the explanation of why ticks or crosses as shown in online tool tips, was provided as well as the ten requirements. The participants had to write the numbers of all the possible technology suggestions from the technology suggestion table provided which could be used to meet each of the ten requirements listed in the form provided in step 4. This TEIF Method step helped the participants to analyse the possible technologies which could be used in evaluating technology solutions related to the interactions when hearing impaired people were involved.

The results of step 4 are shown in Table 9-10 and illustrated in Figure 9-6. The most participants (89%) provided the right answers for requirements 8 and 25. The second highest number of correct answers (72%) was for requirements 1 and 4. There were 67% of participants who provided the right answers for requirement 24. There were 61% of participants who provided the right answers for requirements 11, 14, and 28. There were 56 % of participants who provided the right answers for requirement 21. The requirement 17 was answered correctly by only 50% of participants.

Table 9-10 Number of participates who selected the right answers in step 4

Requirement	**Number of participants who selected the right answer**	**Percent of participants who selected the right answer**
1. help hearing impaired visitors in the audience understand the owner present information	13	72
4. help hearing impaired visitors understand conversation in background music	13	72
8. help notify hearing impaired visitors that the tour starts	16	89
11. help visitors to not miss information when the owner points to exhibits	11	61
14. work with hearing impaired visitors who wear hearing aid and use lip-reading	11	61
17. help visitors to understand the shadow puppet show in the dark	9	50
21. work with pre-prepared speech from the owner to the visitors	10	56
24. work with spontaneous speech between the owner and the visitors	12	67
25. keep costs low by working with existing Wi-Fi and visitors' smartphones	16	89
28. work in Thai language	11	61
Mean	**12.2**	
Standard Deviation	**2.35**	

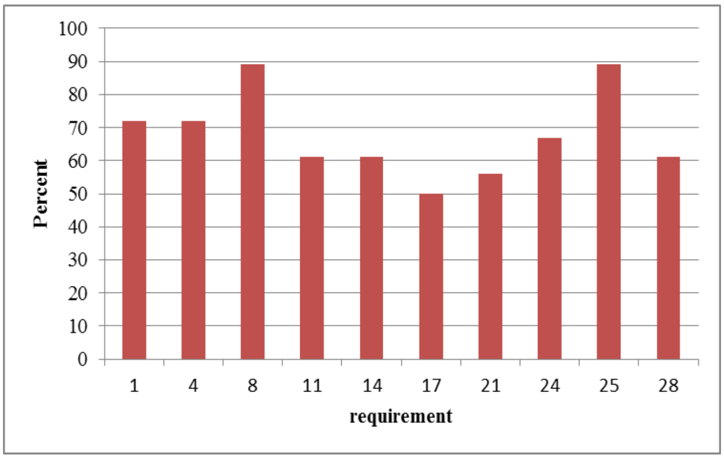


Figure 9-6 Percent of participants who selected the right answers in step 4

9.2.5 *Ratings following TEIF Method*

There were two questions from the questionnaire section which were related to the participants who used TEIF Method steps as follows:

Question 3: Were the TEIF Method steps explained clearly? If not, what was unclear?

Question 4: Did you find any steps of the TEIF Method difficult to carry out? If so, which ones, and in what way?

Those who had used the TEIF Method steps and the participants in the Other Methods group were asked to answer the questions 3 and 4. Note that the Other Methods group reviewed the TEIF Method steps but did not use the TEIF Method to address the tasks so any difference might be because they did not spend as much time understanding the details.

The question 3 was created in order to check whether the TEIF Method steps were explained clearly as if participants did not understand how to apply the TEIF Method then any findings might be due to this lack of understanding rather than the Method.

The question 4 was created in order to check whether the TEIF Method steps were difficult to carry out as if participants found some of the steps difficult it might mean they were unable to apply the method thoroughly in the time available.

An independent sample t-test was conducted in order to check whether the TEIF Method steps were explained clearly (question 3) and whether the TEIF Method steps were difficult to carry out (question 4). This tests that there was no significant difference in the rating between the TEIF Method group and the Other Methods group.

Table 9-11 shows mean ratings of questions 3 and 4 between the TEIF Method and the Other Methods. Approximately 83% of the TEIF Method group and 94% of the Other Methods group thought the TEIF Method was explained clearly. A mean of 1 would occur if 100% of the participants answered the question as ‘Yes’. If the mean rating of question 3 is close to 1, it means the TEIF Method steps were clear. If the mean rating of question 4 is close to 1, it means the TEIF Method steps were difficult.

Table 9-11 Mean rating of questions 3 and 4 between two methods groups

Question	Method	N	Mean	Std. Deviation	Std. Error Mean
Question 3	TEIF	18	.833	.383	.09
	Other	18	.944	.236	.056
Question 4	TEIF	18	.667	.485	.114
	Other	18	.944	.236	.056

Figure 9-7 shows the results of independent samples t-test of questions 3 and 4. There was no significant difference between the two groups for whether the TEIF Method was explained clearly. Only six participants commented on question 3 (five in the TEIF Method group, one in the Other Method group).

Participants' comments on question 3 were:

- 'For the first part, when asking about the presenter – audience / peer-peer interaction, it was not 100% clear if the scenario was the interview of the museum until I reread it.'
- 'It would have been better if an overview of the TEIF Method was presented before the participant gets down to actually performing the task'.
- Two participants commented on step 3 'it was unclear'.
- 'I needed an overview of the TEIF Method steps – are there 4? Or more? I did not understand how one step led to the next, how they related'.
- 'Confused me because I could not understand the purpose'.

There was a significant difference between the groups ($p<0.05$) as shown in Table 9-12 and illustrated in Figure 9-7 for whether any steps in the TEIF Method were difficult to carry out. Approximately 67% of the TEIF Method group and 94% of the Other Methods group found steps in the TEIF Method were difficult to carry out. Only six participants commented: six in the TEIF Method group, none in the Other Method group.

Participants' comments on question 4:

- Three participants agreed that step 3 was difficult to carry out.
- 'I would have preferred a single choice out of three (bad, moderate, good) rather than 0-10 in evaluation technology solutions task.'
- Selecting best ten requirements (step 2 of the TEIF Method) in evaluate requirements task.

Table 9-12 Independent samples t-test of questions 3 and 4 between two methods

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Question 3	Equal variances assumed	4.92	.033	-1.05	34	.302	-.111	.106	-.327	.104
Question 4	Equal variances assumed	29.6	p<.001	-2.19	34	.036	-.278	.127	-.536	-.019

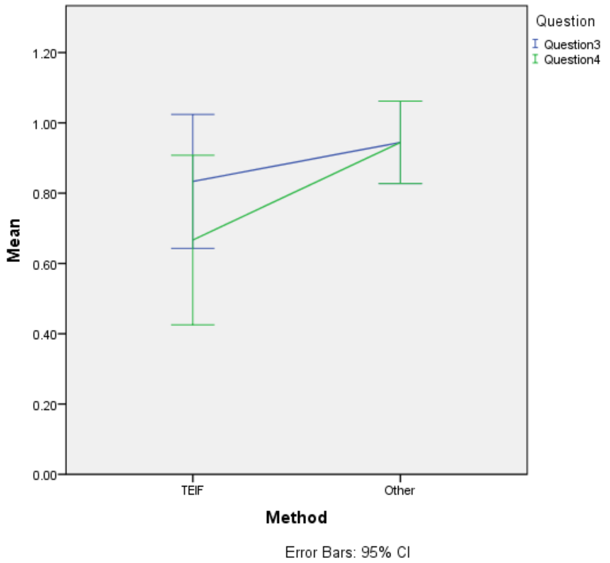


Figure 9-7 Profile graph of mean on question 3 and 4 between two methods

9.2.6 Summary of Evaluating TEIF Method Results

Three interaction types were selected correctly by 100 % of participants, whereas two interaction types were selected correctly by 94 % of participants. For the questions helping analyse how interactions are affected by hearing impairment one answer was selected correctly by only 28% and all other answers were selected correctly by over 67 % of participants. The best ten requirements for a technology solution that solves the disability related problems identified from the interview transcript were selected correctly by at least 67% of participants. When identifying possible technologies at least 72% of the participants provided correct answers for four requirements, at least 61% provided correct answers for another four requirements and at least 50% provided correct answers for the remaining two requirements. Approximately 67% of the TEIF Method group and 94% of the Other Methods group found some steps in the TEIF Method were difficult to carry out. While approximately 83% of the TEIF Method group and 94% of the Other Methods group thought the TEIF Method was explained clearly.

9.3 Task 1: Evaluate Requirements

The participants in both groups were asked to select the ten applicable requirements out of twenty-nine. The following sub research question was explored to help answer research question 3: Can developers use the TEIF Method to help with the software development process when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.1: Can developers use the TEIF Method to help with evaluating requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?

To explore this sub-research question, participants in both groups were asked to evaluate requirements. The participants in the TEIF Method were asked to do this evaluate requirement task after they completed the TEIF Method steps 1 and 2, whereas the participants in the Other Methods group were asked after they had read the interview transcript. An independent samples t-test was used to analyse the differences between using the TEIF Method and the Other Methods in evaluating requirements.

The mean numbers of correct applicable requirements was significantly higher ($p<0.001$) for participants using the TEIF Method (mean = 8.33) than the Other Methods (mean = 3.89) as shown in Table 9-13, Table 9-14, and illustrated in Figure 9-8.

Table 9-13 Mean numbers of correct applicable requirements for both methods

	Method	N	Mean	Std. Deviation	Std. Error Mean
evaluate requirements	TEIF	18	8.33	1.68	.396
	Other	18	3.89	1.68	.395

Table 9-14 Independent samples t-test for two methods

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Evaluate requirements	Equal variances assumed	137	.713	.944	34.0	p<.001	4.44	.559	3.31	5.58
	Equal variances not assumed			.944	34.0	p<.001	4.44	.559	3.31	5.58

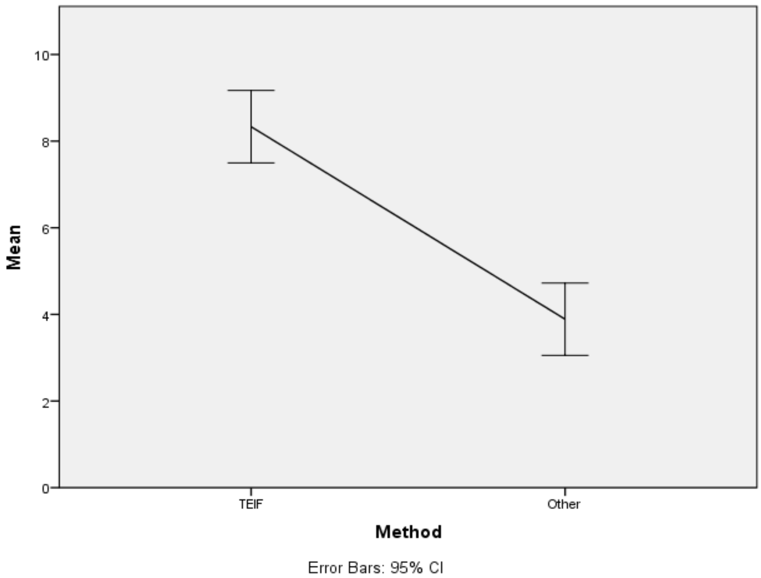


Figure 9-8 Profile graph of mean of the two methods

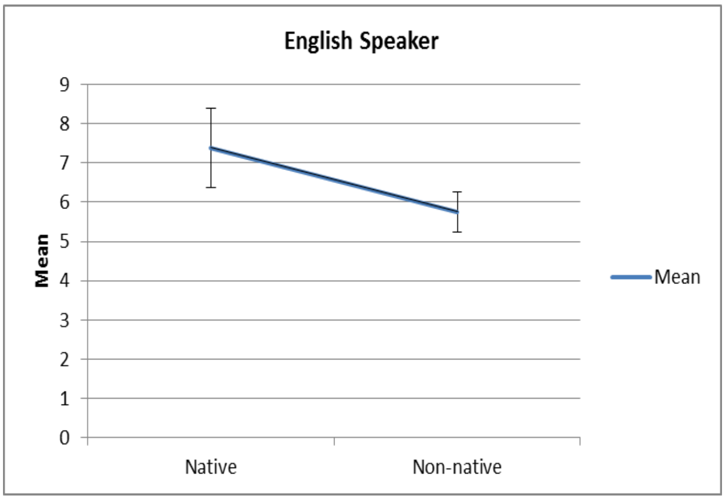
There was no significant difference between the mean ratings of the eight native English speakers and twenty-eight Non- native English speakers as shown in Table 9-15 and Table 9-16 and illustrated in Figure 9-9.

Table 9-15 Mean of native and non-native English speakers

	English_Speaker	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
Evaluate requirements	Native	8	7.38	2.83	.999
	non-native	28	5.75	2.73	.516

Table 9-16 Independent samples t-test of native and non-native English speakers

		Levene's Test for Equality of Variances		**t-test for Equality of Means**						
		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
Evaluate requirements	Equal variances assumed	.017	.897	1.47	34	.15	1.63	1.10	-.615	3.87



Error bars are ±1standard errors

Figure 9-9 Mean of evaluate requirements for two methods considering native and non-native English speakers

Table 9-17 shows and Figure 9-10 illustrates the number of people in each group selecting each correct requirement. The greatest number of participants in the TEIF Method group selecting a correct requirement was 17 participants for requirements 1, 4, 8, and 11, and the lowest number of participants in the TEIF Method group selecting a correct requirement was eight participants for requirement 25. The greatest number of participants in the Other Methods group selecting a correct requirement was 12 participants for requirement 1, and the lowest number of participants in the Other Method group selecting a correct requirement was three participants for requirements 24 and 28. More participants in the TEIF Method group selected each correct requirement than the Other Methods group.

Table 9-17 The number of people in each group selecting each correct requirement

Requirement	TEIF Method	Other Methods
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.	17	12
4. The technology solution should help hearing-impaired visitors understand conversation in background music.	17	8
8. The technology solution should help notify hearing impaired visitors when the tour starts.	17	10
11. The technology solution should help visitors to not miss information when the owner points to exhibits.	17	7
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.	15	11
17. The technology solution should help visitors to understand the shadow puppet show in the dark.	16	7
21. The technology solution should work with pre-prepared speech from the owner to the visitors.	16	5
24. The technology solution should work with spontaneous speech between the owner and the visitors.	13	3
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).	8	5
28. The technology solution should work with Thai language.	15	3

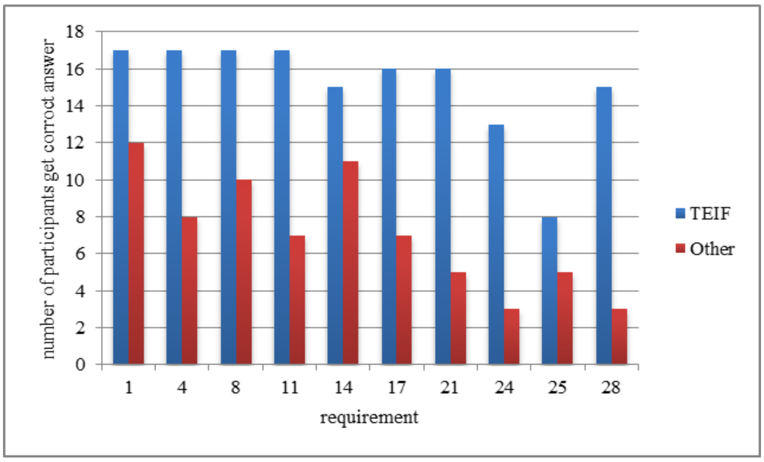


Figure 9-10 Profile graph of the number of people in each group selecting each correct requirement

Table 9-18 shows and Figure 9-11 illustrates the number of people in each group selecting each incorrect requirement. The greatest number of participants selecting an incorrect requirement in the TEIF Method group was nine participants for requirement 6. The lowest number of participants selecting an incorrect requirement in the TEIF Method group was zero participants for requirements 7, 9, 10, 13, 18, and 23. The greatest number of participants selecting an incorrect requirement in the Other Methods group was 17 participants for requirement 22. The lowest number of participants selecting an incorrect requirement in the Other Methods group was zero participants for requirements 9, 18, and 20. More participants in the TEIF Method group selected requirements 6 and 19 than in the Other Methods group. More participants in the Other Methods group selected requirements 2, 5, 7, 10, 12, 13, 15, 16, 20, 21, 26, 27, and 29.

Table 9-18 Number of people in each group selecting each incorrect requirement

Requirement	**TEIF Method**	**Other Methods**
2. The technology solution should help provide sign language for hearing impaired visitors	4	8
3. The technology solution should improve mobile phone signal for hearing impaired visitors	1	1
5. The technology solution should work with hearing impaired people who use sign language	2	3
6. The technology solution should enable hearing impaired visitors to ask the owner questions	9	5
7. The technology solution should help wheelchair users in the museum	0	1
9. The technology solution should help blind visitors to the museum	0	0
10. The technology solution should keep disabled visitors dry by not having to walk between buildings	0	10
12. The technology solution should help find parking facilities for disabled visitors	1	7
13. The technology solution should improve GPS reception for hearing impaired visitors	0	12
15. The technology solution should help the owner make more profit	1	5
16. The technology solution should improve catering for disabled visitors	1	7
18. The technology solution should help hearing impaired visitor's friends email them to discuss the shadow puppet museum	0	0
19. The technology solution should improve Wi-Fi facilities for hearing impaired visitors	1	0
20. The technology solution should reduce costs of shadow puppet souvenirs for disabled visitors	2	7
22. The technology solution should improve toilet facilities for disabled visitors	2	17
23. The technology solution should help find nearest toilet facilities for disabled visitors	0	3
26. The technology solution should improve parking facilities for disabled visitors	2	12
27. help find nearest food outlet for disabled visitors	1	8
29. help hearing impaired visitors email friends to discuss the shadow puppet museum	2	3

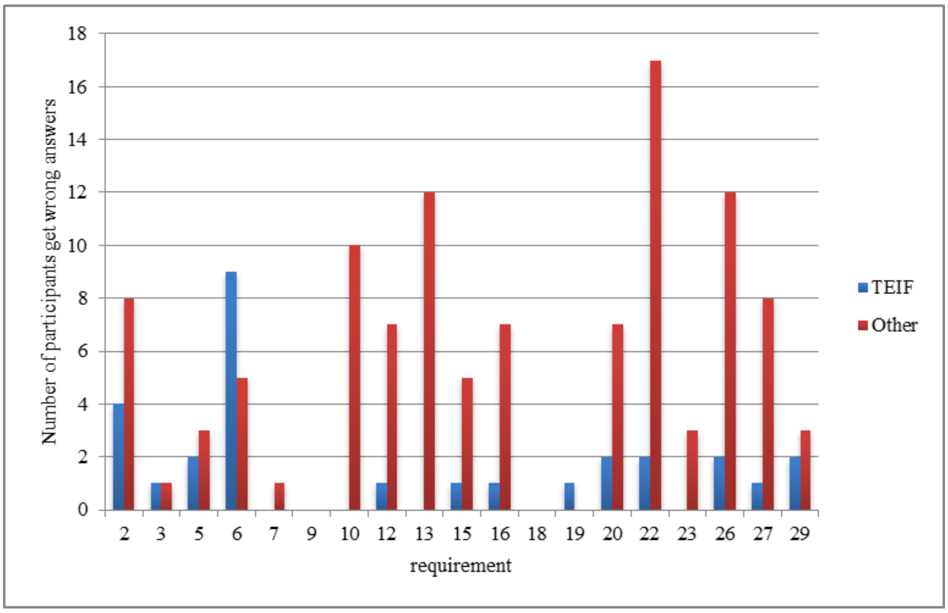


Figure 9-11 Profile graph of the number of people in each group selecting each incorrect requirement

9.3.1 Summary of Task 1: Evaluate Requirements

The mean numbers of correct applicable requirements was significantly higher for participants using the TEIF Method than the Other Methods. There was no significant difference between the mean ratings of the eight native English speakers and twenty-eight non- native English speakers. More participants in the TEIF Method group selected each correct requirement than the Other Methods group. The incorrect requirement selected by the greatest number of participants in the TEIF Method group was requirement 6. Six of the incorrect requirements were selected by none of the TEIF Method group. The incorrect requirement selected by the greatest number of participants in the Other Methods group was requirement 22. Three of the incorrect requirements were selected by none of the Other Methods group.

9.4 Task 2: Evaluate Technology Solutions

The following sub research question was explored to help answer research question 3.

Sub research question 3.2: Can developers use the TEIF Method to help with *evaluating technology solutions* when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.2 was explored using three different approaches:

a. whether the TEIF Method helped developers select the best technology solution(s) more often than the Other Methods? (section 9.4.2)
b. whether the TEIF Method helped developers rate technology solutions closer to the experts' ratings than the Other Methods? (section 9.4.3)
c. whether the TEIF Method helped rate differences (measures amount and direction) between technology solutions closer to experts' difference scores than the Other Methods? The measure amount indicates the closeness to the expert ratings. 'Differential' is the difference between two solutions in terms of the amount and direction of their ratings. The measure direction indicates whether the participant differential is in the same direction as the expert differential (section 9.4.3).

To explore this research question the participants in both groups were asked to complete the evaluate technology solutions task by giving ratings from 0 to 10 for how well each of three different technology solutions met each of ten requirements. Participants were asked to rate the solutions in the different orders explained in section 8.13.

The participants in the TEIF Method group were asked to do the task after they had completed the TEIF Method steps 3 and 4, whereas the participants in the Other Methods group were asked after they had finished the evaluate requirements task (section 8.13).

The mean ratings of participants of the two groups will be presented in section 9.4.2 in order to show the actual mean ratings before comparing to the expert ratings.

9.4.1 Ratings of experts

Table 9-19 shows the ratings of experts for each of the ten requirements used in the evaluate technology solution task and each of the three technology solutions A, B, and C, and the differential ratings between the three pairs of solutions A-B, A-C, and B-C.

Table 9-19 Experts' rating of technology solutions and differential between technology solution pairs

Requirement	**Solution**			**Differential**		
	A	**B**	**C**	**A-B**	**A-C**	**B-C**
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.	9	6	5	3	4	1
4. The technology solution should help hearing-impaired visitors understand conversation in background music.	8	6	6	2	2	0
8. The technology solution should help notify hearing impaired visitors when the tour starts.	10	0	10	10	0	-10
11. The technology solution should help visitors to not miss information when the owner points to exhibits.	7	6	7	1	0	-1
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.	9	6	6	3	3	0
17. The technology solution should help visitors to understand the shadow puppet show in the dark.	9	6	6	3	3	0
21. The technology solution should work with pre-prepared speech from the owner to the visitors.	9	6	7	3	2	-1
24. The technology solution should work with spontaneous speech between the owner and the visitors.	9	0	0	9	9	0
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).	9	9	4	0	5	5
28. The technology solution should work with Thai language.	10	10	10	0	0	0
Average	**8.9**	**5.5**	**6.1**	**3.4**	**2.8**	**-0.6**

Table 9-20 shows the number of requirements rated by experts at each scale point for each solution. Figure 9-12 and Figure 9-13 illustrate the technology solution ratings while Figure 9-14 illustrates the differential ratings.

Solution A is rated higher than solution B for all requirements apart from 25 and 28 for which the ratings are the same for solutions A and B.

Solution A is rated higher than solution C for all requirements apart from 8, 11, and 28 for which the ratings are the same for solutions A and C.

Solution C is rated higher than solution B for requirements apart from 8, 11, and 21, lower than solution B for requirements 1 and 25 and rated the same as solution B for requirements 4, 14, 17, 24, and 28.

The mean rating for solution A is 3.4 higher than for B and 2.8 higher than for C. The differential A-B is the highest for requirement 8 and lowest for requirements 25 and 28.

The differential A-C is the highest for requirement 24 and lowest for requirements 8 and 11.

The differential B-C is the highest for requirement 25 and the lowest for requirement 8.

Differentials are zero for:

- A-B for requirements 25 and 28
- A-C for requirements 8 and 11
- B-C for requirements 4, 14, 17, 24, and 28

Table 9-20 Number of requirements rated by experts at each scale point for each solution

Rating	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Solution A	2	6	1	1	0	0	0	0	0	0	0
Solution B	1	1	0	0	6	0	0	0	0	0	2
Solution C	2	0	0	2	3	1	1	0	0	-	1

Figure 9-12 illustrates experts' rating of technology solutions for each requirement. Figure 9-13 illustrates experts' rating of requirements for each solution. Figure 9-14 illustrates Experts' rating of differential A-B, A-C, and B-C for each requirement.

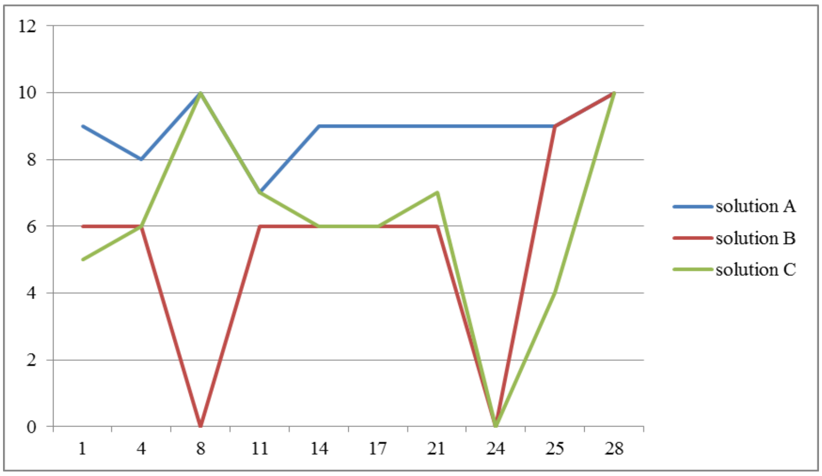


Figure 9-12 Experts' rating of technology solutions on requirements

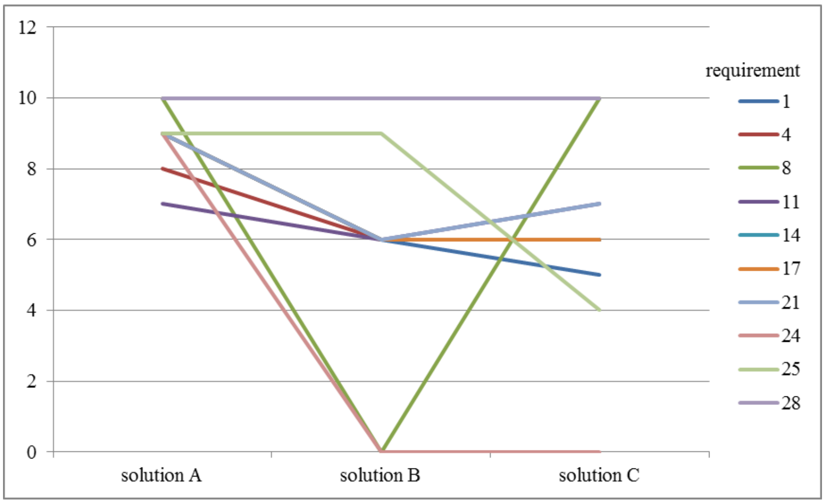


Figure 9-13 Experts' rating of requirements on solutions

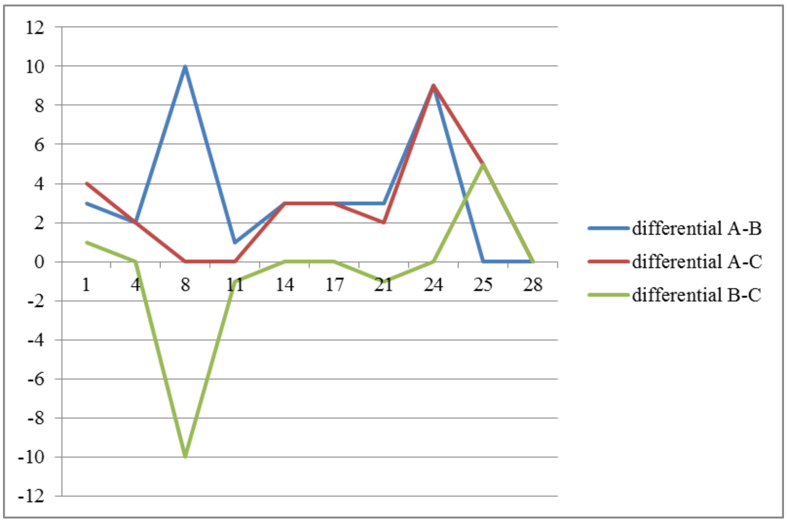


Figure 9-14 Experts' rating of differential A-B, A-C, and B-C on requirements

9.4.2 Participants selecting the best technology solution(s) as selected by experts

In order to explore whether the TEIF Method helped developers select the best technology solution(s) more often than the Other Methods (sub research question 3.2 approach A), the number of times the participants selected the same technology solution(s) as selected by the experts, was analysed using the paired t-test and the chi-square test. The paired t-test analyses if one method selects the best solution significantly more than the other method and the chi-square test analyses whether the pattern of selection of best solution for each requirement is significantly different for each method.

The number of participants using the TEIF Method and the Other Methods rating the same best solution(s) as experts were counted for each requirement (Table 9-21 and Figure 9-15). If experts rated one solution higher than the other two solutions then participants also had to rate that solution higher than the other two solutions to be counted (e.g. solution A for requirement 1 in Table 9-21). If experts rated two solutions equally higher than the third solution then participants also had to rate those two solutions equally higher than the third solution to be counted (e.g. solutions A = C for requirement 8 in Table 9-21). If experts rated all three solutions equally then participants also had to rate all three solutions equally to be counted (e.g. solutions A = B = C for requirement 28 in Table 9-21). These strict criteria are shown in

Table 9-22. The total number of participants rating the same solution(s) as experts as best for the TEIF Method and the Other Methods, and the total number of participants not rating the same solution(s) as experts as best for the TEIF Method and the Other Methods were counted and the expected values calculated from the row and column totals shown in Table 9-21.

The paired t test result was not significant (Table 9-23) and therefore although participants using the TEIF Method rated the same solution(s) as experts as best more times than participants using the Other Methods (69 times compared to 63 times, Table 9-21) this was not a significant difference.

As 25% cells have expected count less than five a continuity correction (Roscoe, 1975) was used in the calculation of chi-square by subtracting 0.5 from the absolute value of the observed minus expected counts as shown in Table 9-24, and the chi-square test applied using the corrected mean square differences shown in Table 9-25.

The chi-square statistic was calculated a = 2.46, with as p value = 0.97 (p >.005) as shown in Table 9-26. Therefore the chi-square test found no significant difference between the methods for the pattern of best solution for each requirement.

Table 9-21 Count of numbers of participants rating same solution(s) as experts as the best

Requirements	**Number of observed number of participants using TEIF method rating same best solution(s) as experts**	**Number of observed number of participants using Other Methods rating same best solution(s) as experts**	**Row totals**	**Solution(s) rated as best by experts**
Requirement 1	7	4	11	A
Requirement 4	6	7	13	A
Requirement 8	9	12	21	A=C
Requirement 11	4	2	6	C
Requirement 14	4	1	5	A
Requirement 17	8	5	13	A
Requirement 21	6	4	10	A
Requirement 24	9	9	18	A
Requirement 25	6	10	16	A=B
Requirement 28	10	9	19	A=B=C
Column total	**69**	**63**	**132**	

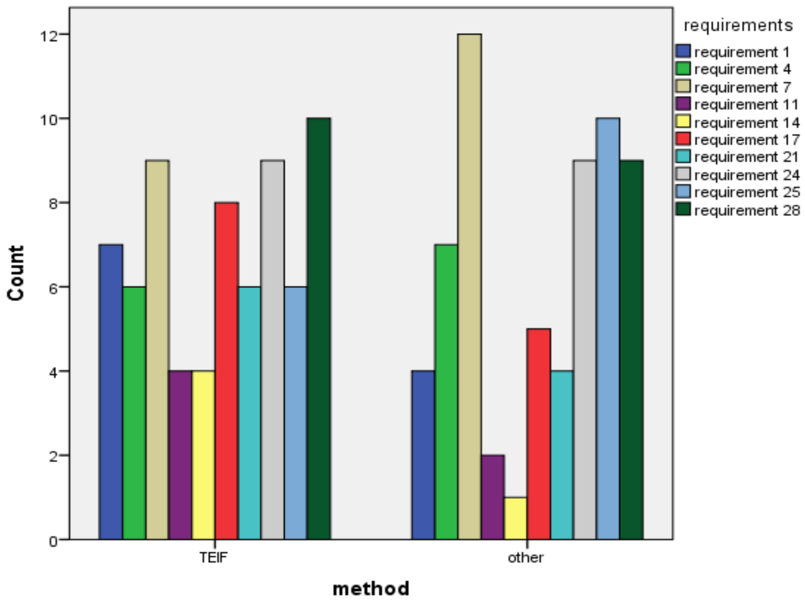


Figure 9-15 Profile graph of number of participants rating the same design solution(s) as experts as the best solution(s) for each method and requirement

Table 9-22 Strict criteria for selecting the exclusive best

Expert ratings	Participant ratings accepted as selecting the best
A has exclusive highest rating (i.e. A>B>C or A>C>B or A>B=C).	A has exclusive highest rating (i.e. A>B>C or A>B=C or A>C>B).
A has joint highest rating with B (i.e. A=B>C).	A has joint highest rating with B (i.e. A=B>C).
A has joint highest rating with C (i.e. A=C>B).	A has joint highest rating with C (i.e. A=C>B).
A has joint highest rating with B & C (i.e. A=B=C).	A has joint highest rating with B & C (i.e. A=B=C).

Table 9-23 Paired t test of participants rating same solution(s) as experts as the best

Paired t-test results	0.48

Table 9-24 Expected values of chi-square

Requirements	Expected Number of participants using TEIF Method rating same best solution(s) as experts	Expected Number of participants using Other Methods rating same best solution(s) as experts
Requirement 1	5.75	5.25
Requirement 4	6.80	6.21
Requirement 8	10.98	10.02
Requirement 11	3.14	2.86
Requirement 14	2.61	2.39
Requirement 17	6.80	6.21
Requirement 21	5.23	4.77
Requirement 24	9.41	8.59
Requirement 25	8.36	7.64
Requirement 28	9.93	9.07
Requirement 28	9.93	9.07

Table 9-25 Corrected mean square differences of chi-square

Requirements	TEIF Method	Other Methods
Requirement 1	.098	.107
Requirement 4	.013	.014
Requirement 8	.199	.218
Requirement 11	.042	.046
Requirement 14	.301	.329
Requirement 17	.073	.08
Requirement 21	.014	.015
Requirement 24	.001	.001
Requirement 25	.415	.455
Requirement 28	.019	.021

Table 9-26 Chi-square test

p value	0.97
chi-square	2.46

A less strict criteria for selecting the best solution than the strict criteria of having to choose exactly the same joint best as the experts was for at least one solution rated highest or equally highest by the experts to also be rated as highest or equally highest by the participant. Another way of stating this is that the participant must select as the best or joint best solution, at least one solution that was not worse than at least one solution rated best or joint best by the experts. An example of these less strict criteria for participant ratings accepted when experts rated 'solution A' highest or joint highest is shown in Table 9-27. Using these criteria the number of participants selecting the same best solution as the experts for each method and requirement is shown in Table 9-28 and the results of the paired t-test in Table 9-29.

The paired t-test showed that the TEIF Method helped them select as the best or joint best solution, at least one solution that was not worse than at least one solution rated best or joint best by the experts significantly more often than the Other Methods.

Table 9-27 Example of participant ratings accepted using less strict criteria

Expert ratings	**Participant ratings accepted as selecting the best**
A>B>C or A>C>B or A>B=C (i.e. A has exclusive highest rating)	A>B>C, A>C>B, A>B=C, A=B>C, A=B=C, A=C>B (i.e. no solution has a higher rating than A)
A=B>C (i.e. A has joint highest rating with B)	A>B>C,A>C>B,A>B=C ,A=B>C,A=B=C, A=C>B, B>A>C, B>C>A, (i.e. Either A or B is rated higher than C)
A=C>B (i.e. A has joint highest rating with C)	A>B>C, A>C>B, A>B=C, A=C>B, A=B=C, A=C>B C>A>B, C>B>A, (i.e. Either A or C is rated higher than B)
A=B=C (i.e. A has joint highest rating with B & C)	Any ratings

Table 9-28 Less strict criteria for selecting best no worse than experts

Requirement	**TEIF Method not worse than experts**	**Other Methods not worse than experts**
1	14	13
4	14	13
8	18	18
11	16	12
14	12	6
17	13	10
21	17	14
24	14	14
25	18	15
28	18	18

Table 9-29 Paired t-test result of less strict criteria for selecting a best no worse than experts

P value	0.01

One issue with these less strict criteria was accepting when the participant's solution rated lowest was the same as the experts' solution rated highest: for example, when the experts ratings were A=B>C and participant's ratings were B>C>A or

A=C>B. A slightly stricter criteria to remove this possibility was to ensure that no solution rated lowest by the participant was rated highest by the experts. If all the solutions are rated equally no solution is considered as rated lowest or highest. These slightly stricter criteria are shown in Table 9-30. Using these criteria the number of participants selecting the same best solution as the experts for each method and requirement is shown in Table 9-31 and the results of the paired t-test in Table 9-32. The paired t-test result was not significant (Table 9-32).

Table 9-30 Example of no solution rated lowest by the participant rated highest by the experts

Expert ratings	**Participant ratings accepted as selecting the best**
A has exclusive highest rating (i.e. A>B>C).	A is rated higher than C and A has highest rating or joint highest with B (i.e. A>B>C, A>C>B, A>B=C, A=B>C).
A has exclusive highest rating (i.e. A>C>B).	A is rated higher than B and A has highest rating or joint highest with C (i.e. A>B>C, A>C>B, A>B=C, A=C>B).
A has exclusive highest rating (i.e. A>B=C).	A is rated higher than both B & C (i.e. A>B=C A>B>C, A>C>B).
A has joint highest rating with B (i.e. A=B>C).	Both A and B are rated higher than C (i.e. A=B>C, A>B>C, B>A>C).
A has joint highest rating with C (i.e. A=C>B).	Both A and C are rated higher than B (i.e. A=C>B, A>C>B, ,C>A>B).
A has joint highest rating with B & C (i.e. A=B=C)	Any ratings

Table 9-31 Count of no solution rated lowest by the participant rated highest by the experts

Requirement	**TEIF Method lowest not experts' highest**	**Other Methods lowest not experts' highest**
1	7	4
4	7	7
8	16	16
11	6	4
14	4	1
17	8	5
21	6	4
24	8	9
25	9	11
28	18	18

Table 9-32 Paired t test results for count of no solution rated lowest by the participant rated highest by the experts

P value	0.12

9.4.2.1 Summary of Task 2: Evaluate Technology Solutions

Participants using the TEIF Method rated the same solution(s) as experts as best significantly more times than participants using the Other Methods when analysing the results using the least strict criteria of selecting as the best or joint best solution, at least one solution that was not worse than at least one solution rated best or joint best by the experts. The difference between methods was not significant using the stricter criteria of not accepting a solution rated lowest by the participants if it was rated highest by the experts or the strictest criteria of requiring participants to select the same highest or joint highest solutions as the experts.

The chi-square test found no significant difference between the methods for the pattern of best solution for each requirement.

9.4.3 Ratings of Technology Solutions Compared to Expert Ratings

Exploring whether the TEIF Method helped developers rate technology solutions closer to the experts' ratings than the Other Methods, involved analysing the ratings of both the TEIF Method and the Other Methods groups to see if there was any differences between the methods (section 9.4.3.1), and then comparing the ratings of the two groups with the expert ratings (section 9.4.3.2).

9.4.3.1 Analysis of Mean Rating Differences between Methods

To help explore the sub research question 3.2 whether the TEIF Method helps evaluate technology solutions for problems involving interaction with hearing impaired people better than the Other Methods, the mean ratings for the TEIF Method and the Other Methods were analysed to see if they were similar or different.

A three way repeated measures analysis of variance with two within subjects factors (*solution* and *requirement*) and one between subjects factor (*method*) was carried out on the differences for the participants' ratings between the TEIF Method and the Other Methods for each of ten requirements and three solutions.

This tests the significance of the differences between the participants' ratings for the TEIF Method and the Other Methods for each of ten requirements and three solutions.

The ten requirements were 1, 4, 8, 11, 14, 17, 21, 24, 25, and 28 from the actual of twenty-nine requirements.

Table 9-33 shows the results of Mauchly's sphericity test for each of three effects. The significance values of these tests indicate that both the main effects and the interaction effect have violated this assumption. The lower-bound significance value is used because it is the most conservative significance value (Field, 2013).

Table 9-33 Mauchly's test of sphericity of the third-order interaction effects of *requirement*solution*method*

Within Subjects Effect	**Mauchly's W**	**Approx. Chi-Square**	**df**	**Sig.**	**Epsilon[b]**		
					Greenhouse-Geisser	**Huynh-Feldt**	**Lower-bound**
Requirement	.086	75.4	4	.003	.609	.762	.111
Solution	.633	15.1	2	.001	.731	.778	.5
Requirement * Solution	.000	309	70	p<.001	.513	.741	.056

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: requirements + solutions + requirements * solutions
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

The result of the third-order interaction effects of *requirement*solution*method* was not significant as shown in Table 9-34.. The second-order interaction effects between *solution*method* ($p< 0.05$) and *requirement*solution* ($p = 0.001 < 0.01$) were significant, whereas the second-order interaction effect of *requirement*method* was not significant. This indicates that the mean ratings of *method* depend on *solution* and the mean ratings of *solution* depend on the *method* used. Moreover, the mean ratings of *requirement* depend on *solution* and the mean ratings of *solution* depend on *requirement*, and the mean ratings of *requirement* depend on *method* and the mean ratings of *method* depend on the *requirement*.

Therefore although the main effects of *solution* and *requirement* were significant, they were not considered further, as they were involved in significant second-order interaction effects. The main effect of *method* was not significant (Table 9-35) but is not considered further as it was involved in a significant second-order interaction effect.

Table 9-34 Tests of within-subjects effects of the third-order interaction effects of *requirement*solution*method*

Source		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement	Sphericity Assumed	985	9	109.5	12	p<.001
	Greenhouse-Geisser	985	5.49	180	12	p<.001
	Huynh-Feldt	985	6.85	144	12	p<.001
	Lower-bound	985	1	985	12	0.001
Requirement*method	Sphericity Assumed	67.3	9	7.48	0.82	0.6
	Greenhouse-Geisser	67.3	5.49	12.3	0.82	0.55
	Huynh-Feldt	67.3	6.85	9.82	0.82	0.57
	Lower-bound	67.3	1	67.3	0.82	0.37
Solution	Sphericity Assumed	700	2	350	31	p<.001
	Greenhouse-Geisser	700	1.46	478	31	p<.001
	Huynh-Feldt	700	1.56	449	31	p<.001
	Lower-bound	700	1	700	31	p<.001
Solution*method	Sphericity Assumed	157	2	78.5	6.96	0.002
	Greenhouse-Geisser	157	1.46	107.3	6.96	0.005
	Huynh-Feldt	157	1.56	101	6.96	0.004
	Lower-bound	157	1	156.9	6.96	0.012
Requirement*solution	Sphericity Assumed	1178	18	65.4	14.6	p<.001
	Greenhouse-Geisser	1178	9.23	128	14.6	p<.001
	Huynh-Feldt	1178	13.34	88.3	14.6	p<.001
	Lower-bound	1178	1	1178	14.6	0.001
Requirement * solution* method	Sphericity Assumed	21.7	18	1.21	0.27	0.999
	Greenhouse-Geisser	21.7	9.23	2.35	0.27	0.984
	Huynh-Feldt	21.7	13.3	1.63	0.27	0.996
	Lower-bound	21.7	1	21.7	0.27	0.607

Table 9-35 Tests of between-subjects effects of the third-order interaction effects of *requirement*solution*method*

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	1679	1	1679	2277	p<.001
Methods	.296	1	.296	.402	.53
error	25.1	34	.737		

As shown in Table 9-34, two second-order interaction effects were significant. Therefore, tests of simple main effects were undertaken.

The following syntax '/EMMEANS' (IBM, 2001) was used to test simple main effects:

/EMMEANS=TABLES(Requirement*Solution)
COMPARE(Requirement)ADJ(sidak)

/EMMEANS=TABLES(Requirement*Solution)

COMPARE(Solution)ADJ(sidak) /EMMEANS=TABLES(Method*Solution)

COMPARE(Solution) ADJ(sidak)

/EMMEANS=TABLES(Method*Solution) COMPARE(Method) ADJ(sidak)

*1) Marginal means ratings for requirement * solution*

Table 9-36 shows the marginal mean ratings over all methods for ten requirements for three solutions with the associated standard errors.

Table 9-36 Marginal mean ratings of *requirement*solution*

Requirement	**Solution**	**Mean**	**Std. Error**	**95% Confidence Interval**	
				Lower Bound	**Upper Bound**
1	A	8.33	0.26	7.81	8.86
	B	6.86	0.446	5.96	7.77
	C	7.08	0.382	6.31	7.86
4	A	7.5	0.394	6.7	8.3
	B	5.69	0.51	4.66	6.73
	C	6.53	0.436	5.64	7.41
8	A	9.17	0.192	8.78	9.56
	B	1.56	0.49	0.56	2.55
	C	8.08	0.367	7.34	8.83
11	A	7.56	0.348	6.85	8.26
	B	7.22	0.401	6.41	8.04
	C	7.11	0.433	6.23	7.99
14	A	6.75	0.468	5.80	7.7
	B	6.06	0.562	4.91	7.2
	C	6.72	0.478	5.75	7.7
17	A	7.22	0.407	6.40	8.05
	B	5.25	0.53	4.17	6.33
	C	6.31	0.45	5.39	7.22
21	A	8.64	0.31	8.01	9.27
	B	6.75	0.582	5.57	7.93
	C	7.86	0.402	7.05	8.68
24	A	6.92	0.478	5.95	7.89
	B	3.67	0.576	2.50	4.84
	C	3.39	0.491	2.39	4.39
25	A	8.36	0.311	7.73	8.99
	B	7.81	0.367	7.06	8.55
	C	5.86	0.494	4.86	6.86
28	A	8.17	0.443	7.27	9.07
	B	8.11	0.473	7.15	9.07
	C	8.36	0.399	7.55	9.17

2) Simple main effects of solution at each level of requirement

Table 9-37 shows the multivariate tests of simple main effects of solutions at each level of requirements. There was a significant simple main effect of solutions for requirements 1, 4, 8, 17, 21, 24, and 25.

Table 9-37 Multivariate tests of simple effects of *solution* at each level of *requirement*

Requirement		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
1	Pillai's trace	0.249	5.48[a]	2	33	0.009
	Wilks' lambda	0.751	5.48[a]	2	33	0.009
	Hotelling's trace	0.332	5.48[a]	2	33	0.009
	Roy's largest root	0.332	5.48[a]	2	33	0.009
4	Pillai's trace	0.321	7.79[a]	2	33	0.002
	Wilks' lambda	0.679	7.79[a]	2	33	0.002
	Hotelling's trace	0.472	7.79[a]	2	33	0.002
	Roy's largest root	0.472	7.79[a]	2	33	0.002
8	Pillai's trace	0.872	112[a]	2	33	$p < .001$
	Wilks' lambda	0.128	112[a]	2	33	$p < .001$
	Hotelling's trace	6.79	112[a]	2	33	$p < .001$
	Roy's largest root	6.79	112[a]	2	33	$p < .001$
11	Pillai's trace	0.023	.386[a]	2	33	0.683
	Wilks' lambda	0.977	.386[a]	2	33	0.683
	Hotelling's trace	0.023	.386[a]	2	33	0.683
	Roy's largest root	0.023	.386[a]	2	33	0.683
14	Pillai's trace	0.031	.519[a]	2	33	0.6
	Wilks' lambda	0.969	.519[a]	2	33	0.6
	Hotelling's trace	0.031	.519[a]	2	33	0.6
	Roy's largest root	0.031	.519[a]	2	33	0.6
17	Pillai's trace	0.259	5.78[a]	2	33	0.007
	Wilks' lambda	0.741	5.78[a]	2	33	0.007
	Hotelling's trace	0.35	5.78[a]	2	33	0.007
	Roy's largest root	0.35	5.78[a]	2	33	0.007
21	Pillai's trace	0.347	8.75[a]	2	33	0.001
	Wilks' lambda	0.653	8.75[a]	2	33	0.001
	Hotelling's trace	0.53	8.75[a]	2	33	0.001
	Roy's largest root	0.53	8.75[a]	2	33	0.001
24	Pillai's trace	0.443	13.1[a]	2	33	$p < .001$
	Wilks' lambda	0.557	13.1[a]	2	33	$p < .001$
	Hotelling's trace	0.796	13.1[a]	2	33	$p < .001$
	Roy's largest root	0.796	13.1[a]	2	33	$p < .001$
25	Pillai's trace	0.412	11.6[a]	2	33	$p < .001$
	Wilks' lambda	0.588	11.6[a]	2	33	$p < .001$
	Hotelling's trace	0.701	11.6[a]	2	33	$p < .001$
	Roy's largest root	0.701	11.6[a]	2	33	$p < .001$
28	Pillai's trace	0.006	.107[a]	2	33	0.899
	Wilks' lambda	0.994	.107[a]	2	33	0.899
	Hotelling's trace	0.007	.107[a]	2	33	0.899
	Roy's largest root	0.007	.107[a]	2	33	0.899

Each F tests the multivariate simple effects of solutions within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

Therefore, the pairwise comparisons of these solutions at each of these requirements were undertaken. Table 9-38 shows the results of pairwise comparison of simple main effects of *solution* at each level of *requirement*. There were significant differences between mean ratings for:

- requirement 1 between solutions A and B, and A and C
- requirement 4 between solutions A and B, and A and C
- requirement 8 between solutions A and B, A and C, and B and C
- requirement 17 between solutions A and B, and A and C
- requirement 21 between solutions A and B, and A and C
- requirement 24 between solutions A and B, and A and C

- requirement 25 between solutions A and C, and B and C

There was no significant difference between mean ratings for:

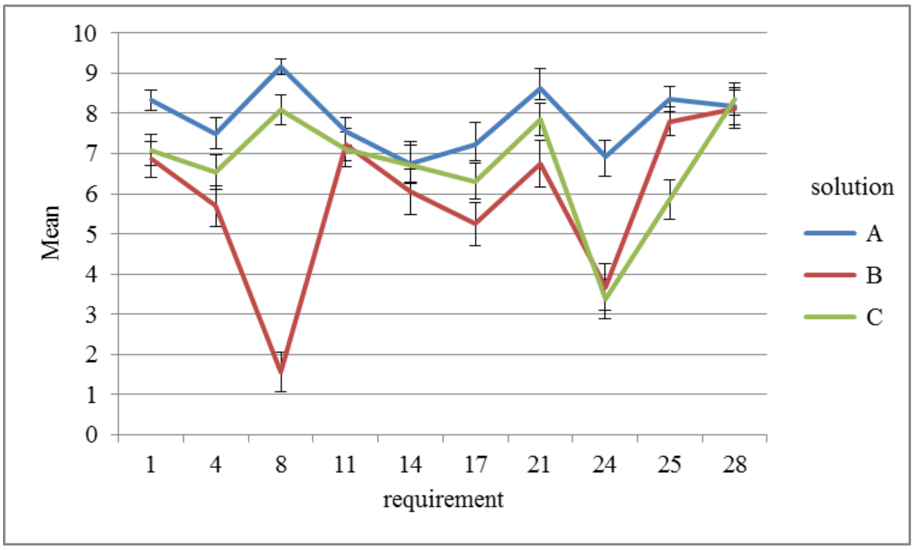
- requirement 1 between solutions B and C
- requirement 4 between solutions B and C
- requirement 11 between solutions A and B, A and C, and B and C
- requirement 14 between solutions A and B, A and C, and B and C
- requirement 17 between solutions B and C
- requirement 21 between solutions B and C
- requirement 24 between solutions B and C
- requirement 25 between solutions A and B
- requirement 28 between solutions A and B, A and C, and B and C

Table 9-38 Pairwise comparisons of simple main effects of *solution* at each level of *requirement*

Requirement	**(I) solutions**	**(J) solutions**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence Interval for Difference[b]**	
						Lower Bound	**Upper Bound**
1	A	B	1.47*	0.522	0.024	0.161	2.78
		C	1.25*	0.421	0.016	0.193	2.31
	B	C	-0.222	0.485	0.957	-1.44	0.997
4	A	B	1.81*	0.493	0.003	0.567	3.04
		C	.972*	0.334	0.019	0.134	1.81
	B	C	-0.833	0.477	0.246	-2.03	0.365
8	A	B	7.61*	0.545	p<.001	6.24	8.98
		C	1.08*	0.339	0.009	0.233	1.93
	B	C	-6.53*	0.695	p<.001	-8.27	-4.78
11	A	B	0.333	0.539	0.903	-1.02	1.69
		C	0.444	0.511	0.774	-0.84	1.73
	B	C	0.111	0.518	0.995	-1.19	1.41
14	A	B	0.694	0.68	0.677	-1.01	2.40
		C	0.028	0.448	1	-1.10	1.15
	B	C	-0.667	0.729	0.746	-2.50	1.16
17	A	B	1.97*	0.603	0.007	0.458	3.49
		C	.917*	0.327	0.024	0.097	1.74
	B	C	-1.056	0.489	0.11	-2.28	0.173
21	A	B	1.89*	0.639	0.017	0.284	3.49
		C	.778*	0.243	0.009	0.168	1.39
	B	C	-1.111	0.672	0.288	-2.80	0.575
24	A	B	3.25*	0.674	p<.001	1.56	4.94
		C	3.53*	0.725	p<.001	1.71	5.35
	B	C	0.278	0.512	0.932	-1.01	1.57
25	A	B	0.556	0.388	0.409	-0.418	1.53
		C	2.50*	0.514	p<.001	1.21	3.79
	B	C	1.94*	0.578	0.006	0.494	3.40
28	A	B	0.056	0.467	0.999	-1.12	1.23
		C	-0.194	0.529	0.977	-1.52	1.13
	B	C	-0.25	0.545	0.957	-1.62	1.12

*. The mean difference is significant at the .05 level.

Figure 9-16 illustrates these simple main effects of *solution* at each level of *requirement*. It may be seen, for example, that the mean rating of requirement 8 was the highest rating score for solution A, whereas it was the lowest for solution B. These ratings are significantly different as shown in Table 9-39.



Error bars are ±1standard errors

Figure 9-16 Profile graph of simple main effects of *solution* at each level of *requirement*

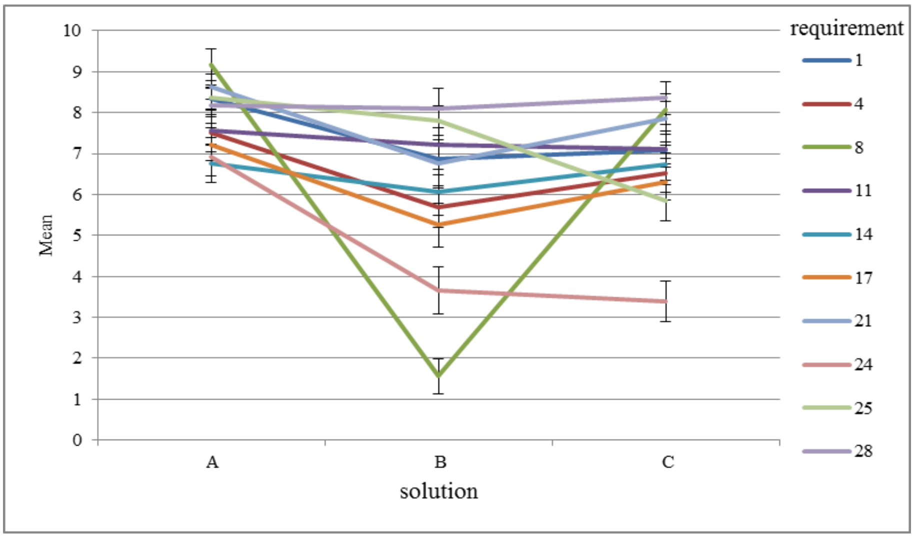
3) *Simple main effects of requirement at each level of solution*

Table 9-39 shows the multivariate tests of simple main effects of *requirement* within each level of three solutions. There was a significant simple main effect of *requirement* for solution A ($p = 0.001 < 0.01$), B ($p < 0.001$), and C ($p < 0.001$). Figure 9-17 illustrates these simple main effects.

Table 9-39 Multivariate tests of simple main effects of *requirement* of each level of *method*

Solution		Value	F	Hypothesis df	Error df	Sig.
A	Pillai's trace	0.638	5.01[a]	9	26	0.001
	Wilks' lambda	0.362	5.01[a]	9	26	0.001
	Hotelling's trace	1.77	5.01[a]	9	26	0.001
	Roy's largest root	1.77	5.01[a]	9	26	0.001
B	Pillai's trace	0.844	15.6[a]	9	26	p < .001
	Wilks' lambda	0.156	15.6[a]	9	26	p < .001
	Hotelling's trace	5.41	15.6[a]	9	26	p < .001
	Roy's largest root	5.41	15.6[a]	9	26	p < .001
C	Pillai's trace	0.752	8.78[a]	9	26	p < .001
	Wilks' lambda	0.248	8.78[a]	9	26	p < .001
	Hotelling's trace	3.04	8.78[a]	9	26	p < .001
	Roy's largest root	3.04	8.78[a]	9	26	p < .001

Each F tests the multivariate simple effects of requirements within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic



Error bars are ±1standard errors

Figure 9-17 Profile graph of the simple main effects of *requirement* at each level of *solution*

Therefore, the pairwise comparisons of these solutions at each of these requirements were undertaken. Table 9-40 shows that there was a significant difference between requirements 4 and 8, 8 and 11, 8 and 14, 8 and 17, 8 and 24, and 17 and 21 for solution A. However, there was no significant difference between requirements 1, 11, 14, 24, and 25 for solution A.

Table 9-40 Pairwise comparisons of main effects of requirements for solution A

Solution	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
						Lower Bound	Upper Bound
A	1	4	0.833	0.501	0.993	-0.947	2.61
		8	-0.833	0.303	0.347	-1.91	0.243
		11	0.778	0.461	0.991	-0.859	2.42
		14	1.583	0.547	0.258	-0.362	3.53
		17	1.11	0.44	0.523	-0.451	2.67
		21	-0.306	0.389	1.00	-1.69	1.08
		24	1.42	0.492	0.267	-0.333	3.17
		25	-0.028	0.416	1	-1.51	1.45
		28	0.167	0.417	1	-1.31	1.65
	4	8	-1.67*	0.441	0.027	-3.23	-0.1
		11	-0.056	0.514	1	-1.88	1.77
		14	0.75	0.654	1	-1.57	3.07
		17	0.278	0.483	1	-1.44	1.1
		21	-1.139	0.394	0.261	-2.54	0.262
		24	0.583	0.521	1.00	-1.27	2.44
		25	-0.861	0.336	0.492	-2.06	0.332
		28	-0.667	0.595	1	-2.78	1.45
	8	11	1.61*	0.396	0.012	0.205	3.02
		14	2.42*	0.52	0.002	0.57	4.26
		17	1.94*	0.453	0.006	0.336	3.55
		21	0.528	0.337	0.998	-0.67	1.73
		24	2.25*	0.496	0.003	0.487	4.01
		25	0.806	0.33	0.594	-0.366	1.98
		28	1	0.465	0.832	-0.654	2.65
	11	14	0.806	0.41	0.93	-0.65	2.26
		17	0.333	0.552	1	-1.63	2.3
		21	-1.08	0.47	0.712	-2.75	0.586
		24	0.639	0.65	1.00	-1.67	2.95
		25	-0.806	0.426	0.956	-2.32	0.707
		28	-0.611	0.616	1	-2.8	1.58
	14	17	-0.472	0.689	1	-2.92	1.98
		21	-1.89	0.632	0.208	-4.14	0.357
		24	-0.167	0.624	1	-2.38	2.05
		25	-1.61	0.577	0.321	-3.66	0.441
		28	-1.42	0.683	0.878	-3.84	1.01
	17	21	-1.42*	0.397	0.048	-2.83	-0.007
		24	0.306	0.624	1	-1.91	2.52
		25	-1.14	0.413	0.344	-2.61	0.33
		28	-0.944	0.405	0.693	-2.39	0.5
	21	24	1.72	0.541	0.131	-0.201	3.65
		25	0.278	0.31	1	-0.825	1.38
		28	0.472	0.524	1	-1.39	2.34
	24	25	-1.44	0.482	0.206	-3.16	0.27
		28	-1.25	0.691	0.976	-3.71	1.21
	25	28	0.194	0.493	1	-1.56	1.95

*. The mean difference is significant at the .05 level.

Table 9-41 shows that there was a significant difference between requirements 1 and 8, 1 and 24, 4 and 8, 4 and 25, 4 and 28, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 25, 8 and 28, 11 and 17, 11 and 24, 14 and 24, 17 and 25, 17 and 28, 21 and 24, 24 and 25, 24 and 28 for solution B.

However, there was no significant difference between requirements 1 and 4, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 25, 1 and 28, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 24, 11 and 14, 11 and 21, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 25, 14 and 28, 17 and 21, 17 and 24, 21 and 25, 21 and 28, and 25 and 28.

Table 9-41 Pairwise comparisons of simple main effects of requirements for solution B

Solution	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
						Lower Bound	Upper Bound
B	1	4	1.17	0.537	0.815	-0.741	3.08
		8	5.31*	0.637	p<.001	3.04	7.57
		11	-0.361	0.53	1	-2.25	1.52
		14	0.806	0.585	1	-1.28	2.89
		17	1.61	0.615	0.448	-0.58	3.8
		21	0.111	0.672	1	-2.28	2.5
		24	3.19*	0.607	p<.001	1.04	5.35
		25	-0.944	0.584	0.996	-3.02	1.13
		28	-1.25	0.688	0.974	-3.7	1.2
	4	8	4.14*	0.692	p<.001	1.68	6.6
		11	-1.528	0.552	0.338	-3.49	0.436
		14	-0.361	0.599	1	-2.49	1.77
		17	0.444	0.517	1	-1.4	2.28
		21	-1.056	0.643	0.995	-3.34	1.23
		24	2.03	0.756	0.397	-0.658	4.71
		25	-2.11*	0.562	0.029	-4.11	-0.113
		28	-2.42*	0.578	0.009	-4.47	-0.363
	8	11	-5.67*	0.644	p<.001	-7.96	-3.38
		14	-4.5*	0.689	p<.001	-6.95	-2.05
		17	-3.69*	0.701	p<.001	-6.19	-1.20
		21	-5.19*	0.641	p<.001	-7.48	-2.92
		24	-2.11	0.698	0.192	-4.59	0.371
		25	-6.25*	0.692	p<.001	-8.71	-3.79
		28	-6.56*	0.68	p<.001	-8.97	-4.14
	11	14	1.17	0.512	0.735	-0.653	2.99
		17	1.97*	0.469	0.008	0.307	3.64
		21	0.47	0.657	1	-1.86	2.81
		24	3.56*	0.553	p<.001	1.59	5.52
		25	-0.583	0.401	0.999	-2.01	0.841
		28	-0.889	0.601	0.999	-3.02	1.25
	14	17	0.806	0.563	1	-1.19	2.81
		21	-0.694	0.683	1	-3.12	1.73
		24	2.39*	0.65	0.036	0.078	4.7
		25	-1.75	0.599	0.241	-3.88	0.377
		28	-2.06	0.795	0.475	-4.88	0.771
	17	21	-1.5	0.725	0.881	-4.08	1.08
		24	1.58	0.705	0.761	-0.922	4.09
		25	-2.56*	0.554	0.002	-4.53	-0.586
		28	-2.86*	0.733	0.019	-5.47	-0.255
	21	24	3.08*	0.728	0.007	0.497	5.67
		25	-1.06	0.606	0.986	-3.21	1.1
		28	-1.36	0.726	0.961	-3.94	1.22
	24	25	-4.14*	0.724	p<.001	-6.71	-1.57
		28	-4.44*	0.836	p<.001	-7.41	-1.48
	25	28	-0.31	0.51	1	-2.12	1.51

*. The mean difference is significant at the .05 level.

Table 9-42 shows there was a significant difference between requirements 1 and 24, 4 and 24, 8 and 24, 8 and 25, 11 and 24, 14 and 24, 17 and 21, 17 and 24, 17 and 28, 24 and 14, 24 and 17, 25 and 8, 25 and 21, 25 and 28, 28 and 17, 8 and 24, 11 and 24, 14 and 24, 17 and 21, 17 and 24, 17 and 28, 21 and 24, 21 and 25, 24 and 28, and 25 and 28 for solution C.

However, there was no significant difference between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 25, 1 and 28, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 25, 4 and 28, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 25, 14 and 28, 21 and 28, and 24 and 25 for solution C.

Table 9-42 Pairwise comparisons of simple main effects of requirements for solution C

Solution	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
						Lower Bound	Upper Bound
C	1	4	0.556	0.508	1	-1.25	2.36
		8	-1	0.39	0.491	-2.39	0.385
		11	-0.028	0.586	1.00	-2.11	2.06
		14	0.361	0.591	1.00	-1.74	2.46
		17	0.778	0.526	0.999	-1.09	2.65
		21	-0.778	0.485	0.997	-2.50	0.947
		24	3.69*	0.699	p<.001	1.21	6.18
		25	1.22	0.618	0.926	-0.975	3.42
		28	-1.28	0.487	0.445	-3.01	0.454
	4	8	-1.56	0.567	0.354	-3.57	0.46
		11	-0.583	0.603	1	-2.73	1.56
		14	-0.194	0.638	1	-2.46	2.07
		17	0.222	0.44	1	-1.34	1.79
		21	-1.33	0.48	0.331	-3.04	0.374
		24	3.14*	0.694	0.003	0.672	5.61
		25	0.667	0.625	1	-1.56	2.89
		28	-1.83	0.577	0.132	-3.88	0.216
	8	11	0.972	0.569	0.99	-1.05	3.0
		14	1.36	0.612	0.778	-0.813	3.54
		17	1.78	0.535	0.092	-0.124	3.68
		21	0.222	0.535	1	-1.68	2.12
		24	4.7*	0.666	p<.001	2.33	7.06
		25	2.22*	0.596	0.031	0.103	4.34
		28	-0.278	0.443	1	-1.85	1.3
	11	14	0.389	0.432	1	-1.15	1.93
		17	0.806	0.625	1	-1.41	3.03
		21	-0.75	0.492	0.999	-2.5	0.998
		24	3.72*	0.648	p<.001	1.42	6.03
		25	1.25	0.499	0.542	-0.523	3.02
		28	-1.25	0.618	0.905	-3.45	0.946
	14	17	0.417	0.74	1	-2.21	3.05
		21	-1.14	0.651	0.985	-3.45	1.17
		24	3.33*	0.652	0.001	1.02	5.65
		25	0.861	0.622	1.00	-1.35	3.07
		28	-1.64	0.664	0.574	-4.00	0.722
	17	21	-1.56*	0.431	0.043	-3.09	-0.026
		24	2.92*	0.674	0.006	0.521	5.31
		25	0.444	0.68	1	-1.97	2.86
		28	-2.06*	0.473	0.005	-3.74	-0.375
	21	24	4.47*	0.732	p<.001	1.87	7.07
		25	2.00*	0.545	0.036	0.065	3.94
		28	-0.5	0.528	1	-2.38	1.38
	24	25	-2.47	0.728	0.076	-5.06	0.114
		28	-4.97*	0.667	p<.001	-7.34	-2.60
	25	28	-2.50*	0.579	0.006	-4.56	-0.443

*. The mean difference is significant at the .05 level.

*4) Marginal means ratings for method*solution*

Table 9-43 shows the marginal mean ratings overall requirements of the TEIF Method and the Other Methods for three solutions with the associated standard errors.

Table 9-43 Marginal mean ratings for *method*solution*

Method	**Solution**	**Mean**	**Std. Error**	**95% Confidence Interval**	
				Lower Bound	**Upper Bound**
TEIF	A	8.38	0.222	7.93	8.83
	B	5.49	0.362	4.75	6.23
	C	6.89	0.26	6.37	7.42
Other	A	7.34	0.222	6.89	7.8
	B	6.31	0.362	5.57	7.04
	C	6.57	0.26	6.04	7.1

Each F tests the simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.

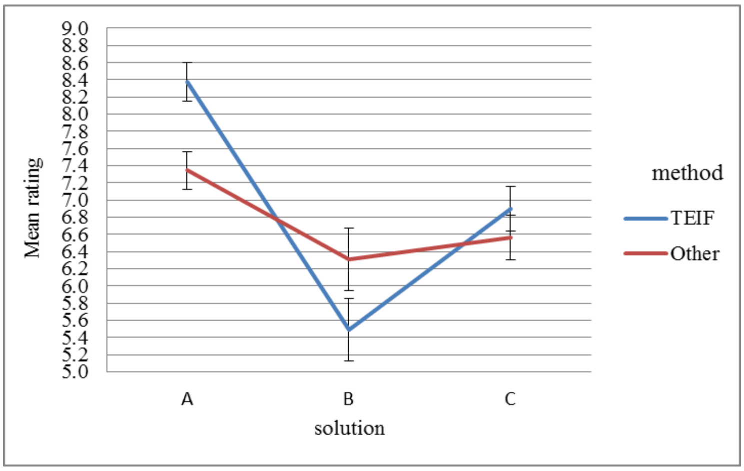
5) Simple main effects of method at different level of solution

Table 9-44 shows the univariate tests of simple main effects of method within each level of three solutions. There was a significant simple main effect ($p = 0.002 < 0.05$) of *method* for solution A, whereas there was no significant simple main effect of *method* for solutions B and C. Figure 9-18 illustrates these simple main effects. It may be seen that the mean ratings of TEIF Method was significantly higher than the Other Methods for solution A but not significantly different for solutions B and C over the ten requirements.

Table 9-44 Univariate tests of simple main effects of *method* at each level of *solution*

Solution		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
A	Method	9.61	1	9.61	10.8	0.002
	Error	30.2	34	0.888		
B	Method	6	1	6.00	2.55	0.12
	Error	80.2	34	2.36		
C	Method	0.967	1	0.967	0.792	0.38
	Error	41.6	34	1.22		

Each F tests the simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.



Error bars are ±1standard error

Figure 9-18 Profile graph of the simple main effects of *method* at each level of *solution*

6) *Simple main effects of solution at each level of method*

The significant value for multivariate analysis of variance (MANOVA) suggested by Pillai's trace is used in this research because it is considered to be the most powerful and most robust of the four statistics (Field, 2013). Table 9-45 shows the multivariate tests of simple main effects of *solution* within each level of method. There were significant simple main effects of *solution* for the TEIF Method ($p < 0.001$) and the Other Methods ($p<0.05$). Therefore, the pairwise comparisons of solutions for each level of method were undertaken.

Table 9-45 Multivariate simple effects of *solution* within each level of *method*

Method		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
TEIF	Pillai's trace	0.633	28.4[a]	2	33	p < .001
	Wilks' lambda	0.367	28.4[a]	2	33	p < .001
	Hotelling's trace	1.72	28.4[a]	2	33	p < .001
	Roy's largest root	1.72	28.4[a]	2	33	p < .001
Other	Pillai's trace	0.263	5.9[a]	2	33	0.006
	Wilks' lambda	0.737	5.9[a]	2	33	0.006
	Hotelling's trace	0.357	5.9[a]	2	33	0.006
	Roy's largest root	0.357	5.9[a]	2	33	0.006

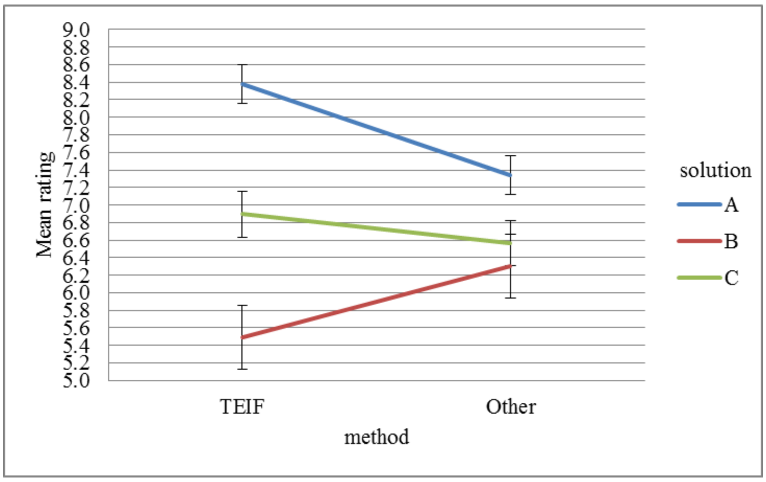
Each F tests the multivariate simple effects of solutions within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.

Table 9-46 shows the results of pairwise comparisons of simple main effects of *solution* at each level of *method*. There were significant difference between solutions A and B ($p < 0.001$), A and C ($p < 0.001$), and B and C ($p<0.05$) for the TEIF Method, and there was a significant difference between solutions A and C ($p < 0.05$) for the Other Methods. However, there was no significant difference between solutions A and B, and B and C, for the Other Methods. Figure 9-19 illustrates these simple main effects.

Table 9-46 Pairwise comparisons of simple main effects of *solution* at each level of *method*

Method	(I) solutions	(J) solutions	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
TEIF	A	B	2.89*	0.427	p < .001	1.82	3.96
		C	1.48*	0.231	p < .001	0.903	2.06
	B	C	-1.41*	0.374	0.002	-2.35	-0.466
Other	A	B	1.04	0.427	0.06	-0.034	2.11
		C	.778*	0.231	0.006	0.197	1.36
	B	C	-0.261	0.374	0.867	-1.2	0.678

Based on marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.



Error bars are ±1standard error

Figure 9-19 Profile graph of simple main effects of *solution* at different level of *method*

7) Summary of results for mean ratings differences between methods

Over all requirements, the mean rating of the TEIF Method shows a significantly higher rating for solution A but not significantly different for B and C than the Other Methods.

Over all requirements, solutions A, B, and C are rated differently for the TEIF Method but for the Other Methods only A was significantly different from C and neither was different from B.

9.4.3.2 Differences from experts

The experimental task asked the participants in both groups to give ratings from 0-10 for how well each of three different technology solutions met each of ten requirements.

In order to explore whether the TEIF Method helps developers rate technology solutions closer to the experts' ratings than the Other Methods (sub research question 3.2 approach B), a three way repeated measures analysis of variance with two within subjects factors (*solution* and *requirement*) and one between subjects factor (*method*) was carried out on the differences between the participants ratings and the experts' ratings for the TEIF Method and the Other Methods across ten requirements and three solutions.

Table 9-47 shows the results of Mauchly's sphericity test for each of three effects. The significance values of these tests indicate that only *solution* was not significant for Mauchly's test of sphericity and so sphericity can only be assumed for *solution*. The main effects of *requirement* and the second-order interaction effects of *requirement*solution* have violated this assumption. The Lower-bound of significance can be used as the most conservative (Field, 2013), but in other circumstances the Greenhouse-Geisser or the Huynh-Feldt bound may be more appropriate.

Table 9-47 Mauchly's test of sphericity of mean discrepancy ratings from experts

Within Subjects Effect	**Mauchly's W**	**Approx. Chi-Square**	**df**	**Sig.**	**Epsilon[b]**		
					Greenhouse-Geisser	**Huynh-Feldt**	**Lower-bound**
Requirement	.025	113.3	44	p<.001	.527	.640	.111
Solution	.967	1.09	2	.580	.969	1	.500
Requirement*solution	.000	299	170	p<.001	.479	.675	.056

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: requirements + solutions + requirements * solutions
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

The result of the third-order interaction effect of *requirement*solution*method* was not significant, which can be seen in Table 9-48. The second-order interaction effect of *solution*method* ($p < 0.05$) was significant. This indicates that the mean discrepancy ratings of *solution* depend on *method* and the mean discrepancy ratings of *method* depend on *solution*.

Although, the second-order interaction effect of *requirement*solution* was not significant as suggested by the Lower-bound, it was investigated because it was significant according to both the Greenhouse-Geisser (p = 0.009) and Huynd-Feldt (p = 0.003) tests (Field, 2013). This indicates that the mean discrepancy ratings of *requirement* depend on *solution* and the mean discrepancy ratings of *solution* depend on *requirement*. The second-order interaction effect of *requirement*method* was not significant.

Therefore although the main effects of *solution* and *requirement* were significant (Table 9-48) they were not considered further as they were involved in significant second-order interactions effects. The main effect of *method* was not significant (Table 9-49).

Table 9-48 Tests of within-subjects effects of discrepancy mean rating from experts

Source		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Requirement	Sphericity Assumed	189	9	20.9	3.87	p<.001
	Greenhouse-Geisser	189	4.74	39.8	3.87	.003
	Huynh-Feldt	189	5.76	32.7	3.87	.001
	Lower-bound	189	1	189	3.87	.057
Requirement * Method	Sphericity Assumed	15.8	9	1.75	.323	.967
	Greenhouse-Geisser	15.8	4.74	3.32	.323	.890
	Huynh-Feldt	15.8	5.76	2.73	.323	.919
	Lower-bound	15.8	1	15.8	.323	.574
Error(requirement)	Sphericity Assumed	1657	306	5.42		
	Greenhouse-Geisser	1657	161	10.3		
	Huynh-Feldt	1657	196	8.46		
	Lower-bound	1657	34	48.7		
Solution	Sphericity Assumed	104	2	52.2	20.9	p<.001
	Greenhouse-Geisser	104	1.94	53.9	20.9	p<.001
	Huynh-Feldt	104	2	52.2	20.9	p<.001
	Lower-bound	104	1	104	20.9	p<.001
Solution * Method	Sphericity Assumed	23.5	2	11.8	4.72	.012
	Greenhouse-Geisser	23.5	1.94	12.2	4.72	.013
	Huynh-Feldt	23.5	2	11.8	4.72	.012
	Lower-bound	23.5	1	23.5	4.72	.037
Error(solution)	Sphericity Assumed	170	68	2.5		
	Greenhouse-Geisser	170	65.9	2.58		
	Huynh-Feldt	170	68	2.5		
	Lower-bound	170	34	4.99		
Requirement * Solution	Sphericity Assumed	149	18	8.26	2.55	p<.001
	Greenhouse-Geisser	149	8.62	17.2	2.55	.009
	Huynh-Feldt	149	12.2	12.2	2.55	.003
	Lower-bound	149	1	149	2.55	.119
Requirement * Solution * Method	Sphericity Assumed	102	18	5.65	1.75	.028
	Greenhouse-Geisser	102	8.62	11.8	1.75	.081
	Huynh-Feldt	102	12.2	8.37	1.75	.054
	Lower-bound	102	1	102	1.75	.195
Error(requirement*solution)	Sphericity Assumed	1978	612	3.23		
	Greenhouse-Geisser	1978	293	6.75		
	Huynh-Feldt	1978	413	4.79		
	Lower-bound	1978	34	58.2		

Table 9-49 Tests of between-subjects effects of mean discrepancy rating for *method*

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Intercept	171	1	171	659	p<.001
Methods	.174	1	.174	.668	.419
Error	8.84	34	.260		

As shown in Table 9-48, two second-order interaction effects were significant. Therefore, tests of simple main effects were undertaken.

The following syntax '/EMMEANS' (SPSS, 2001) was used to test simple main effects:

/EMMEANS=TABLES(Method*Solution) COMPARE(Method)ADJ(sidak)
/EMMEANS=TABLES(Methods*Solution) COMPARE(Solution)ADJ(sidak)
/EMMEANS=TABLES(Requirement*Solution) COMPARE(Requirement)ADJ(sidak)
/EMMEANS=TABLES(Requirement*Solution) COMPARE(Solution)ADJ(sidak)

1) Marginal mean discrepancy ratings for method and solution

Table 9-50 shows the marginal mean discrepancy ratings over all requirements of the TEIF Method and the Other Methods for three solutions with the associated standard errors.

Table 9-50 Marginal mean discrepancy ratings for *method*solution*

Method	Solution	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
TEIF	A	1.48	.168	1.14	1.82
	B	2.46	.165	2.13	2.8
	C	2.4	.126	2.14	2.65
Other	A	2.02	.168	1.68	2.36
	B	2.48	.165	2.15	2.82
	C	2.24	.126	1.99	2.5

2) Simple main effects of solution at each level of method

Table 9-51 shows the multivariate tests of simple main effects of *solution* at each level of *method*. Pillai's trace is used in this research because it is considered to be the most powerful and most robust of the four statistics (Field, 2013). There were significant simple main effects of *solution* for the TEIF Method ($p < 0.001$). The Other Methods simple main effects were marginally significant, $p = 0.056$. It was decided to explore this marginal result further.

Table 9-51 Multivariate tests of simple effect of solutions

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.544	19.7[a]	2	33	P < .001
	Wilks' lambda	.456	19.7[a]	2	33	P < .001
	Hotelling's trace	1.2	19.7[a]	2	33	P < .001
	Roy's largest root	1.2	19.7[a]	2	33	P < .001
Other	Pillai's trace	.16	3.15[a]	2	33	.056
	Wilks' lambda	.84	3.15[a]	2	33	.056
	Hotelling's trace	.191	3.15[a]	2	33	.056
	Roy's largest root	.191	3.15[a]	2	33	.056

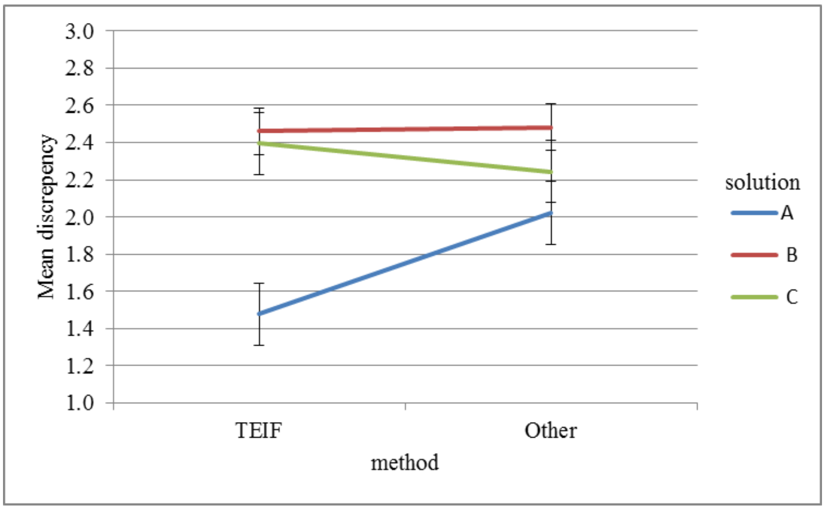
Each F tests the multivariate simple effects of solutions within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

A pairwise comparison of simple main effects of *solution* for each level of *method* was undertaken. Table 9-52 shows that there were significant differences between solutions A and B, and A and C ($p < 0.001$) for the TEIF Method, whereas there was no significant difference between solutions B and C. There was a significant difference between solutions A and B for the Other Methods, whereas there were no significant differences between solutions A and C, and B and C. Figure 9-20 illustrates the simple main effects.

Table 9-52 Pairwise comparisons of simple main effects of *solution* for each level of *method*

Method	**(I) solutions**	**(J) solutions**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**[b]	**95% Confidence Interval for Difference**[b]	
						Lower Bound	**Upper Bound**
TEIF	A	B	-.983*	.181	p < .001	-1.44	-.529
		C	-.917*	.158	p < .001	-1.31	-.52
	B	C	.067	.16	.967	-.335	.468
Other	A	B	-.461*	.181	.046	-.915	-.007
		C	-.222	.158	.425	-.619	.174
	B	C	.239	.16	.374	-.163	.64

Based on marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.



Error bars are ±1standard error

Figure 9-20 Profile graph of simple main effects of *solution* at each level of *methods* on mean ratings discrepancy

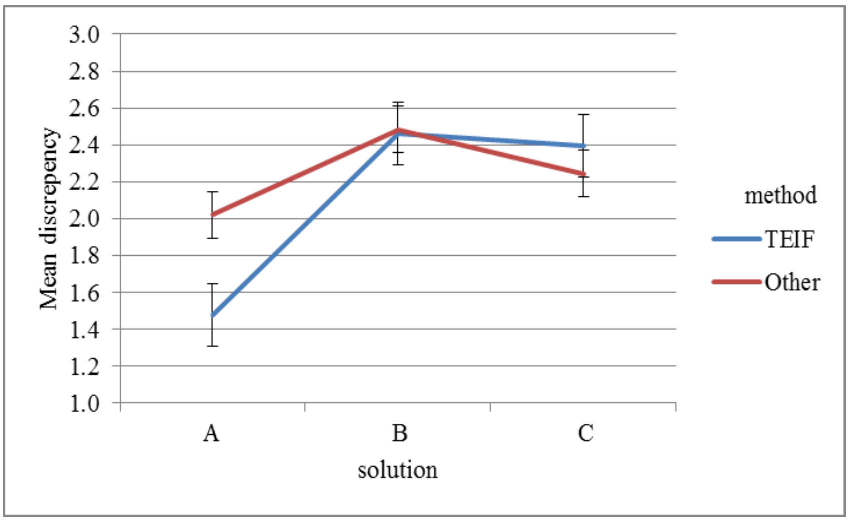
3) *Simple main effects of method at each level of solution*

Table 9-53 shows the univariate tests of simple main effects over all the ten requirements of *method* within each level of three solutions. There was a significant simple main effect ($p < 0.05$) of the two methods for solution A, whereas there was no significant simple main effect of *method* for solutions B and C. Figure 9-21 illustrates theses main effects of *method* at each level of *solution.*

Table 9-53 Univariate tests of simple main effects of *method* at each level of *solution*

Solution		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
A	Method	2.67	1	2.67	5.27	.028
	Error	17.2	34	.506		
B	Method	.004	1	.004	.009	.925
	Error	16.6	34	.488		
C	Method	.203	1	.203	.712	.405
	Error	9.67	34	.285		

Each F tests the simple effects of methods within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.



Error bars are ±1standard error

Figure 9-21 Profile graph of simple main effects of *method* at each level of *solution* on mean discrepancy ratings

4) Marginal mean discrepancy ratings for requirement and solution

Table 9-54 shows the marginal mean discrepancy ratings from the experts over all methods of ten requirements for three solutions with the associated standard errors.

Table 9-54 Marginal mean discrepancy ratings of *requirement*solution*

Requirement	Solution	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
1	A	1.25	.210	.823	1.68
	B	2.36	.264	1.82	2.9
	C	2.69	.232	2.22	3.17
4	A	1.78	.271	1.23	2.33
	B	2.56	.281	1.98	3.13
	C	2.19	.255	1.68	2.71
8	A	.778	.187	.398	1.16
	B	1.56	.490	.560	2.55
	C	1.86	.372	1.11	2.62
11	A	2.19	.234	1.72	2.67
	B	2.22	.255	1.7	2.74
	C	1.86	.293	1.27	2.46
14	A	2.64	.413	1.8	3.48
	B	2.83	.298	2.23	3.44
	C	2.33	.284	1.76	2.91
17	A	2.11	.354	1.39	2.83
	B	2.67	.291	2.08	3.26
	C	2.11	.279	1.55	2.68
21	A	1.39	.235	.911	1.87
	B	3.28	.238	2.79	3.76
	C	2.14	.276	1.58	2.7
24	A	2.25	.343	1.55	2.95
	B	3.50	.575	2.33	4.67
	C	3.39	.491	2.39	4.39
25	A	1.36	.206	.942	1.78
	B	1.67	.264	1.13	2.20
	C	3.06	.289	2.47	3.64
28	A	1.75	.441	.853	2.65
	B	2.08	.516	1.03	3.13
	C	1.56	.398	.746	2.37

5) Simple main effects of solution at each level of requirement

Table 9-55 shows the multivariate tests of simple main effects of *solution* at each level of *requirement*. There was a significant simple main effect of solutions for requirements 1, 4, 8 ($p < 0.05$), 21, and 25 ($p < 0.001$), whereas there was no significant simple main effect of *solution* for requirements 11, 14, 17, 24, and 28.

Table 9-55 Multivariate tests of simple effects of *solution* at each level of *requirement*

Requirement		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.356	9.13[a]	2	33	.001
	Wilks' lambda	.644	9.13[a]	2	33	.001
	Hotelling's trace	.553	9.13[a]	2	33	.001
	Roy's largest root	.553	9.13[a]	2	33	.001
4	Pillai's trace	.211	4.42[a]	2	33	.020
	Wilks' lambda	.789	4.42[a]	2	33	.020
	Hotelling's trace	.268	4.42[a]	2	33	.020
	Roy's largest root	.268	4.42[a]	2	33	.020
8	Pillai's trace	.238	5.16[a]	2	33	.011
	Wilks' lambda	.762	5.16[a]	2	33	.011
	Hotelling's trace	.313	5.16[a]	2	33	.011
	Roy's largest root	.313	5.16[a]	2	33	.011
11	Pillai's trace	.031	.531[a]	2	33	.593
	Wilks' lambda	.969	.531[a]	2	33	.593
	Hotelling's trace	.032	.531[a]	2	33	.593
	Roy's largest root	.032	.531[a]	2	33	.593
14	Pillai's trace	.077	1.38[a]	2	33	.267
	Wilks' lambda	.923	1.38[a]	2	33	.267
	Hotelling's trace	.083	1.38[a]	2	33	.267
	Roy's largest root	.083	1.38[a]	2	33	.267
17	Pillai's trace	.077	1.38[a]	2	33	.266
	Wilks' lambda	.923	1.38[a]	2	33	.266
	Hotelling's trace	.084	1.38[a]	2	33	.266
	Roy's largest root	.084	1.38[a]	2	33	.266
21	Pillai's trace	.537	19.14[a]	2	33	p < .001
	Wilks' lambda	.463	19.14[a]	2	33	p < .001
	Hotelling's trace	1.16	19.14[a]	2	33	p < .001
	Roy's largest root	1.16	19.14[a]	2	33	p < .001
24	Pillai's trace	.094	1.71[a]	2	33	.196
	Wilks' lambda	.906	1.71[a]	2	33	.196
	Hotelling's trace	.104	1.71[a]	2	33	.196
	Roy's largest root	.104	1.71[a]	2	33	.196
25	Pillai's trace	.370	9.69[a]	2	33	p < .001
	Wilks' lambda	.630	9.69[a]	2	33	p < .001
	Hotelling's trace	.587	9.69[a]	2	33	p < .001
	Roy's largest root	.587	9.69[a]	2	33	p < .001
28	Pillai's trace	.023	.393[a]	2	33	.678
	Wilks' lambda	.977	.393[a]	2	33	.678
	Hotelling's trace	.024	.393[a]	2	33	.678
	Roy's largest root	.024	.393[a]	2	33	.678

Each F tests the multivariate simple effects of solutions within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

The pairwise comparison of these solutions at each of these requirements was undertaken.

Table 9-56 shows there was a significant difference between mean discrepancy ratings for:

- requirement 1 between solutions A and B ($p < 0.05$), and A and C ($p < 0.001$)
- requirement 4 between solutions A and B ($p < 0.05$)
- requirement 8 between solutions A and C ($p < 0.05$)
- requirement 21 between solutions A and B, A and C ($p < 0.005$), and B and C ($p < 0.001$)

- requirement 25 between solutions A and C ($p<0.001$), and B and C ($p < 0.05$)

There were no significant differences in the mean discrepancy rating for requirements 11, 14, 17, 24, and 28 for any of the solutions, requirement 1 between solutions B and C, requirement 4 between solutions A and C, and B and C, requirement 8 between solutions A and B, and B and C, requirement 25 between solutions A and B.

Table 9-56 Pairwise comparisons of means discrepancy between requirements and solutions

Requirement	(I) solutions	(J) solutions	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
1	A	B	-1.11*	0.358	0.011	-2.01	-0.213
		C	-1.44*	0.333	p < .001	-2.28	-0.608
	B	C	-0.333	0.268	0.53	-1.01	0.34
4	A	B	-.778*	0.262	0.016	-1.44	-0.119
		C	-0.417	0.344	0.55	-1.28	0.446
	B	C	0.361	0.292	0.533	-0.371	1.09
8	A	B	-0.778	0.501	0.342	-2.04	0.481
		C	-1.08*	0.339	0.009	-1.93	-0.233
	B	C	-0.306	0.516	0.914	-1.6	0.991
11	A	B	-0.028	0.247	0.999	-0.648	0.593
		C	0.333	0.333	0.691	-0.503	1.17
	B	C	0.361	0.376	0.717	-0.583	1.31
14	A	B	-0.194	0.503	0.973	-1.46	1.07
		C	0.306	0.341	0.758	-0.551	1.16
	B	C	0.5	0.359	0.433	-0.401	1.4
17	A	B	-0.556	0.495	0.61	-1.8	0.687
		C	0	0.36	1	-0.905	0.905
	B	C	0.556	0.329	0.273	-0.272	1.38
21	A	B	-1.89*	0.301	p < .001	-2.64	-1.13
		C	-.750*	0.224	0.006	-1.31	-0.188
	B	C	1.14*	0.265	p < .001	0.473	1.81
24	A	B	-1.25	0.733	0.265	-3.09	0.591
		C	-1.14	0.644	0.236	-2.76	0.477
		C	0.111	0.525	0.995	-1.21	1.43
25	A	B	-0.306	0.304	0.689	-1.07	0.459
		C	-1.7*	0.381	p < .001	-2.65	-0.738
	B	C	-1.39*	0.408	0.005	-2.41	-0.365
28	A	B	-0.333	0.525	0.896	-1.65	0.984
		C	0.194	0.529	0.977	-1.13	1.52
	B	C	0.528	0.597	0.765	-0.971	2.03

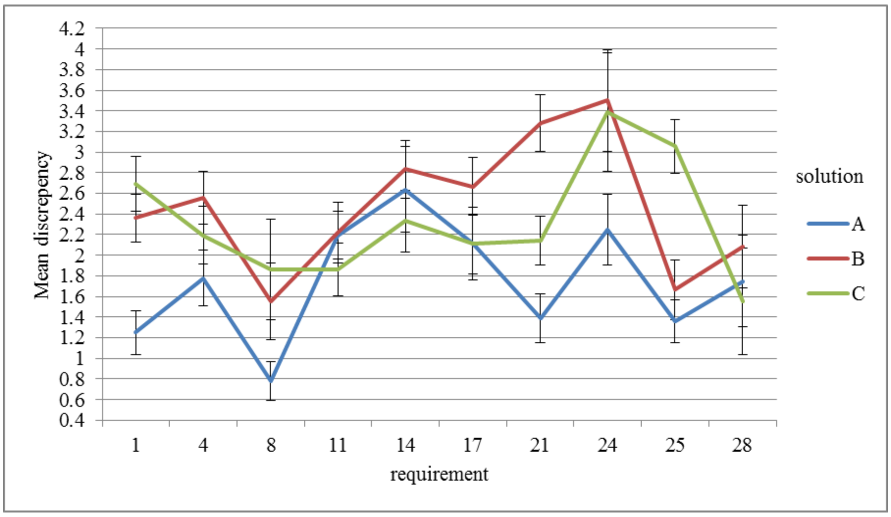
Based on marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Figure 9-22 illustrates these simple main effects of *solution* at each level of *requirement* as described for

Table 9-56. In the profile graph where the error bars overlap, there is no significant difference, and where the error bars do not overlap, there are significant differences.



Error bars are ±1standard error

Figure 9-22 Profile graph of simple main effects of *requirement*solution* on mean discrepancy ratings

6) *Simple main effects of requirement at each level of solution*

Table 9-57 shows the multivariate tests of simple main effects of *requirement* at each level of *solution*. There was a significant simple main effect of *requirement* for solutions A (p <0.05), B, and C (p < 0.001).

Table 9-57 Multivariate tests of simple effects of *requirement* at each level of *solution*

solutions		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
A	Pillai's trace	.526	3.2[a]	9	26	.01
	Wilks' lambda	.474	3.2[a]	9	26	.01
	Hotelling's trace	1.11	3.2[a]	9	26	.01
	Roy's largest root	1.11	3.2[a]	9	26	.01
B	Pillai's trace	.648	5.31[a]	9	26	p<.001
	Wilks' lambda	.352	5.31[a]	9	26	p<.001
	Hotelling's trace	1.84	5.31[a]	9	26	p<.001
	Roy's largest root	1.84	5.31[a]	9	26	p<.001
C	Pillai's trace	.449	2.35[a]	9	26	.043
	Wilks' lambda	.551	2.35[a]	9	26	.043
	Hotelling's trace	.814	2.35[a]	9	26	.043
	Roy's largest root	.814	2.35[a]	9	26	.043

Each F tests the multivariate simple effects of requirements within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.

a. Exact statistic

The pairwise comparisons of simple main effects of *requirement* at each level of *solution* were undertaken.

Table 9-58 shows that:

- there were significant differences in mean discrepancy rating from the experts' rating between requirements 8 and 11, 8 and 16, and 8 and 24 for solution A.
- there were no significant differences of mean discrepancy rating from the experts' rating between requirements 1, 4, 17, 21, 25, and 28, and requirements 8 and 17, 8 and 21, 8 and 25, 8 and 28 for solution A.

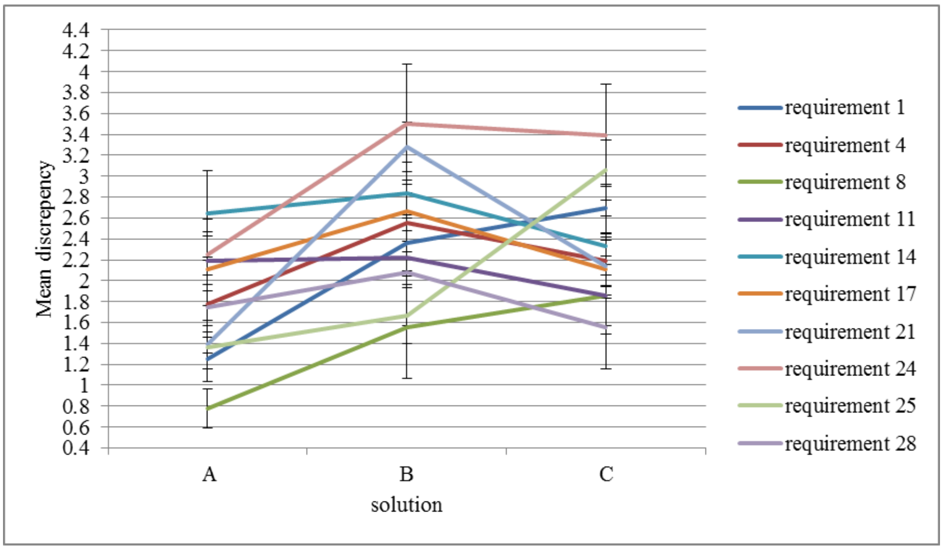
Table 9-59 shows that:

- there were significant differences in the mean discrepancy ratings between requirements 21 and 25 for solution B.
- there were no significant differences in the mean discrepancy ratings between requirements 1, 4, 8, 11, 14, 17, 24 and 25, and requirements 21 and 24, and 21 and 28 for solution B.

Table 9-60 shows that

- there were no significant differences in the mean discrepancy ratings between any of requirements 1, 4, 8, 11, 14, 17, 24, 25, and 28 for solution C.

Figure 9-23 illustrates these simple main effects of *requirement* at each level of *solution*.



Error bars are ±1standard error

Figure 9-23 Profile graph of simple main effects of *requirement* at each level of *solution* on ratings discrepancy from the experts

Table 9-58 Pairwise comparisons of simple main effects of *requirement* for solution A

Solution	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
A	1	4	-0.53	0.348	0.999	-1.77	0.709
		8	0.472	0.284	0.994	-0.538	1.48
		11	-0.944	0.334	0.299	-2.13	0.244
		14	-1.39	0.499	0.325	-3.16	0.383
		17	-0.861	0.401	0.833	-2.29	0.564
		21	-0.139	0.325	1	-1.3	1.02
		24	-1	0.417	0.636	-2.48	0.483
		25	-0.111	0.323	1	-1.26	1.04
		28	-0.500	0.399	1	-1.92	0.919
	4	8	1	0.353	0.294	-0.26	2.26
		11	-0.417	0.318	1.000	-1.55	0.715
		14	-0.861	0.499	0.988	-2.64	0.913
		17	-0.333	0.426	1	-1.85	1.18
		21	0.389	0.307	1	-0.703	1.48
		24	-0.472	0.373	1	-1.8	0.853
		25	0.417	0.253	0.994	-0.483	1.32
		28	0.028	0.538	1.00	-1.89	1.94
	8	11	-1.42*	0.344	0.01	-2.64	-0.195
		14	-1.86*	0.464	0.014	-3.51	-0.211
		17	-1.33	0.419	0.132	-2.82	0.157
		21	-0.611	0.313	0.936	-1.72	0.502
		24	-1.47*	0.382	0.022	-2.83	-0.114
		25	-0.583	0.284	0.889	-1.59	0.426
		28	-0.972	0.466	0.871	-2.63	0.683
	11	14	-0.444	0.424	1	-1.95	1.06
		17	0.083	0.427	1	-1.44	1.6
		21	0.806	0.349	0.71	-0.434	2.05
		24	-0.056	0.386	1	-1.43	1.32
		25	0.833	0.302	0.344	-0.241	1.91
		28	0.444	0.478	1.00	-1.26	2.14
	14	17	0.528	0.575	1.00	-1.52	2.57
		21	1.25	0.5	0.544	-0.525	3.03
		24	0.389	0.452	1	-1.22	2
		25	1.28	0.434	0.231	-0.265	2.82
		28	0.889	0.633	1	-1.36	3.14
	17	21	0.722	0.371	0.937	-0.595	2.04
		24	-0.139	0.51	1	-1.95	1.67
		25	0.75	0.324	0.705	-0.401	1.90
		28	0.361	0.396	1	-1.05	1.77
	21	24	-0.861	0.385	0.769	-2.23	0.51
		25	0.028	0.26	1	-0.896	0.95
		28	-0.361	0.526	1	-2.23	1.51
	24	25	0.889	0.359	0.567	-0.387	2.17
		28	0.5	0.597	1	-1.62	2.62
	25	28	-0.389	0.455	1	-2.01	1.23

Based on marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

Table 9-59 Pairwise comparisons of simple main effects of *requirement* for solution B

Solution	**(I) requirements**	**(J) requirements**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**[b]	**95% Confidence Interval for Difference**[b]	
						Lower Bound	**Upper Bound**
B	1	4	-0.194	0.29	1	-1.23	0.836
		8	0.806	0.606	1	-1.35	2.96
		11	0.139	0.323	1	-1.01	1.29
		16	-0.472	0.343	1	-1.69	0.748
		17	-0.306	0.337	1	-1.51	0.894
		21	-0.917	0.278	0.098	-1.90	0.071
		24	-1.14	0.668	0.99	-3.51	1.24
		25	0.694	0.418	0.993	-0.79	2.18
		28	0.278	0.624	1	-1.94	2.5
	4	8	1	0.662	0.999	-1.35	3.35
		11	0.333	0.354	1	-0.925	1.59
		16	-0.278	0.344	1	-1.5	0.946
		17	-0.111	0.354	1	-1.37	1.15
		21	-0.722	0.304	0.657	-1.8	0.36
		24	-0.944	0.637	0.999	-3.21	1.32
		25	0.889	0.392	0.746	-0.506	2.28
		28	0.472	0.543	1	-1.46	2.4
	8	11	-0.667	0.59	1	-2.77	1.43
		16	-1.28	0.609	0.865	-3.44	0.887
		17	-1.11	0.625	0.981	-3.33	1.11
		21	-1.72	0.559	0.168	-3.71	0.264
		24	-1.94	0.69	0.304	-4.4	0.508
		25	-0.111	0.495	1	-1.87	1.65
		28	-0.528	0.721	1	-3.09	2.03
	11	16	-0.611	0.313	0.936	-1.72	0.502
		17	-0.444	0.342	1	-1.66	0.77
		21	-1.06	0.35	0.195	-2.3	0.188
		24	-1.28	0.615	0.877	-3.46	0.908
		25	0.556	0.373	0.999	-0.77	1.88
		28	0.139	0.662	1	-2.21	2.49
	14	17	0.167	0.369	1	-1.14	1.48
		21	-0.444	0.33	1	-1.62	0.727
		24	-0.667	0.651	1	-2.98	1.65
		25	1.17	0.368	0.136	-0.142	2.48
		28	0.75	0.61	1	-1.42	2.92
	17	21	-0.611	0.36	0.991	-1.89	0.668
		24	-0.833	0.751	1	-3.5	1.84
		25	1	0.367	0.369	-0.306	2.31
		28	0.583	0.668	1	-1.79	2.96
	21	24	-0.222	0.701	1	-2.72	2.27
		25	1.61*	0.358	0.003	0.341	2.88
		28	1.19	0.552	0.822	-0.767	3.16
	24	25	1.83	0.651	0.305	-0.48	4.15
		28	1.42	0.7	0.905	-1.07	3.91
	25	28	-0.417	0.533	1	-2.31	1.48

Based on marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

Table 9-60 Pairwise comparisons of simple main effects of *requirement* for solution C

Solution	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
C	1	4	0.5	0.286	0.985	-0.515	1.52
		8	0.833	0.449	0.965	-0.761	2.43
		11	0.833	0.353	0.665	-0.42	2.09
		14	0.361	0.318	1	-0.77	1.5
		17	0.583	0.329	0.982	-0.586	1.8
		21	0.556	0.358	0.998	-0.717	1.83
		24	-0.694	0.617	1	-2.89	1.5
		25	-0.361	0.346	1	-1.59	0.867
		28	1.14	0.478	0.649	-0.561	2.84
	4	8	0.333	0.526	1	-1.54	2.2
		11	0.333	0.367	1	-0.972	1.64
		14	-0.139	0.364	1	-1.43	1.16
		17	0.083	0.317	1	-1.04	1.21
		21	0.056	0.302	1	-1.02	1.13
		24	-1.19	0.605	0.926	-3.34	0.954
		25	-0.861	0.345	0.552	-2.09	0.366
		28	0.639	0.512	1	-1.18	2.46
	8	11	0	0.482	1	-1.71	1.71
		14	-0.472	0.527	1	-2.34	1.4
		17	-0.25	0.504	1	-2.04	1.54
		21	-0.278	0.53	1	-2.16	1.61
		24	-1.53	0.562	0.372	-3.53	0.47
		25	-1.19	0.47	0.511	-2.86	0.475
		28	0.306	0.441	1	-1.26	1.87
	11	14	-0.472	0.338	1	-1.67	0.728
		17	-0.25	0.361	1	-1.53	1.03
		21	-0.278	0.321	1	-1.42	0.861
		24	-1.53	0.619	0.574	-3.73	0.672
		25	-1.2	0.414	0.265	-2.67	0.28
		28	0.306	0.548	1	-1.64	2.25
	14	17	0.222	0.363	1	-1.07	1.51
		21	0.194	0.342	1	-1.02	1.41
		24	-1.06	0.684	0.998	-3.49	1.37
		25	-0.722	0.385	0.961	-2.09	0.647
		28	0.778	0.542	1	-1.15	2.72
	17	21	-0.028	0.346	1	-1.26	1.2
		24	-1.28	0.615	0.876	-3.46	0.907
		25	-0.944	0.359	0.436	-2.22	0.33
		28	0.556	0.448	1	-1.04	2.15
	21	24	-1.25	0.628	0.92	-3.48	0.98
		25	-0.917	0.389	0.671	-2.3	0.466
		28	0.583	0.562	1	-1.41	2.58
	24	25	0.333	0.606	1	-1.82	2.49
		28	1.83	0.602	0.183	-0.307	3.97
	25	28	1.5	0.542	0.338	-0.428	3.43

Based on marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

7) Summary of results for mean ratings discrepancy from experts

Over all requirements, the mean discrepancy rating of the TEIF Method was less for solution A than the other solutions, and was less than the Other Methods. There were no other requirement differences between methods or solutions.

Over all methods, solution A showed lower mean discrepancy ratings than solution B and / or C for five of ten requirements. Solution B showed a higher mean discrepancy rating than solution A and / or C for the ten requirements, and solution C showed a higher mean discrepancy rating than solution A and / or B for five of ten requirements.

There were significant differences in mean discrepancy rating from the experts' rating between requirement 8 and three other requirements for solution A. There were significant differences in the mean discrepancy ratings between requirements 21 and 25 for solution B. There were no significant differences in the mean discrepancy ratings between any requirement pairs for solution C.

9.4.3.3 Solution differential closer to experts

There are two measures, (a) direction and (b) amount of the differential between pairs of solutions. The measure amount indicates the closeness to the expert ratings and is calculated by subtracting the expert difference in ratings from the participant difference in ratings and taking the absolute value of the result. For example, a measure amount of zero (0) indicates no difference between participant differential and expert differential – i.e. both rate one solution equally different from the other. Some examples are shown in Table 9-61. The sign of the difference is used to calculate the direction.

Table 9-61 Examples of calculating for measure amount

Expert rating difference	**Participant rating difference**	**Measure amount**
1	1	0
1	2	1
1	0	1
1	-1	2
-1	1	2
0	-1	1

The measure direction indicates whether the participant differential is in the same direction as the expert differential. A measure direction of one (1) indicates that participant and expert agree on the direction of the differential – both rate the same solution better than the other. Measure direction scores were assigned as shown in Table 9-62.

Table 9-62 Counting the difference direction score

Expert measure direction	**Participant measure direction**	**Measure direction score**
A>B	A>B	1
A>B	A=B	0
A>B	A<B	-1
A=B	A>B	0
A=B	A=B	1
A=B	A<B	0
A<B	A>B	-1
A<B	A=B	0
A<B	A<B	1

The sub research question 3.2 approach C explores whether the TEIF Method helps participant differentials (measures amount and direction) between the three solution pairs to be closer to the experts than the Other Methods.

To explore this, a three way repeated measures multivariate analysis of variance with two within subject factors (*requirement* and *differential)* and one between subject factor (*method*) was carried out. The two measures were (a) amount and (b) direction. Both measures were calculated for the TEIF Method and the Other Methods for each of ten requirements and each of the pairs of differentials A-B, A-C, and B-C.

Table 9-63 shows the results of multivariate tests. The third-order interaction effect of *requirement***differential*method* over all ten requirements was significantly different as suggested by Pillai's Trace. This indicates that the mean ratings of *requirement* depend on *differential* and *method* and the mean ratings of *differential* depend on *requirement* and *method,* and the mean ratings of *method* depend on *differential* and *requirement*.

Table 9-63 Multivariate tests of *differential* over all ten *requirements*

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
*Requirement*differential*method*	Pillai's Trace	.193	3.63	36	1224	p <.001
	Wilks' Lambda	.811	3.75[c]	36	1222	p <.001
	Hotelling's Trace	.228	3.86	36	1220	p <.001
	Roy's Largest Root	.204	6.92[d]	18	612	p <.001

a. Design: Intercept + Method
Within Subjects Design: Requirement + Differential + Requirement * Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Therefore, three simple interaction effects analyses will be presented. Following the significant third-order interaction (*requirement*differential*method)*, the simple effects of *requirement, method,* and *requirement*method* at each level of *differential* were analysed. A multivariate two-way analysis of variance with one within subject factor (*requirement)* and one between subject factors (*method*) was carried out, for each differential A-B, A-C, and B-C. The two measures were (a) amount (b) direction.

9.4.3.3.1 Differential between solutions A-B

Table 9-64 shows the results of multivariate tests. The second-order simple interaction effect of *requirement*method* for differential A-B was significant as suggested by Pillai's Trace. This indicates that the differential mean ratings of *requirement* depend on *method* and the mean differential ratings of *method* depend on *requirement*. Although the simple main effects of *method* (Table 9-65) and *requirement* (Table 9-64) were significant, they were not considered further as they were involved in the significant second-order simple interaction effect.

Table 9-64 Multivariate tests of *requirement*method* for differential A-B

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Requirement	Pillai's Trace	1.04	37	18	612	p<.001
	Wilks' Lambda	.182	45.5[c]	18	610	p<.001
	Hotelling's Trace	3.25	54.9	18	608	p<.001
	Roy's Largest Root	2.81	95.7[d]	9	306	p<.001
Requirement * Method	Pillai's Trace	.141	2.59	18	612	p<.001
	Wilks' Lambda	.862	2.61[c]	18	610	p<.001
	Hotelling's Trace	.156	2.63	18	608	p<.001
	Roy's Largest Root	.123	4.18[d]	9	306	p<.001

a. Design: Intercept + Method
Within Subjects Design: requirements
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-65 Tests of between-subjects effects of *methods* on *for* differential A-B using measures amount and direction

Source	**Measure**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Method	differential amount	76.544	1	76.544	5.774	.022
	differential direction	9.669	1	9.669	6.598	.015
error	differential amount	450.744	34	13.257		
	differential direction	49.828	34	1.466		

Table 9-66 shows the results of Mauchly's sphericity test for differential A-B on measure amount and direction. The significant values of this test indicate that measure direction failed the assumption of sphericity, whereas measure amount met the assumption. Therefore Greenhouse-Geisser and Huynh-Feldt adjustments to significance were used for measure direction (Field, 2013).

Table 9-66 Mauchly's sphericity test for differential A-B on measures amount and direction

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Requirement	Amount	.140	60.5	44	.053	.720	.935	.111
	Direction	.063	85.3	44	p<.001	.667	.850	.111

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: requirements

Table 9-67 shows the result of the univariate tests. The second-order simple interaction effect of *requirement***method* was significant for both measures amount and direction, using both Greenhouse-Geisser and Huynh-Feldt adjustments. This indicates that the simple simple main effect of *requirement* on measures amount and direction depend on *method,* and the simple simple main effects of *method* depend on *requirement*. Although the simple simple main effects of both *requirement* and *method* were significant (Table 9-64 - Table 9-65), they were not considered further as they were involved in the significant second-order simple interaction effect.

Table 9-67 Univariate tests of *requirement***method* for differential A-B

Source	Variable		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement * Method	Amount	Sphericity Assumed	244	9	27.1	3.62	p<.001
		Greenhouse-Geisser	244	6.48	37.5	3.62	.001
		Huynh-Feldt	244	8.41	29	3.62	p<.001
		Lower-bound	244	1	243	3.62	.065
	Direction	Sphericity Assumed	14.7	9	1.63	3.62	p<.001
		Greenhouse-Geisser	14.7	6	2.45	3.62	.002
		Huynh-Feldt	14.7	7.65	1.92	3.62	.001
		Lower-bound	14.7	1	14.7	3.62	.066
Error(requirement)	Amount	Sphericity Assumed	2285	306	7.47		
		Greenhouse-Geisser	2285	221	10.4		
		Huynh-Feldt	2285	286	7.99		
		Lower-bound	2285	34	67.2		
	Direction	Sphericity Assumed	138	306	.451		
		Greenhouse-Geisser	138	204	.677		
		Huynh-Feldt	138	260	.531		
		Lower-bound	138	34	4.06		

The following syntax ‘/EMMEANS’ (IBM, 2001)was used to test simple main effects:

/EMMEANS=TABLES(Method*requirement)COMPARE(Method)ADJ(sidak)

/EMMEANS=TABLES(Method*requirement)COMPARE(Requirement)ADJ(sidak)

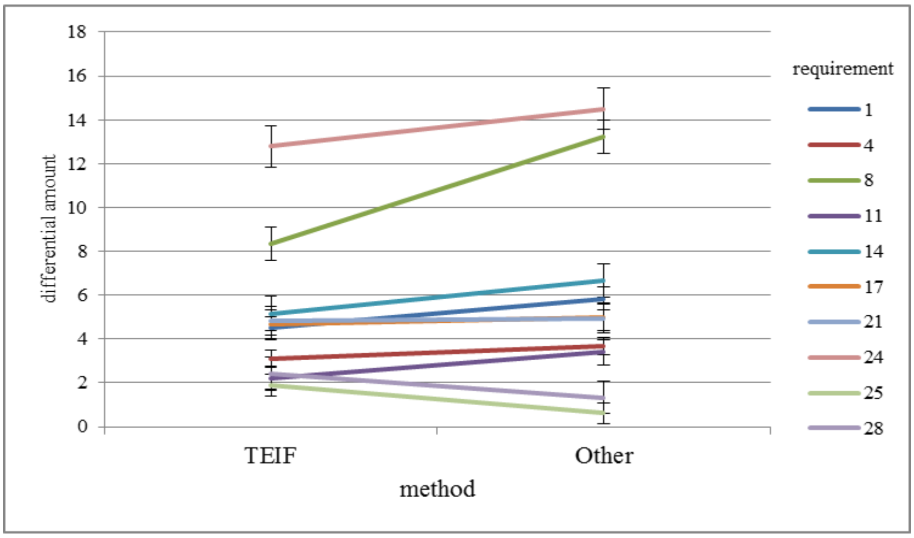
1) Marginal means for measures amount and direction for method and requirement for differential A-B

Table 9-68 shows the marginal means of measures amount and direction for differential A-B for *method* with the associated standard errors for each level of *requirement.*

Table 9-68 Marginal means of measures amount and direction for *method*requirement* for differential A-B

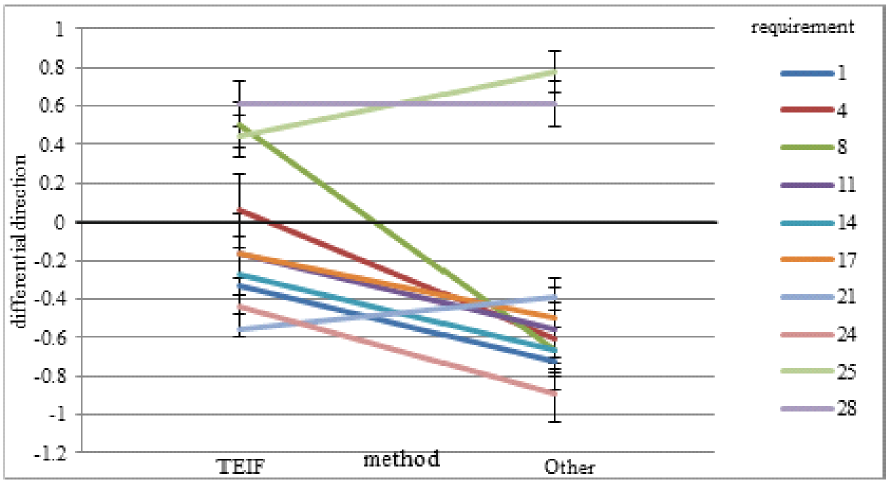
Measure	Method	Requirement	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Amount	TEIF	1	4.5	.525	3.43	5.57
		4	3.11	.408	2.28	3.94
		8	8.33	.760	6.79	9.88
		11	2.22	.562	1.08	3.37
		14	5.17	.776	3.59	6.74
		17	4.67	.637	3.37	5.96
		21	4.83	.668	3.48	6.19
		24	12.8	.946	10.9	14.7
		25	1.89	.489	.896	2.88
		28	2.44	.739	.942	3.95
	Other	1	5.83	.525	4.77	6.9
		4	3.67	.408	2.84	4.5
		8	13.2	.760	11.7	14.8
		11	3.39	.562	2.25	4.53
		14	6.67	.776	5.09	8.24
		17	5	.637	3.71	6.29
		21	4.94	.668	3.59	6.3
		24	14.5	.946	12.58	16.4
		25	.611	.489	-.382	1.6
		28	1.33	.739	-.169	2.84
Direction	TEIF	1	-.333	.188	-.715	.049
		4	.056	.195	-.340	.451
		8	.500	.118	.260	.740
		11	-.167	.210	-.593	.260
		14	-.278	.205	-.694	.138
		17	-.167	.210	-.594	.260
		21	-.556	.201	-.964	-.147
		24	-.444	.152	-.754	-.135
		25	.444	.111	.219	.670
		28	.611	.118	.371	.851
	Other	1	-.722	.188	-1.1	-.340
		4	-.611	.195	-1.01	-.215
		8	-.667	.118	-.906	-.427
		11	-.556	.210	-.982	-.129
		14	-.667	.205	-1.08	-.251
		17	-.500	.210	-.927	-.073
		21	-.389	.201	-.797	.020
		24	-.889	.152	-1.2	-.579
		25	.778	.111	.552	1
		28	.611	.118	.371	.851

Figure 9-24 illustrates marginal means for measures amount and direction for differential A-B over requirements for the two methods as shown in Table 9-68. Figure 9-25 illustrates marginal means for measure direction for differential A-B over requirements for the two methods as shown in Table 9-68.



Error bars are ±1standard error

Figure 9-24 Profile graph of marginal means for measures amount and direction for differential A-B over requirements for the two methods



Error bars are ±1standard error

Figure 9-25 Profile graph of marginal means for measure direction for differential A-B over requirements for the two methods

2) Simple simple main effects of method at each level of requirement

Table 9-69 shows the multivariate tests of simple simple main effects of *method* at each level of *requirement*. The significant value for multivariate test as suggested by Pillai's trace was used. There was only a significant simple simple main effect ($p<0.001$) of *method* for requirement 8, whereas there were no significant simple simple main effects of *method* for requirements 1, 4, 11, 14, 17, 21, 24, 25, and 28.

Table 9-69 Multivariate of simple simple main effects of *method* at each level of *requirement*

Requirement		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.089	1.6[a]	2	33	.216
	Wilks' lambda	.911	1.6[a]	2	33	.216
	Hotelling's trace	.097	1.6[a]	2	33	.216
	Roy's largest root	.097	1.6[a]	2	33	.216
4	Pillai's trace	.154	3.01[a]	2	33	.063
	Wilks' lambda	.846	3.01[a]	2	33	.063
	Hotelling's trace	.182	3.01[a]	2	33	.063
	Roy's largest root	.182	3.01[a]	2	33	.063
8	Pillai's trace	.591	23.8[a]	2	33	p<.001
	Wilks' lambda	.409	23.8[a]	2	33	p<.001
	Hotelling's trace	1.44	23.8[a]	2	33	p<.001
	Roy's largest root	1.44	23.8[a]	2	33	p<.001
11	Pillai's trace	.084	1.52[a]	2	33	.234
	Wilks' lambda	.916	1.52[a]	2	33	.234
	Hotelling's trace	.092	1.52[a]	2	33	.234
	Roy's largest root	.092	1.52[a]	2	33	.234
14	Pillai's trace	.057	1[a]	2	33	.379
	Wilks' lambda	.943	1[a]	2	33	.379
	Hotelling's trace	.061	1[a]	2	33	.379
	Roy's largest root	.061	1[a]	2	33	.379
17	Pillai's trace	.066	1.17[a]	2	33	.323
	Wilks' lambda	.934	1.17[a]	2	33	.323
	Hotelling's trace	.071	1.17[a]	2	33	.323
	Roy's largest root	.071	1.17[a]	2	33	.323
21	Pillai's trace	.026	.44[a]	2	33	.648
	Wilks' lambda	.974	.44[a]	2	33	.648
	Hotelling's trace	.027	.44[a]	2	33	.648
	Roy's largest root	.027	.44[a]	2	33	.648
24	Pillai's trace	.114	2.12[a]	2	33	.137
	Wilks' lambda	.886	2.12[a]	2	33	.137
	Hotelling's trace	.128	2.12[a]	2	33	.137
	Roy's largest root	.128	2.12[a]	2	33	.137
25	Pillai's trace	.122	2.3[a]	2	33	.116
	Wilks' lambda	.878	2.3[a]	2	33	.116
	Hotelling's trace	.139	2.3[a]	2	33	.116
	Roy's largest root	.139	2.3[a]	2	33	.116
28	Pillai's trace	.077	1.38[a]	2	33	.265
	Wilks' lambda	.923	1.38[a]	2	33	.265
	Hotelling's trace	.084	1.38[a]	2	33	.265
	Roy's largest root	.084	1.38[a]	2	33	.265

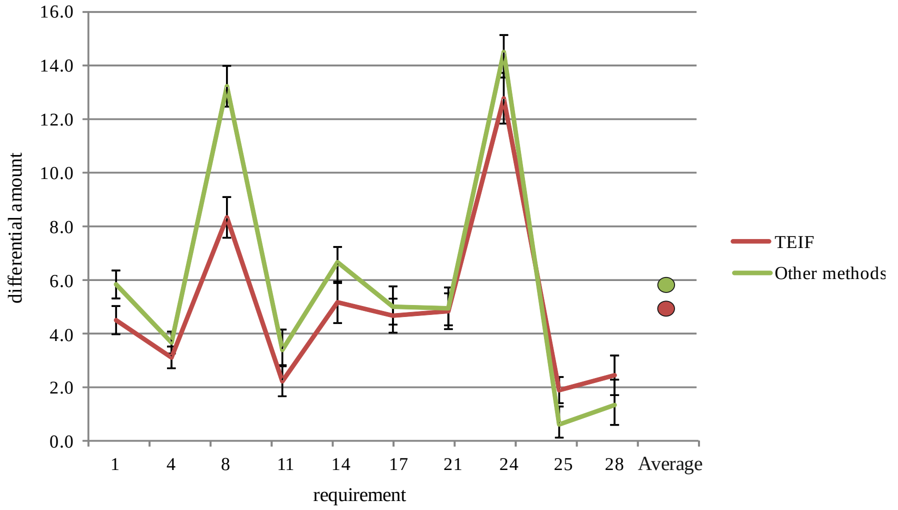
Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

Table 9-70 shows the univariate tests of simple simple main effects of *method* at each level of *requirement* on measures amount and direction for differential A-B. There was only a significant simple simple main effect of *method* for requirement 8 on both measures amount and direction for differential A-B. The full table is shown in Table 0-55, Appendix K. Figure 9-26 and Figure 9-27 illustrate these effects.

Table 9-70 Univariate tests of simple simple main effects of *method* at each level of *requirement* on measures amount and direction for differential A-B

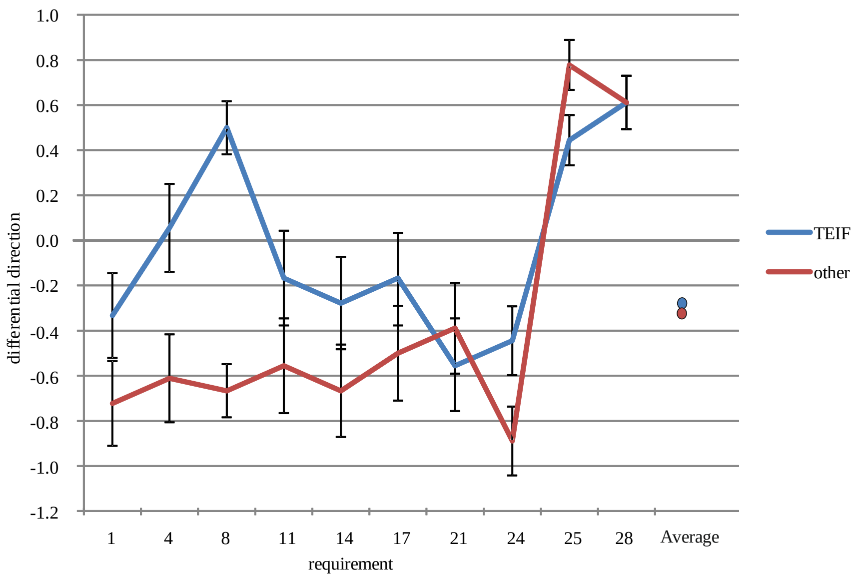
Measure	requirements		Sum of Squares	df	Mean Square	F	Sig.
Amount	8	Method	215	1	215	20.7	p<.001
		Error	353	34	10.4		
Direction	8	Method	12.3	1	12.3	49	p<.001
		Error	8.5	34	0.25		

Each F tests the simple effects of methods within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.



Error bars are ±1standard error

Figure 9-26 Profile graph of simple simple main effects of *method* at each level of *requirement* on measure amount for differential A-B



Error bars are ±1standard error

Figure 9-27 Profile graph of simple simple main effects of *method* at each level of *requirement* on measure direction for differential A-B

3) Simple simple main effects of requirement at each level of method

Table 9-71 shows the multivariate tests of simple simple main effects of *requirement* at each level of *method* for differential A-B. The significant value for multivariate test as suggested by Pillai's trace was used. There was a significant simple simple main effect of *requirement* for both the TEIF Method and the Other Methods (p < 0.001).

Table 9-71 Multivariate tests of simple main effects of *requirement* at each level of *method* for differential A-B

Method		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
TEIF	Pillai's trace	.917	10.5[a]	18	17	p<.001
	Wilks' lambda	.083	10.5[a]	18	17	p<.001
	Hotelling's trace	11.1	10.5[a]	18	17	p<.001
	Roy's largest root	11.1	10.5[a]	18	17	p<.001
Other	Pillai's trace	.931	12.7[a]	18	17	p<.001
	Wilks' lambda	.069	12.7[a]	18	17	p<.001
	Hotelling's trace	13.4	12.7[a]	18	17	p<.001
	Roy's largest root	13.4	12.7[a]	18	17	p<.001

Each F tests the multivariate simple effects of requirements within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

Table 9-72 shows the results of pairwise comparison between requirements using measure amount for the TEIF Method. There was a significant difference for measure amount for the TEIF Method between requirements 1 and 8, 1 and 24, 4 and 8, 4 and 24, 8 and 11, 8 and 17, 8 and 21, 8 and 24, 8 and 25, 8 and 28, 11 and 24, 14 and 24, 17 and 24, 21 and 24, 24 and 25, and 24 and 28.

However, there were no significant differences for measure amount for the TEIF Method between requirements 1 and 4, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 25, 1 and 28, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 25, 4 and 28, 8 and 14, 11 and 14, 11 and 17, 11 and 21, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 25, 14 and 28, 17 and 21, 17 and 25, 17 and 28, 21 and 25, 21 and 28, and 25 and 28.

Table 9-72 Pairwise comparisons of simple simple main effects between requirements on measure amount for differential A-B for the TEIF Method

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Amount	TEIF	1	4	1.39	0.625	0.778	-0.831	3.61
			8	-3.83*	0.966	0.016	-7.27	-0.401
			11	2.28	0.82	0.317	-0.617	5.17
			14	-0.667	0.82	1	-3.58	2.24
			17	-0.167	0.787	1	-2.96	2.63
			21	-0.333	0.878	1	-3.45	2.79
			24	-8.28*	1.01	p<0.001	-11.9	-4.71
			25	2.61	0.866	0.196	-0.468	5.69
			28	2.06	0.83	0.566	-0.893	5.01
		4	8	-5.22*	0.844	p<0.001	-8.22	-2.22
			11	0.889	0.649	1	-1.42	3.19
			14	-2.06	0.776	0.425	-4.82	0.704
			17	-1.56	0.701	0.781	-4.05	0.934
			21	-1.72	0.733	0.677	-4.33	0.884
			24	-9.67*	1.02	p<0.001	-13.3	-6.04
			25	1.22	0.659	0.966	-1.12	3.57
			28	0.667	0.967	1	-2.77	4.1
		8	11	6.11*	1.01	p<0.001	2.54	9.68
			14	3.17	1.02	0.157	-0.453	6.79
			17	3.67*	0.86	0.007	0.609	6.72
			21	3.5*	0.802	0.005	0.648	6.35
			24	-4.44*	1.09	0.011	-8.3	-0.584
			25	6.444*	0.977	p<0.001	2.97	9.92
			28	5.889*	1.063	p<0.001	2.11	9.67
		11	14	-2.944	1.056	0.323	-6.7	0.808
			17	-2.444	0.883	0.335	-5.58	0.692
			21	-2.611	0.966	0.382	-6.04	0.821
			24	-10.556*	1.117	p<0.001	-14.5	-6.58
			25	0.333	0.63	1	-1.91	2.57
			28	-0.222	0.875	1	-3.33	2.89
		14	17	0.5	0.791	1	-2.31	3.31
			21	0.333	0.941	1	-3.01	3.68
			24	-7.611*	0.94	p<0.001	-11	-4.27
			25	3.278	1.015	0.117	-0.329	6.89
			28	2.722	1.054	0.476	-1.02	6.47
		17	21	-0.167	0.826	1	-3.1	2.77
			24	-8.111*	0.908	p<0.001	-11.3	-4.89
			25	2.778	0.885	0.146	-0.367	5.92
			28	2.222	0.874	0.509	-0.882	5.32
		21	24	-7.944*	0.975	p<0.001	-11.4	-4.48
			25	2.944	0.89	0.096	-0.219	6.11
			28	2.389	1.078	0.783	-1.44	6.22
		24	25	10.889*	1.137	p<0.001	6.85	14.9
			28	10.333*	1.07	p<0.001	6.53	14.1
		25	28	-0.556	0.893	1	-3.73	2.62

*. The mean difference is significant at the .05 level.

Table 9-73 shows the results of pairwise comparison of simple simple main effects between requirements using measure amount for differential A-B for the Other Methods. There were significant differences for measure amount for differential A-B for the Other Methods between requirements 1 and 8, 1 and 24, 1 and 25, 1 and 28, 4 and 8, 4 and 14, 4 and 24, 4 and 25, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 25, 8 and 28, 11 and 24, 11 and 25, 14 and 24, 14 and 25, 14 and 28, 17 and 24, 17 and 25, 17 and 28, 21 and 24, 21 and 25, 24 and 25, and 24 and 28.

However, there were no significant differences for measure amount for differential A-B for the Other Methods between requirements 1 and 4, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 4 and 11, 4 and 17, 4 and 21, 4 and 28, 8 and 24, 11 and 14, 11 and 17, 11 and 21, 11 and 28, 14 and 17, 14 and 21, 17 and 21, 21 and 28, and 25 and 28.

Table 9-73 Pairwise comparisons between simple main effects of *requirement* on measure amount for the Other Methods for differential A-B

Measure	**Method**	**(I) requirements**	**(J) requirements**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence Interval for Difference[b]**	
							Lower Bound	**Upper Bound**
Amount	Other	1	4	2.17	0.625	0.063	-0.053	4.39
			8	-7.39*	0.966	p<0.001	-10.8	-3.96
			11	2.44	0.815	0.202	-0.45	5.34
			14	-0.833	0.819	1	-3.74	2.08
			17	0.833	0.787	1	-1.96	3.63
			21	0.889	0.878	1	-2.23	4.01
			24	-8.67*	1.01	p<0.001	-12.2	-5.1
			25	5.22*	0.866	p<0.001	2.14	8.3
			28	4.5*	0.83	p<0.001	1.55	7.45
		4	8	-9.56*	0.844	p<0.001	-12.6	-6.56
			11	0.278	0.649	1	-2.03	2.58
			14	-3*	0.776	0.021	-5.76	-0.241
			17	-1.33	0.701	0.953	-3.82	1.16
			21	-1.28	0.733	0.986	-3.88	1.33
			24	-10.8*	1.02	p<0.001	-14.5	-7.21
			25	3.06*	0.659	0.002	0.712	5.4
			28	2.33	0.967	0.621	-1.1	5.8
		8	11	9.83*	1.01	p<0.001	6.26	13.4
			14	6.56*	1.02	p<0.001	2.94	10.2
			17	8.22*	0.86	p<0.001	5.16	11.3
			21	8.28*	0.802	p<0.001	5.43	11.1
			24	-1.28	1.09	1	-5.14	2.58
			25	12.61*	0.977	p<0.001	9.14	16.1
			28	11.89*	1.06	p<0.001	8.11	15.7
		11	14	-3.28	1.06	0.159	-7.03	0.475
			17	-1.61	0.883	0.972	-4.75	1.53
			21	-1.56	0.966	0.996	-4.99	1.88
			24	-11.1*	1.12	p<0.001	-15.1	-7.14
			25	2.78*	0.63	0.004	0.538	5.02
			28	2.06	0.875	0.675	-1.05	5.16
		14	17	1.67	0.791	0.858	-1.14	4.48
			21	1.72	0.941	0.971	-1.62	5.07
			24	-7.83*	0.94	p<0.001	-11.2	-4.49
			25	6.06*	1.02	p<0.001	2.45	9.66
			28	5.33*	1.05	0.001	1.59	9.08
		17	21	0.056	0.826	1	-2.88	2.99
			24	-9.5*	0.908	p<0.001	-12.7	-6.27
			25	4.39*	0.885	0.001	1.24	7.53
			28	3.67*	0.874	0.008	0.562	6.77
		21	24	-9.56*	0.975	p<0.001	-13	-6.09
			25	4.33*	0.89	0.001	1.17	7.5
			28	3.61	1.08	0.085	-0.218	7.44
		24	25	13.9*	1.14	p<0.001	9.85	17.9
			28	13.2*	1.07	p<0.001	9.37	17
		25	28	-0.722	0.893	1	-3.9	2.45

Table 9-74 shows the results of pairwise comparison of simple simple main effects between requirements using measure direction for differential A-B for the TEIF Method. There were significant differences for measure direction for the TEIF Method between requirements 1 and 8, 1 and 28, 8 and 14, 8 and 17, 8 and 21, 8 and 24, 14 and 28, 21 and 25, 21 and 28, 24 and 25, and 24 and 28.

However, there were no significant differences for measure direction for differential A-B for the TEIF Method between requirements 1 and 4, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 25, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 4 and 25, 4 and 28, 8 and 11, 8 and 25, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 24, 14 and 25, 17 and 21, 17 and 24, 17 and 25,17 and 28, 21 and 24, and 25 and 28.

Table 9-74 Pairwise comparisons of simple simple main effects between requirements on measure direction for differential A-B for TEIF Method

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	TEIF	1	4	-0.389	0.236	0.994	-1.23	0.449
			8	-.833*	0.234	0.049	-1.66	-0.003
			11	-0.167	0.271	1	-1.13	0.797
			14	-0.056	0.18	1	-0.7	0.585
			17	-0.167	0.248	1	-1.05	0.714
			21	0.222	0.253	1	-0.67	1.12
			24	0.111	0.182	1	-0.536	0.758
			25	-0.778	0.234	0.093	-1.61	0.055
			28	-.944*	0.217	0.005	-1.72	-0.172
		4	8	-0.444	0.219	0.903	-1.22	0.334
			11	0.222	0.243	1	-0.64	1.09
			14	0.333	0.185	0.977	-0.324	0.991
			17	0.222	0.258	1	-0.696	1.14
			21	0.611	0.219	0.322	-0.168	1.39
			24	0.5	0.207	0.615	-0.234	1.23
			25	-0.389	0.238	0.995	-1.23	0.456
			28	-0.556	0.267	0.873	-1.5	0.392
		8	11	0.667	0.221	0.193	-0.117	1.45
			14	.778*	0.218	0.048	0.003	1.55
			17	.667*	0.174	0.023	0.049	1.29
			21	1.056*	0.208	0.001	0.315	1.8
			24	.944*	0.198	0.002	0.24	1.65
			25	0.056	0.159	1	-0.508	0.619
			28	-0.111	0.159	1	-0.675	0.452
		11	14	0.111	0.227	1	-0.696	0.918
			17	0	0.239	1	-0.849	0.849
			21	0.389	0.276	1	-0.594	1.37
			24	0.278	0.273	1	-0.692	1.25
			25	-0.611	0.257	0.648	-1.52	0.301
			28	-0.778	0.261	0.211	-1.7	0.149
		14	17	-0.111	0.191	1	-0.789	0.567
			21	0.278	0.203	1	-0.444	0.999
			24	0.167	0.179	1	-0.469	0.803
			25	-0.722	0.249	0.256	-1.61	0.164
			28	-.889*	0.24	0.034	-1.74	-0.034
		17	21	0.389	0.229	0.991	-0.424	1.2
			24	0.278	0.221	1	-0.508	1.06
			25	-0.611	0.262	0.688	-1.54	0.319
			28	-0.778	0.232	0.085	-1.6	0.046
		21	24	-0.111	0.199	1	-0.819	0.597
			25	-1.000*	0.244	0.011	-1.87	-0.132
			28	-1.167*	0.237	0.001	-2.01	-0.323
		24	25	-.889*	0.197	0.003	-1.59	-0.188
			28	-1.056*	0.178	p<0.001	-1.69	-0.422
		25	28	-0.167	0.146	1	-0.685	0.351

*. The mean difference is significant at the .05 level.

Table 9-75 shows the results of pairwise comparison of simple simple main effects between requirements using measure direction for differential A-B for the Other Methods. There were significant differences for measure direction for the Other Methods between requirements 1 and 25, 1 and 28, 4 and 25, 4 and 28, 8 and 25, 8 and 28, 11 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 25, 21 and 28, 24 and 25, and 24 and 28.

However, there were no significant differences for direction A-B for the Other Methods between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 24, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 14 and 17, 14 and 21, 14 and 24, 17 and 21, 17 and 24, 21 and 24, and 25 and 28.

Table 9-75 Pairwise comparisons of simple simple main effects between requirements on measure direction for Other Methods for differential A-B

Measure	**Method**	**(I) requirements**	**(J) requirements**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence Interval for Difference[b]**	
							Lower Bound	**Upper Bound**
Direction	Other	1	4	-0.111	0.236	1	-0.949	0.727
			8	-0.056	0.234	1	-0.886	0.775
			11	-0.167	0.271	1	-1.13	0.797
			14	-0.056	0.18	1	-0.696	0.585
			17	-0.222	0.248	1	-1.1	0.659
			21	-0.333	0.253	1	-1.23	0.565
			24	0.167	0.182	1	-0.48	0.814
			25	-1.5*	0.234	p<0.001	-2.33	-0.667
			28	-1.33*	0.217	p<0.001	-2.11	-0.561
		4	8	0.056	0.219	1	-0.723	0.834
			11	-0.056	0.243	1	-0.918	0.807
			14	0.056	0.185	1	-0.602	0.713
			17	-0.111	0.258	1	-1.03	0.807
			21	-0.222	0.219	1	-1	0.557
			24	0.278	0.207	1	-0.456	1.01
			25	-1.39*	0.238	p<0.001	-2.23	-0.544
			28	-1.22*	0.267	0.003	-2.17	-0.274
		8	11	-0.111	0.221	1	-0.895	0.673
			14	0	0.218	1	-0.775	0.775
			17	-0.167	0.174	1	-0.785	0.451
			21	-0.278	0.208	1	-1.02	0.462
			24	0.222	0.198	1	-0.482	0.927
			25	-1.44*	0.159	p<0.001	-2.01	-0.881
			28	-1.28*	0.159	p<0.001	-1.84	-0.714
		11	14	0.111	0.227	1	-0.696	0.918
			17	-0.056	0.239	1	-0.905	0.794
			21	-0.167	0.276	1	-1.15	0.816
			24	0.333	0.273	1	-0.637	1.3
			25	-1.33*	0.257	p<0.001	-2.25	-0.422
			28	-1.17*	0.261	0.004	-2.09	-0.24
		14	17	-0.167	0.191	1	-0.845	0.511
			21	-0.278	0.203	1	-0.999	0.444
			24	0.222	0.179	1	-0.414	0.858
			25	-1.44*	0.249	p<0.001	-2.33	-0.558
			28	-1.28*	0.24	p<0.001	-2.13	-0.423
		17	21	-0.111	0.229	1	-0.924	0.702
			24	0.389	0.221	0.984	-0.396	1.17
			25	-1.28*	0.262	0.001	-2.21	-0.348
			28	-1.11*	0.232	0.001	-1.94	-0.287
		21	24	0.5	0.199	0.537	-0.208	1.21
			25	-1.17*	0.244	0.001	-2.04	-0.299
			28	-1*	0.237	0.008	-1.84	-0.156
		24	25	-1.67*	0.197	p<0.001	-2.37	-0.966
			28	-1.5*	0.178	p<0.001	-2.13	-0.867
		25	28	0.167	0.146	1	-0.351	0.685

*. The mean difference is significant at the .05 level.

4) Summary of results for differential A-B

The measures amount and direction for differential A-B for the TEIF Method was closer to the experts for requirement 8 compared to the Other Methods. All other requirements were not significantly different.

The measures amount and direction for differential A-B for requirements 8 and 24 were different from the remaining requirements for both the TEIF Method and the Other Methods.

9.4.3.3.2 Differential between solutions A-C

Table 9-76 shows the results of multivariate tests. The second-order simple interaction effect of *requirement***method* for differential A-C was significant as suggested by Pillai's Trace. This indicates that the differential mean ratings of *requirement* depend on *method* and the mean differential ratings of *method* depend on *requirement*. Although the simple main effects of *requirement* and *method* (Table 9-77) were significant, they were not considered further as they were involved in the significant second-order simple interaction effect.

Table 9-76 Multivariate tests between differential A-C

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Requirement	Pillai's Trace	1.19	50	18	612	p<.001
	Wilks' Lambda	.145	55.2[c]	18	610	p<.001
	Hotelling's Trace	3.59	60.6	18	608	p<.001
	Roy's Largest Root	2.75	93.4[d]	9	306	p<.001
Requirement * Method	Pillai's Trace	.098	1.75	18	612	.028
	Wilks' Lambda	.904	1.75[c]	18	610	.028
	Hotelling's Trace	.104	1.75	18	608	.028
	Roy's Largest Root	.072	2.44[d]	9	306	.011

a. Design: Intercept + Method
Within Subjects Design: requirements
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-77 Tests of between-subjects effects between differential A-C

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
methods	different amount	.900	1	.900	.120	.731
	different direction	.711	1	.711	1.473	.233
Error	different amount	255.600	34	7.518		
	different direction	16.411	34	.483		

Table 9-78 shows the results of Mauchly's sphericity test between requirements within subjects effect for each of measure amount and direction. The significance values of this test indicate that both measures amount and direction failed the assumption of sphericity. Therefore the Lower- bound adjustment to significance was used for both measures amount and direction because it is the most conservative significance value (Field, 2013).

Table 9-78 Mauchly's test of sphericity between differential A-C

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Requirement	Amount	.024	115	44	p<.001	.559	.687	.111
	Direction	.135	61.7	44	.043	.745	.975	.111

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: requirements

Table 9-79 shows the univariate tests. The second-order simple interaction effect of *requirement***method* was significant (p<0.001) for measure direction, using both Greenhouse-Geisser and Hynh-Feldt adjustments. This indicates that the simple simple main effects of requirement on measure direction depend on *method,* and the simple simple main effects of method on measure direction depend on *requirement.*

The second-order simple interaction effect of *requirement***method* was not significant for measure amount. This indicates that the simple main effects of *requirement* on measure amount do not depend on *method*, and the simple main effects of *method* do not depend on *requirement.* The simple main effect of *requirement***method* on measure amount was considered further because there was not a significant second-order simple interaction effect.

The simple simple main effect of *requirement* was significant for both measures amount and direction as shown in Table 9-79. Table 9-80 shows that the simple main effect of method was not significant for both measures amount and direction.

Table 9-79 Univariate tests of simple main effects of *requirement***method* for differential A-C using measures amount and direction

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement	Amount	Sphericity Assumed	4313	9	479	70.44	p<.001
		Greenhouse-Geisser	4313	5.03	857	70.44	p<.001
		Huynh-Feldt	4313	6.18	698	70.44	p<.001
		Lower-bound	4313	1	4313	70.44	p<.001
	Direction	Sphericity Assumed	97	9	10.8	29.93	p<.001
		Greenhouse-Geisser	97	6.71	14.5	29.93	p<.001
		Huynh-Feldt	97	8.77	11.1	29.93	p<.001
		Lower-bound	97	1	97	29.93	p<.001
Requirement * Method	Amount	Sphericity Assumed	72.5	9	8.05	1.18	.305
		Greenhouse-Geisser	72.5	5.03	14.4	1.18	.319
		Huynh-Feldt	72.5	6.18	11.7	1.18	.316
		Lower-bound	72.5	1	72.5	1.18	.284
	Direction	Sphericity Assumed	6.9	9	.767	2.13	.027
		Greenhouse-Geisser	6.9	6.705	1.03	2.13	.044
		Huynh-Feldt	6.9	8.771	.787	2.13	.028
		Lower-bound	6.9	1	6.9	2.13	.154
Error(requirement)	Amount	Sphericity Assumed	2082	306	6.8		
		Greenhouse-Geisser	2082	171	12.2		
		Huynh-Feldt	2082	210	9.9		
		Lower-bound	2082	34	61.2		
	Direction	Sphericity Assumed	110	306	.360		
		Greenhouse-Geisser	110	228	.484		
		Huynh-Feldt	110	298	.370		
		Lower-bound	110	34	3.24		

Table 9-80 Tests of between-subjects simple main effects of method for differential A-C using measures amount and direction

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Method	Amount	.900	1	.9	.120	.731
	Direction	.711	1	.711	1.47	.233
Error	Amount	256	34	7.52		
	Direction	16.4	34	.483		

The following syntax '/EMMEANS' (IBM, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Method*requirement)COMPARE(Method)ADJ(sidak)

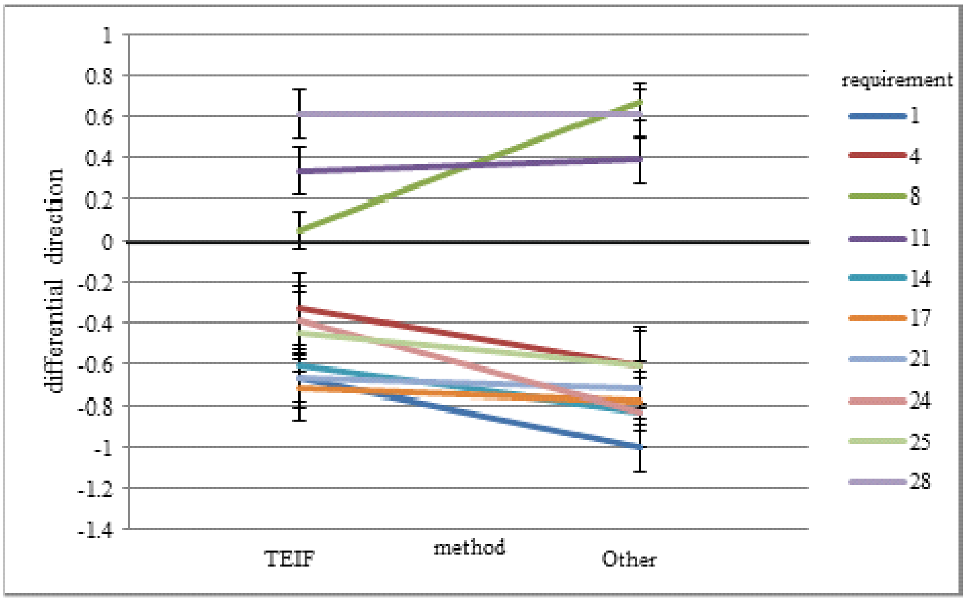
/EMMEANS=TABLES(Method*requirement)COMPARE(Requirement)ADJ(sidak)

1) *Marginal means for measures amount and direction for method and requirement for differential A-C*

Table 9-81 shows the marginal means for measure direction for differential A-C for *method* with the associated standard errors at each level of *requirement*. Figure 9-28 illustrates simple simple main effects of *requirement* on measure direction for differential A-C for *method.*

Table 9-81 Marginal means for measure direction for differential A-C for *requirement* and *method*

Measure	Method	requirements	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Direction	TEIF	1	-.667	.114	-.899	-.434
		4	-.333	.173	-.685	.018
		8	.056	.090	-.127	.238
		11	.333	.116	.097	.570
		14	-.611	.155	-.927	-.295
		17	-.722	.144	-1.02	-.429
		21	-.667	.138	-.947	-.387
		24	-.389	.166	-.725	-.052
		25	-.444	.193	-.836	-.053
		28	.611	.118	.371	.851
	Other	1	-1	.114	-1.23	-.768
		4	-.611	.173	-.962	-.260
		8	.667	.090	.484	.849
		11	.389	.116	.153	.625
		14	-.833	.155	-1.15	-.518
		17	-.778	.144	-1.07	-.485
		21	-.722	.138	-1	-.442
		24	-.833	.166	-1.17	-.497
		25	-.611	.193	-1	-.220
		28	.611	.118	.371	.851



Error bars are ±1standard error

Figure 9-28 Profile graph of simple simple main effects of *requirement* on measure direction for differential A-C for *method*

Table 9-82 shows the marginal means for measure amount for differential A-C for *method* overall requirement. Figure 9-29 and Figure 9-30 illustrate profile graph of marginal means for measure amount for *method* for differential A-C overall requirements.

Table 9-82 Marginal means measure amount for *method* overall requirements

Measure	Method	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Amount	TEIF	5.07	.204	4.65	5.48
	Other	5.17	.204	4.75	5.58

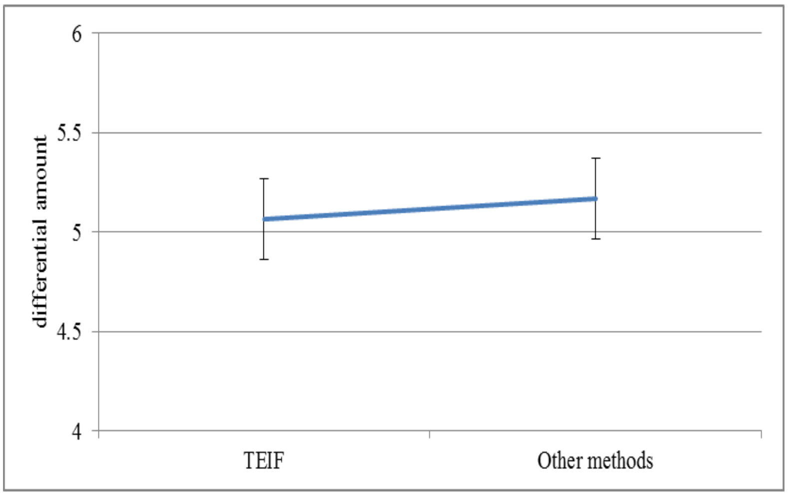
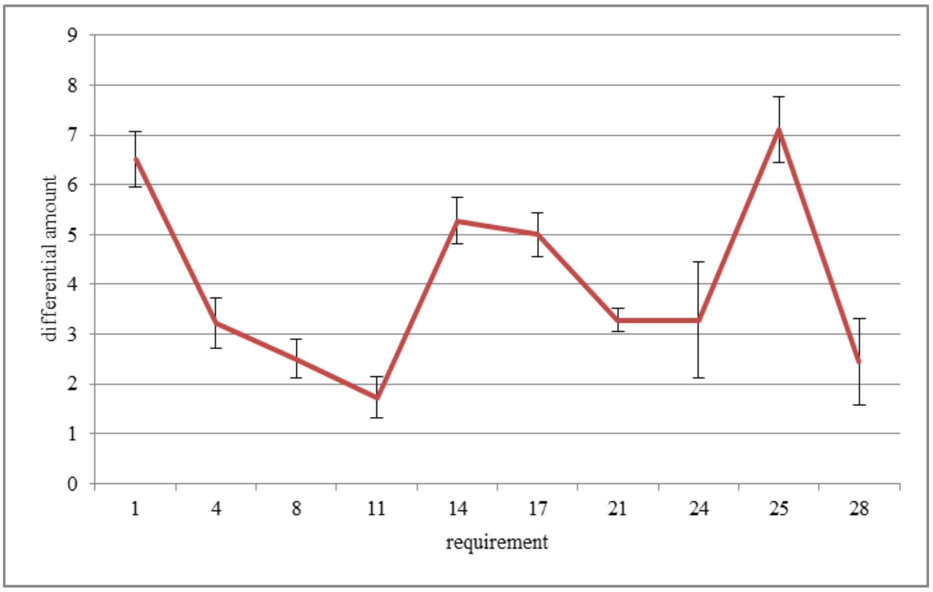


Figure 9-29 Profile graph of marginal means for measure amount for *method* for differential A-C overall requirements



Error bars are ±1standard error

Figure 9-30 Profile graph of simple main effects of *requirement* on measure amount for differential A-C overall methods

Table 9-83 shows the marginal means for measure amount for *method* with the associated standard errors for each level of *requirement* for differential A-C.

Table 9-83 Marginal means for measure amount for differential A-C for *requirement* overall methods

Measure	Requirement	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	**Upper Bound**
Amount	1	6.89	.373	6.13	7.65
	4	3.19	.285	2.62	3.77
	8	1.56	.244	1.06	2.05
	11	1.94	.402	1.13	2.76
	14	6.03	.447	5.12	6.94
	17	5.17	.323	4.51	5.82
	21	3.31	.221	2.86	3.75
	24	13.5	.730	12	15
	25	7.53	.517	6.48	8.58
	28	2.03	.561	.888	3.17

Table 9-84 shows the results of pairwise comparison of simple simple main effects between requirements on measure amount for differential A-C overall methods. There were significant differences for measure amount between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 17, 1 and 21, 1 and 24, 1 and 28, 4 and 8, 4 and 14, 4 and 17, 4 and 24, 4 and 25, 8 and 14, 8 and 17, 8 and 21, 8 and 24, 8 and 25, 11 and 14, 11 and 17, 11 and 24, 11 and 25, 14 and 21, 14 and 24, 14 and 28, 17 and 21, 17 and 24, 17 and 28, 21 and 24, 21 and 25, 24 and 25, 24 and 28, and 25 and 28.

However, there were no significant differences between requirements 1 and 14, 1 and 25, 4 and 11, 4 and 21, 4 and 28, 8 and 11, 8 and 28, 11 and 21, 11 and 28, 14 and 17, 14 and 25, 17 and 25, and 21 and 28. Figure 9-30 illustrates these results.

Table 9-84 Pairwise comparisons of simple simple main effects between requirements on measure amount overall method for differential A-C

Measure	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Amount	1	4	3.694*	0.511	0	1.875	5.514
		8	5.333*	0.422	0	3.83	6.837
		11	4.944*	0.535	0	3.037	6.852
		14	0.861	0.578	1	-1.2	2.922
		17	1.722*	0.402	0.006	0.291	3.153
		21	3.583*	0.333	0	2.396	4.771
		24	-6.639*	0.917	0	-9.908	-3.37
		25	-0.639	0.664	1	-3.006	1.728
		28	4.861*	0.607	0	2.699	7.024
	4	8	1.639*	0.333	0.001	0.451	2.827
		11	1.25	0.527	1	-0.629	3.129
		14	-2.833*	0.551	0.001	-4.795	-0.871
		17	-1.972*	0.48	0.011	-3.681	-0.263
		21	-0.111	0.342	1	-1.331	1.109
		24	-10.333*	0.773	0	-13.088	-7.578
		25	-4.333*	0.577	0	-6.387	-2.279
		28	1.167	0.641	1	-1.118	3.452
	8	11	-0.389	0.491	1	-2.14	1.362
		14	-4.472*	0.513	0	-6.298	-2.646
		17	-3.611*	0.422	0	-5.115	-2.107
		21	-1.750*	0.309	0	-2.85	-0.65
		24	-11.972*	0.852	0	-15.007	-8.937
		25	-5.972*	0.538	0	-7.889	-4.055
		28	-0.472	0.593	1	-2.586	1.642
	11	14	-4.083*	0.549	0	-6.039	-2.128
		17	-3.222*	0.498	0	-4.998	-1.446
		21	-1.361	0.467	0.282	-3.025	0.303
		24	-11.583*	0.914	0	-14.841	-8.326
		25	-5.583*	0.639	0	-7.859	-3.308
		28	-0.083	0.722	1	-2.656	2.489
	14	17	0.861	0.566	1	-1.155	2.877
		21	2.722*	0.5	0	0.94	4.505
		24	-7.500*	0.806	0	-10.373	-4.627
		25	-1.5	0.528	0.339	-3.38	0.38
		28	4.000*	0.709	0	1.475	6.525
	17	21	1.861*	0.34	0	0.649	3.073
		24	-8.361*	0.764	0	-11.082	-5.64
		25	-2.361	0.674	0.059	-4.762	0.04
		28	3.139*	0.663	0.002	0.777	5.501
	21	24	-10.222*	0.782	0	-13.007	-7.438
		25	-4.222*	0.532	0	-6.119	-2.326
		28	1.278	0.614	1	-0.911	3.467
	24	25	6.000*	0.8	0	3.15	8.85
		28	11.500*	0.976	0	8.024	14.976
	25	28	5.500*	0.709	0	2.973	8.027

Based on estimated marginal means

*. The mean difference is significant at the

b. Adjustment for multiple comparisons: Bonferroni.

2) Simple simple main effects of method at different level of requirement

Analysis of the simple simple main effects of *method* at different levels of *requirement* is only needed on measure direction as a univariate test. The multivariate test is shown in Table 0-56, Appendix K.

Table 9-85 shows the univariate tests of simple simple main effects of *method* for each level of *requirement* on measure direction for differential A-C. The simple simple main effects of *method* for requirements 1 and 8 were significant on measure direction for differential A-C. Figure 9-31 illustrates these results.

Table 9-85 Univariate tests of simple simple main effects of *method* at each level of *requirement* for differential A-C

Measure	requirements		Sum of Squares	df	Mean Square	F	Sig.
Direction	1	Method	1	1	1	4.25	.047
		Error	8	34	.235		
	4	Method	.694	1	.694	1.29	.264
		Error	18.3	34	.538		
	8	Method	3.36	1	3.36	23.1	p<.001
		Error	4.94	34	.145		
	11	Method	.028	1	.028	.114	.738
		Error	8.28	34	.243		
	14	Method	.444	1	.444	1	.319
		Error	14.8	34	.435		
	17	Method	.028	1	.028	.074	.787
		Error	12.7	34	.374		
	21	Method	.028	1	.028	.081	.777
		Error	11.6	34	.342		
	24	Method	1.778	1	1.78	3.6	.066
		Error	16.8	34	.493		
	25	Method	.250	1	.250	.374	.545
		Error	22.7	34	.668		
	28	Method	.000	1	.000	.000	1
		Error	8.56	34	.252		

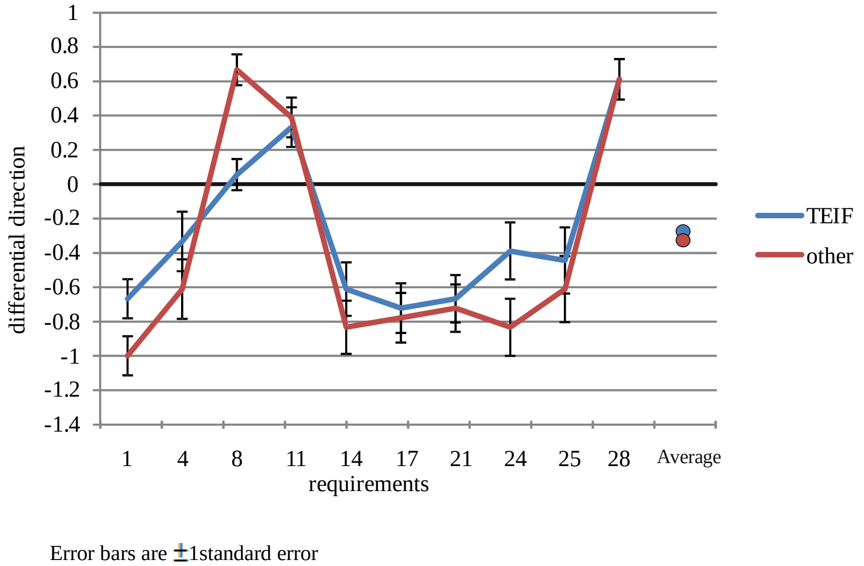


Figure 9-31 Profile graph of simple simple main effects of *requirement* on measure direction for differential A-C

3) Simple simple main effects of requirement at each level of method

Analysis of the simple simple main effects between requirements at each level of *method* is only needed on measure direction as pairwise comparisons.

Table 9-86 shows the results of pairwise comparison of simple simple main effects between requirements on measure direction for the TEIF Method for differential A-C. There were significant differences for measure direction for the TEIF Method between requirements 1 and 8, 1 and 11, 1 and 28, 4 and 28, 8 and 14, 8 and 17, 8 and 21, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 14 and 28, 17 and 28, 21 and 28, 24 and 28, and 25 and 28.

However, there were no significant differences for measure direction for the TEIF Method between requirements 1 and 4, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 25, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 4 and 25, 8 and 11, 8 and 24, 8 and 25, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 24, 14 and 25, 17 and 21, 17 and 24, 17 and 25, 21 and 24, 21 and 25, and 24 and 25.

Table 9-86 Pairwise comparisons of simple simple main effects between requirements on measure direction for TEIF Method for differential A-C

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.^{b}	95% Confidence Interval for Difference^{b}	
							Lower Bound	Upper Bound
Direction	TEIF	1	4	-0.333	0.222	0.999	-1.12	0.457
			8	-0.722*	0.149	0.001	-1.25	-0.192
			11	-1*	0.13	p<0.001	-1.46	-0.539
			14	-0.056	0.196	1	-0.751	0.64
			17	0.056	0.162	1	-0.52	0.631
			21	0	0.16	1	-0.568	0.568
			24	-0.278	0.229	1	-1.09	0.536
			25	-0.222	0.234	1	-1.05	0.608
			28	-1.278*	0.171	p<0.001	-1.89	-0.67
		4	8	-0.389	0.161	0.621	-0.961	0.184
			11	-0.667	0.221	0.198	-1.45	0.12
			14	0.278	0.238	1	-0.569	1.12
			17	0.389	0.224	0.987	-0.408	1.19
			21	0.333	0.213	0.998	-0.424	1.09
			24	0.056	0.214	1	-0.705	0.816
			25	0.111	0.248	1	-0.772	0.994
			28	-0.944*	0.222	0.007	-1.73	-0.157
		8	11	-0.278	0.135	0.891	-0.759	0.203
			14	0.667*	0.174	0.023	0.049	1.29
			17	0.778*	0.179	0.005	0.143	1.41
			21	0.722*	0.171	0.008	0.115	1.33
			24	0.444	0.194	0.721	-0.244	1.13
			25	0.5	0.198	0.53	-0.205	1.21
			28	-0.556*	0.136	0.012	-1.04	-0.071
		11	14	0.944*	0.206	0.003	0.211	1.68
			17	1.06*	0.169	p<0.001	0.456	1.66
			21	1*	0.18	p<0.001	0.361	1.64
			24	0.722*	0.201	0.045	0.008	1.44
			25	0.778	0.225	0.066	-0.023	1.58
			28	-0.278	0.175	0.997	-0.899	0.344
		14	17	0.111	0.201	1	-0.603	0.825
			21	0.056	0.193	1	-0.629	0.74
			24	-0.222	0.203	1	-0.942	0.498
			25	-0.167	0.212	1	-0.921	0.588
			28	-1.22*	0.188	p<0.001	-1.89	-0.555
		17	21	-0.056	0.18	1.000	-0.696	0.585
			24	-0.333	0.202	0.994	-1.05	0.384
			25	-0.278	0.262	1	-1.21	0.654
			28	-1.33*	0.215	p<0.001	-2.1	-0.569
		21	24	-0.278	0.212	1	-1.03	0.474
			25	-0.222	0.217	1	-0.994	0.55
			28	-1.28*	0.205	p<0.001	-2.01	-0.551
		24	25	0.056	0.243	1	-0.807	0.918
			28	-1*	0.208	0.001	-1.74	-0.261
		25	28	-1.06*	0.222	0.002	-1.84	-0.268

Based on marginal means
* The mean difference is significant at the
b Adjustment for multiple comparisons: Sidak.

Table 9-87 shows the results of pairwise comparison of simple simple main effects between requirements on measure direction for the Other Methods. There were significant differences for measure direction for the Other Methods between requirements 1 and 8, 1 and 11, 1 and 28, 4 and 8, 4 and 11, 4 and 28, 8 and 14, 8 and

17, 8 and 21, 8 and 24, 8 and 25, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 11 and 25, 14 and 28, 17 and 28, 21 and 28, 24 and 28, and 25 and 28.

However, there were no significant differences for *requirement* on measure direction for the Other Methods between requirements 1 and 4, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 25, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 4 and 25, 8 and 11, 8 and 28, 11 and 28, 14 and 17, 14 and 21, 14 and 24, 14 and 25, 17 and 21, 17 and 24, 17 and 25, 21 and 24, 21 and 25, and 24 and 25.

Table 9-87 Pairwise comparisons of simple simple main effects of *requirement* on measure direction for Other Methods for differential A-C

Measure	**Method**	**requirements** (I)	(J)	**Mean Difference (I-J)**	**Std. Error**	**Sig.**[b]	**95% Confidence Interval for Difference** [b] **Lower Bound**	**Upper Bound**
Direction	Other	1	4	-0.389	0.222	0.985	-1.18	0.402
			8	-1.67*	0.149	p<0.001	-2.2	-1.14
			11	-1.39*	0.13	p<0.001	-1.85	-0.928
			14	-0.167	0.196	1	-0.862	0.529
			17	-0.222	0.162	1	-0.798	0.353
			21	-2.78	0.16	0.986	-0.845	0.29
			24	-0.167	0.229	1	-0.981	0.647
			25	-0.389	0.234	0.993	-1.22	0.441
			28	-1.611*	0.171	p<0.001	-2.22	-1
		4	8	-1.278*	0.161	p<0.001	-1.85	-0.705
			11	-1*	0.221	0.003	-1.79	-0.213
			14	0.222	0.238	1	-0.624	1.07
			17	0.167	0.224	1	-0.63	0.964
			21	0.111	0.213	1	-0.646	0.868
			24	0.222	0.214	1	-0.539	0.983
			25	0	0.248	1	-0.883	0.883
			28	-1.222*	0.222	p<0.001	-2.01	-0.435
		8	11	0.278	0.135	0.891	-0.203	0.759
			14	1.5*	0.174	p<0.001	0.882	2.12
			17	1.44*	0.179	p<0.001	0.809	2.08
			21	1.39*	0.171	p<0.001	0.781	2
			24	1.5*	0.194	p<0.001	0.812	2.19
			25	1.28*	0.198	p<0.001	0.572	1.98
			28	0.056	0.136	1	-0.429	0.54
		11	14	1.22*	0.206	p<0.001	0.489	1.96
			17	1.17*	0.169	p<0.001	0.567	1.77
			21	1.11*	0.18	p<0.001	0.472	1.75
			24	1.22*	0.201	p<0.001	0.508	1.94
			25	1*	0.225	0.004	0.199	1.8
			28	-0.222	0.175	1	-0.844	0.399
		14	17	-0.056	0.201	1	-0.77	0.659
			21	-0.111	0.193	1	-0.796	0.574
			24	0	0.203	1	-0.72	0.72
			25	-0.222	0.212	1	-0.977	0.533
			28	-1.44*	0.188	p<0.001	-2.11	-0.778
		17	21	-0.056	0.18	1	-0.696	0.585
			24	0.056	0.202	1	-0.662	0.773
			25	-0.167	0.262	1	-1.1	0.766
			28	-1.39*	0.215	p<0.001	-2.15	-0.625
		21	24	0.111	0.212	1	-0.641	0.863
			25	-0.111	0.217	1	-0.883	0.661
			28	-1.33*	0.205	p<0.001	-2.06	-0.606
		24	25	-0.222	0.243	1	-1.09	0.64
			28	-1.44*	0.208	p<0.001	-2.18	-0.706
		25	28	-1.22*	0.222	p<0.001	-2.01	-0.435

Based on marginal means

4) Summary of results for differential A-C

There was no significant difference between methods for measure amount for differential A-C. The measure direction for differential A-C for the TEIF Method was closer to the experts for requirements 1 and 24 compared to the Other Methods. The measure direction for differential A-C for the Other Methods was closer to the experts for requirement 8 compared to the TEIF Method.

The results of pairwise comparison for *requirement* on measure direction showed significant differences for measure direction for the TEIF Method between 17 pairs of requirements and for measure direction for the Other Methods between 21 pairs of requirements.

9.4.3.3.3 Differences between solutions B-C

Table 9-88 shows the results of multivariate tests. The second-order simple interaction effect of *requirement*method* for differential B-C was significant (p<0.001) as suggested by Pillai's Trace. This indicates that the differential mean ratings of *requirement* depend on *method* and the differential mean ratings of *method* depend on *requirement*. Although, the simple simple main effects of *method* (Table 9-89) and *requirement* (Table 9-88) were significant, they were not considered separately as they were involved in the significant second-order simple interaction.

Table 9-88 Multivariate tests between differential B-C

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Requirement	Pillai's Trace	.957	31.2	18	612	p<.001
	Wilks' Lambda	.248	34.2[c]	18	610	p<.001
	Hotelling's Trace	2.21	37.3	18	608	p<.001
	Roy's Largest Root	1.73	58.8[d]	9	306	p<.001
Requirement * Method	Pillai's Trace	.228	4.38	18	612	p<.001
	Wilks' Lambda	.775	4.61[c]	18	610	p<.001
	Hotelling's Trace	.287	4.84	18	608	p<.001
	Roy's Largest Root	.272	9.26[d]	9	306	p<.001

a. Design: Intercept + Method
Within Subjects Design: requirements
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-89 Tests of between-subjects effects between solutions B-C

Source	**Variable**	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Method	differential amount	14.400	1	14.400	1.498	.229
	differential direction	2.669	1	2.669	8.181	.007
Error	differential amount	326.856	34	9.613		
	differential direction	11.094	34	.326		

Table 9-90 shows the results of Mauchly's sphericity test of the *requirement* within subjects effect for each of measure amount and direction. The significance values of this test indicate that both measures amount and direction failed the assumption of sphericity. Therefore the Lower-bound adjustment to significance was used for both measures amount and direction because it is the most conservative significance value (Field, 2013).

Table 9-90 Mauchly's test of sphericity of differential B-C

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Requirement	Amount	.039	100	44	p<.001	.619	.775	.111
	Direction	.034	104	44	p<.001	.602	.750	.111

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: requirements
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-91 shows the univariate tests of the second-order simple interaction effect of *requirement***method* was significant for both measures amount and direction. The significance values of these tests indicate that the mean differential ratings of *requirement* on both measures amount and direction depend on *method*, and similarly the mean differential ratings of *method* depend on *requirement*. Therefore the simple simple main effects of *requirement* (Table 9-88) and *method* (Table 9-89) were not considered further as they were involved in significant second-order simple interactions.

Table 9-91 Univariate tests of *requirement***method* for differential B-C

Source	Variable		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement * Method	Amount	Sphericity Assumed	459	9	51	8	p<.001
		Greenhouse-Geisser	459	5.57	82	8	p<.001
		Huynh-Feldt	459	6.98	66	8	p<.001
		Lower-bound	459	1	459	8	.008
	Direction	Sphericity Assumed	23.8	9	2.65	6	p<.001
		Greenhouse-Geisser	23.8	5.42	4.39	6	p<.001
		Huynh-Feldt	23.8	6.75	3.52	6	p<.001
		Lower-bound	23.8	1	23.8	6	.020
Error(requirement)	Amount	Sphericity Assumed	1949	306	6.7		
		Greenhouse-Geisser	1949	189	10.3		
		Huynh-Feldt	1949	237	8.22		
		Lower-bound	1949	34	57.3		
	Direction	Sphericity Assumed	135	306	.440		
		Greenhouse-Geisser	135	184	.731		
		Huynh-Feldt	135	230	.587		
		Lower-bound	135	34	3.96		

The following syntax '/EMMEANS' (SPSS, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Method*Requirement)COMPARE(Method) ADJ(sidak)

/EMMEANS=TABLES(Method*Requirement)COMPARE(Requirement) ADJ(sidak)

1) *Marginal means for measures amount and direction for method and requirement for differential B-C*

Table 9-92 shows the marginal for measures amount and direction for method and requirement for differential B-C with the associated standard errors.

Table 9-92 Marginal means of differential B-C

Variable	**Method**	**requirements**	**Mean**	**Std. Error**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Amount	TEIF	1	3.56	.543	2.45	4.66
		4	2.67	.502	1.65	3.68
		8	7.17	.794	5.55	8.78
		11	2.83	.537	1.74	3.92
		14	2.89	.716	1.43	4.34
		17	2.67	.533	1.58	3.75
		21	2.67	.544	1.56	3.77
		24	2.5	.603	1.27	3.73
		25	8.44	.817	6.78	10.1
		28	.000	.359	-.730	.730
	Other	1	2.11	.543	1	3.21
		4	1.39	.502	.369	2.41
		8	13.7	.794	12.1	15.3
		11	3.11	.537	2.02	4.2
		14	3.33	.716	1.88	4.79
		17	1.67	.533	.583	2.75
		21	3.94	.544	2.84	5.5
		24	1.39	.603	.163	2.62
		25	7.67	.817	6	9.33
		28	1.06	.359	.326	1.79
Direction	TEIF	1	-.556	.200	-.962	-.149
		4	.222	.111	-.004	.448
		8	.833	.112	.607	1.06
		11	-.222	.220	-.669	.225
		14	.278	.109	.057	.499
		17	.222	.108	.003	.441
		21	-.389	.217	-.829	.051
		24	.389	.118	.149	.629
		25	-.611	.184	-.985	-.237
		28	1	.084	.830	1.17
	Other	1	-.333	.200	-.739	.073
		4	.444	.111	.219	.670
		8	-.778	.112	-1	-.551
		11	-.500	.220	-.947	-.053
		14	.278	.109	.057	.499
		17	.333	.108	.114	.552
		21	-.444	.217	-.885	-.004
		24	.389	.118	.149	.629
		25	-.556	.184	-.930	-.182
		28	.611	.084	.441	.781

2) Simple simple main effects of method at each level of requirement for differential B-C

Table 9-93 shows the multivariate tests of simple main effects of *method* at each level of *requirement*. The significant value for multivariate tests as suggested by Pillai's trace was used. There were significant simple simple main effects of *method* for requirements 8 ($p<0.001$) and 28 ($p<0.05$), whereas there were no significant simple simple main effects of *method* for requirements 1, 4, 11, 14, 17, 21, 24, and 25.

Table 9-93 Multivariate simple simple main effects of *method* at each level of *requirement* for differential B-C

Requirement		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
1	Pillai's trace	.094	1.719[a]	2	33	.195
	Wilks' lambda	.906	1.719[a]	2	33	.195
	Hotelling's trace	.104	1.719[a]	2	33	.195
	Roy's largest root	.104	1.719[a]	2	33	.195
4	Pillai's trace	.090	1.630[a]	2	33	.211
	Wilks' lambda	.910	1.630[a]	2	33	.211
	Hotelling's trace	.099	1.630[a]	2	33	.211
	Roy's largest root	.099	1.630[a]	2	33	.211
8	Pillai's trace	.756	51.231[a]	2	33	p<.001
	Wilks' lambda	.244	51.231[a]	2	33	p<.001
	Hotelling's trace	3.105	51.231[a]	2	33	p<.001
	Roy's largest root	3.105	51.231[a]	2	33	p<.001
11	Pillai's trace	.023	.389[a]	2	33	.681
	Wilks' lambda	.977	.389[a]	2	33	.681
	Hotelling's trace	.024	.389[a]	2	33	.681
	Roy's largest root	.024	.389[a]	2	33	.681
14	Pillai's trace	.010	.163[a]	2	33	.850
	Wilks' lambda	.990	.163[a]	2	33	.850
	Hotelling's trace	.010	.163[a]	2	33	.850
	Roy's largest root	.010	.163[a]	2	33	.850
17	Pillai's trace	.049	.855[a]	2	33	.434
	Wilks' lambda	.951	.855[a]	2	33	.434
	Hotelling's trace	.052	.855[a]	2	33	.434
	Roy's largest root	.052	.855[a]	2	33	.434
21	Pillai's trace	.085	1.527[a]	2	33	.232
	Wilks' lambda	.915	1.527[a]	2	33	.232
	Hotelling's trace	.093	1.527[a]	2	33	.232
	Roy's largest root	.093	1.527[a]	2	33	.232
24	Pillai's trace	.075	1.346[a]	2	33	.274
	Wilks' lambda	.925	1.346[a]	2	33	.274
	Hotelling's trace	.082	1.346[a]	2	33	.274
	Roy's largest root	.082	1.346[a]	2	33	.274
25	Pillai's trace	.020	.337[a]	2	33	.716
	Wilks' lambda	.980	.337[a]	2	33	.716
	Hotelling's trace	.020	.337[a]	2	33	.716
	Roy's largest root	.020	.337[a]	2	33	.716
28	Pillai's trace	.241	5.250[a]	2	33	.010
	Wilks' lambda	.759	5.250[a]	2	33	.010
	Hotelling's trace	.318	5.250[a]	2	33	.010
	Roy's largest root	.318	5.250[a]	2	33	.010

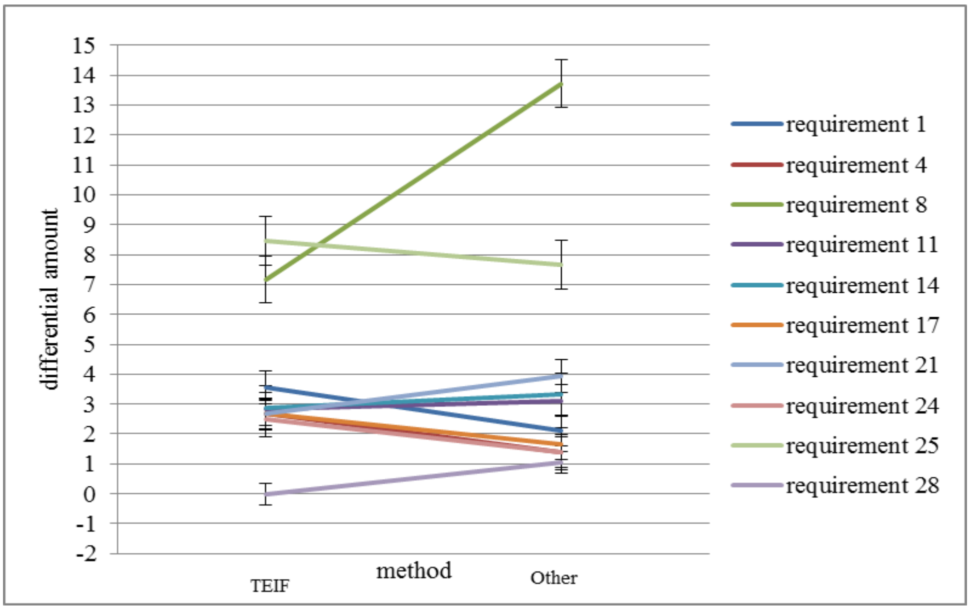
Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

Table 9-94 shows the univariate tests of simple simple main effects of *method* within each level of *requirement* on measures amount and direction. There were significant simple simple main effects of *method* on both measures amount and direction for requirements 8 ($p<0.001$) and 28 ($p<0.05$). The full table is shown in Table 0-57, Appendix K. Figure 9-32 and Figure 9-33 illustrate these results.

Table 9-94 Univariate tests of simple simple main effects of *method* at each level of *requirement* for differential B-C

Difference	**Requirement**		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Amount	8	Method	387	1	387	34.6	p<.001
		error	386	34	11.4		
	28	Method	10	1	10	4.32	.045
		error	78.9	34	2.32		
Direction	8	Method	23.4	1	23.4	104	p<.001
		error	7.61	34	.224		
	28	Method	1.36	1	1.36	10.9	.002
		error	4.28	34	.126		

Each F tests the simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.



Error bars are ±1standard error

Figure 9-32 Profile graph of simple simple main effects of *requirement* on measure amount at each level of *method* for differential B-C

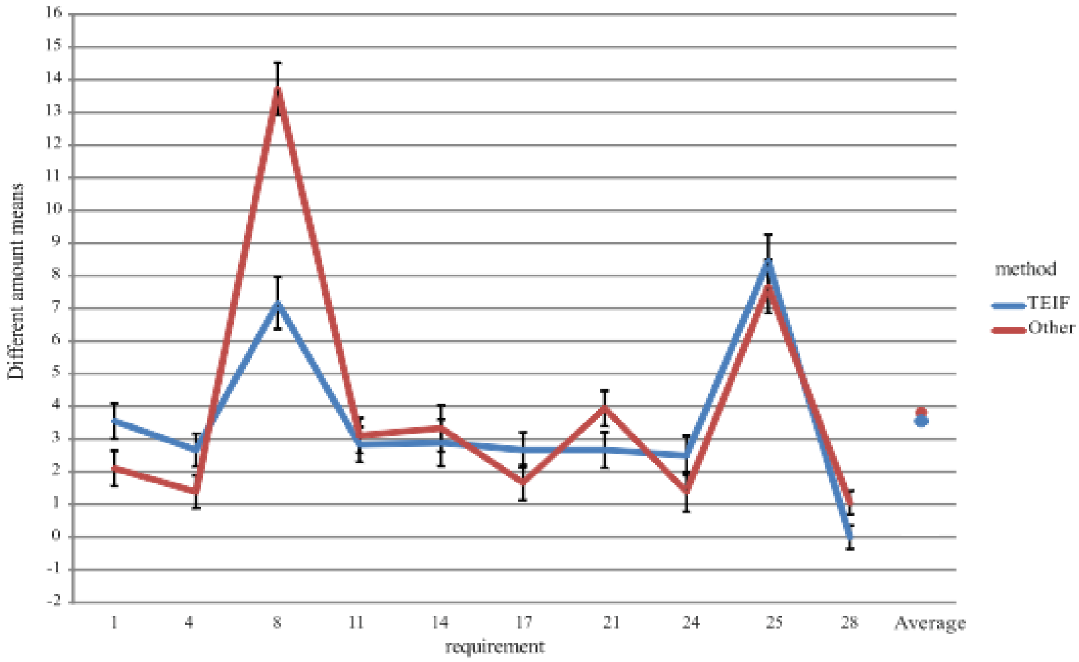
3) Simple simple main effects of requirement at each level of method for differential B-C

Table 9-95 shows the multivariate tests of simple simple main effects of *requirement* at each level of *method*. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects for *requirement* for the TEIF Method and the Other Methods (p < 0.001).

Table 9-95 Multivariate tests of simple simple main effects for *requirement* at each level of *method* for differential B-C

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.967	27.5[a]	18	17	p<.001
	Wilks' lambda	.033	27.5[a]	18	17	p<.001
	Hotelling's trace	29.1	27.5[a]	18	17	p<.001
	Roy's largest root	29.1	27.5[a]	18	17	p<.001
Other	Pillai's trace	.952	18.6[a]	18	17	p<.001
	Wilks' lambda	.048	18.6[a]	18	17	p<.001
	Hotelling's trace	19.7	18.6[a]	18	17	p<.001
	Roy's largest root	19.7	18.6[a]	18	17	p<.001

Each F tests the multivariate simple effects of requirements within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic



Error bars are ±1standard error

Figure 9-33 Profile graph of simple simple main effects of *method* on measure amount at each level of *requirement* for differential B-C

Table 9-96 shows the results of pairwise comparison of simple simple main effects between requirements on measure amount for the TEIF Method. There were significant differences for *requirement* on measure amount for the TEIF Method between requirements 1 and 25, 4 and 8, 4 and 25, 4 and 28, 8 and 17, 8 and 21, 8 and 24, 8 and 28, 11 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 25, 21 and 28, 24 and 25, 24 and 28, and 25 and 28.

However, there were no significant differences for measure amount for the TEIF Method between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 28, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 11, 8 and 14, 8 and 25, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 14 and 17, 14 and 21, 14 and 24, 17 and 21, 17 and 24, 21 and 24.

Table 9-96 Pairwise comparisons of simple simple main effects between requirements on measure amount for differential B-C at each level of *method* for TEIF Method

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Amount	TEIF	1	4	0.889	0.547	0.996	-1.06	2.83
			8	-3.61	1.02	0.052	-7.24	0.013
			11	0.722	0.729	1	-1.87	3.31
			14	0.667	0.859	1	-2.38	3.72
			17	0.889	0.815	1	-2.01	3.78
			21	8.89	0.679	1	-1.53	3.3
			24	1.06	0.91	1	-2.18	4.29
			25	-4.89*	0.969	0.001	-8.33	-1.45
			28	3.56	0.559	1.000	1.57	5.54
		4	8	-4.5*	1.02	0.004	-8.12	-0.876
			11	-0.167	0.725	1	-2.75	2.41
			14	-0.222	0.649	1	-2.53	2.09
			17	0	0.539	1	-1.91	1.91
			21	0	0.64	1	-2.27	2.27
			24	0.167	0.94	1	-3.17	3.51
			25	-5.78*	0.795	p<.001	-8.6	-2.95
			28	2.67*	0.6	0.004	0.536	4.8
		8	11	4.33	0.891	0.001	1.166	7.5
			14	4.28	1.25	0.072	-0.168	8.7
			17	4.5*	0.98	0.003	1.018	7.99
			21	4.5*	1.013	0.004	0.901	8.1
			24	4.67*	0.98	0.002	1.18	8.15
			25	-1.28	1.1	1	-5.19	2.63
			28	7.17*	0.815	p<.001	4.27	10.1
		11	14	-0.056	0.915	1	-3.3	3.2
			17	0.167	0.759	1	-2.53	2.87
			21	0.167	0.64	1	-2.11	2.44
			24	0.333	0.909	1	-2.9	3.56
			25	-5.61*	1.088	p<.001	-9.5	-1.74
			28	2.83*	0.688	0.01	0.389	5.28
		14	17	0.222	0.635	1	-2.04	2.48
			21	0.222	0.758	1	-2.47	2.92
			24	0.389	0.956	1	-3.01	3.79
			25	-5.56*	0.908	p<.001	-8.78	-2.33
			28	2.89*	0.787	0.037	0.091	5.69
		17	21	0	0.758	1	-2.69	2.69
			24	0.167	0.854	1	-2.87	3.2
			25	-5.78*	0.881	p<.001	-8.91	-2.65
			28	2.67*	0.691	0.022	0.211	5.12
		21	24	0.167	0.912	1	-3.07	3.4
			25	-5.78*	0.86	p<.001	-8.83	-2.72
			28	2.667*	0.7	0.025	0.18	5.15
		24	25	-5.94*	0.879	p<.001	-9.07	-2.82
			28	2.5*	0.691	0.042	0.043	4.96
		25	28	8.44*	0.883	p<.001	5.31	11.6

Table 9-97 shows the results of pairwise comparison of simple simple main effects between requirements on measure amount for the Other Methods that there were significant differences for measure amount for the Other Methods between requirements 1 and 25, 4 and 8, 4 and 25, 4 and 28, 8 and 11, 8 and 17, 8 and 21, 8 and 24, 8 and 25, 11 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 25, 21 and 28, 24 and 25, 24 and 28, and 25 and 28.

However, there were no significant difference for measure amount for the Other Methods between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 28, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 14, 8 and 25, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 14 and 17, 14 and 21, 14 and 24, 17 and 21, 17 and 24, and 21 and 24.

Table 9-97 Pairwise comparisons of simple simple main effects between requirements on measure amount for Other Methods for differential B-C

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b] Lower Bound	Upper Bound
Amount	Other	1	4	0.722	0.547	1	-1.22	2.67
			8	-11.6	1.02	p<.001	-15.2	-7.99
			11	-1	0.729	1	-3.59	1.59
			14	-1.22	0.859	1	-4.27	1.83
			17	0.444	0.815	1	-2.45	3.34
			21	-1.83	0.679	0.385	-4.25	0.58
			24	0.722	0.910	1	-2.51	3.96
			25	-5.56*	0.969	p<.001	-9	-2.113
			28	1.06	0.559	0.957	-0.932	3.04
		4	8	-12.3*	1.02	p<.001	-16	-8.709
			11	-1.72	0.725	0.655	-4.3	0.856
			14	-1.94	0.649	0.205	-4.25	0.363
			17	-0.278	0.539	1	-2.19	1.64
			21	-2.556	0.640	0.015	-4.83	-0.282
			24	0.00	0.940	1	-3.34	3.34
			25	-6.28*	0.795	p<.001	-9.1	-3.45
			28	0.333*	0.600	1	-1.8	2.46
		8	11	10.6*	0.891	p<.001	7.44	13.8
			14	10.4	1.25	p<.001	5.94	14.9
			17	12.1*	0.980	p<.001	8.57	15.6
			21	9.78*	1.01	p<.001	6.18	13.4
			24	12.3*	0.980	p<.001	8.85	15.8
			25	6.06	1.1	p<.001	2.15	10
			28	12.67*	0.815	p<.001	9.77	15.6
		11	14	-0.222	0.915	1	-3.47	3.03
			17	1.44	0.759	0.953	-1.25	4.14
			21	-0.833	0.640	1	-3.11	1.44
			24	1.72	0.909	0.955	-1.51	4.95
			25	-4.56*	1.09	0.008	-8.42	-0.688
			28	2.06*	0.688	0.208	-0.388	4.5
		14	17	1.67	0.635	0.444	-0.591	3.93
			21	-0.611	0.758	1	-3.3	2.08
			24	1.94	0.956	0.900	-1.45	5.34
			25	-4.33*	0.908	0.002	-7.56	-1.11
			28	2.28*	0.787	0.258	-0.52	5.08
		17	21	-2.28	0.758	0.200	-4.97	0.416
			24	0.278	0.854	1	-2.76	3.31
			25	-6*	0.881	p<.001	-9.13	-2.87
			28	0.611*	0.691	1	-1.85	3.07
		21	24	2.56	0.912	0.313	-0.685	5.8
			25	-3.72*	0.860	0.006	-6.78	-0.666
			28	2.89*	0.700	0.010	0.402	5.38
		24	25	-6.28*	0.879	p<.001	-9.4	-3.2
			28	0.333*	0.691	1	-2.12	2.79
		25	28	6.61*	0.883	p<.001	3.48	9.75

Table 9-98 shows the results of pairwise comparison of simple simple main effects between requirements on measure direction for the TEIF Method that there were significant differences of measures direction for the TEIF Method between requirements 1 and 8, 1 and 24, 1 and 28, 4 and 25, 4 and 28, 8 and 11, 8 and 17, 8 and 21, 8 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 28, 24 and 25, 24 and 28, and 25 and 28.

However, there were no significant differences for measure direction for the TEIF Method between requirements 1 and 4, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 25, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 14, 8 and 24, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 11and 25, 14 and 17, 14 and 21, 14 and 24, 17 and 21,17 and 24, 21 and 24, and 21 and 25.

Table 9-98 Pairwise comparisons of simple simple main effects between requirements on measure direction for TEIF Method for differential B-C

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Differenceb	
							Lower Bound	Upper Bound
Direction	TEIF	1	4	-0.778	0.222	0.058	-1.57	0.012
			8	-1.39*	0.224	p<.001	-2.19	-0.593
			11	-0.333	0.298	1	-1.39	0.727
			14	-0.833	0.252	0.095	-1.73	0.061
			17	-0.778	0.233	0.087	-1.6	0.049
			21	-0.167	0.334	1.000	-1.35	1.02
			24	-0.944*	0.238	0.016	-1.79	-0.100
			25	0.056	0.274	1	-0.919	1.03
			28	-1.56*	0.212	p<.001	-2.31	-0.804
		4	8	-0.611	0.178	0.069	-1.24	0.021
			11	0.444	0.266	0.993	-0.502	1.39
			14	-0.056	0.148	1	-0.582	0.471
			17	0.000	0.126	1	-0.449	0.449
			21	0.611	0.249	0.589	-0.275	1.5
			24	-0.167	0.169	1	-0.767	0.433
			25	0.833*	0.208	0.014	0.094	1.57
			28	-0.778*	0.138	p<.001	-1.267	-0.288
		8	11	1.06*	0.244	0.006	0.187	1.92
			14	0.556	0.169	0.098	-0.043	1.16
			17	0.611*	0.162	0.027	0.036	1.19
			21	1.22*	0.203	p<.001	0.502	1.94
			24	0.444	0.134	0.092	-0.031	0.92
			25	1.44*	0.204	p<.001	0.718	2.17
			28	-0.167	0.133	1	-0.638	0.305
		11	14	-0.5	0.248	0.908	-1.38	0.381
			17	-0.444	0.232	0.949	-1.27	0.38
			21	0.167	0.317	1	-0.959	1.29
			24	-0.611	0.256	0.643	-1.52	0.298
			25	0.389	0.316	1	-0.735	1.51
			28	-1.22*	0.232	p<.001	-2.05	-0.398
		14	17	0.056	0.139	1	-0.440	0.551
			21	0.667	0.241	0.339	-0.191	1.52
			24	-0.111	0.159	1	-0.678	0.455
			25	0.889*	0.222	0.015	0.098	1.68
			28	-0.722*	0.138	p<.001	-1.21	-0.233
		17	21	0.611	0.254	0.625	-0.29	1.51
			24	-0.167	0.178	1	-0.8	0.467
			25	0.833*	0.230	0.041	0.017	1.65
			28	-0.778*	0.155	0.001	-1.33	-0.227
		21	24	-0.778	0.220	0.052	-1.56	0.004
			25	0.222	0.321	1	-0.917	1.36
			28	-1.39*	0.219	p<.001	-2.17	-0.612
		24	25	1*	0.210	0.002	0.254	1.75
			28	-0.611*	0.136	0.004	-1.1	-0.126
		25	28	-1.611*	0.201	p<.001	-2.33	-0.896

Table 9-99 shows the results of pairwise comparison of simple simple main effects between requirements on measure direction for the Other Methods. There were significant differences for measure direction for the Other Methods between requirements 1 and 4, 1 and 28, 4 and 8, 4 and 21, 4 and 25, 8 and 14, 8 and 17, 8 and 24, 8 and 28, 11 and 17, 11 and 24, 11 and 28, 14 and 25, 17 and 25, 21 and 24, 21 and 28, 24 and 25, and 25 and 28.

However, there were no significant difference for measure direction for the Other Methods between requirements 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 25, 4 and 11, 4 and 14, 4 and 17, 4 and 24, 4 and 28, 8 and 11, 8 and 21, 8 and 25, 11 and 14, 11 and 21, 11 and 25, 14 and 17, 14 and 21, 14 and 24, 14 and 28, 17 and 21, 17 and 24, 17 and 28, 21 and 25, and 24 and 28. Figure 9-34 and Figure 9-35 illustrate these results.

Table 9-99 Pairwise comparisons of simple simple main effects between requirements on measure direction for Other Methods for differential B-C

Measure	Method	(I) requirements	(J) requirements	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	Other	1	4	-0.778*	0.222	0.058	-1.57	0.012
			8	0.444	0.224	0.923	-0.352	1.24
			11	0.167	0.298	1	-0.894	1.23
			14	-0.611	0.252	0.609	-1.51	0.283
			17	-0.667	0.233	0.274	-1.49	0.16
			21	0.111	0.334	1.000	-1.08	1.3
			24	-0.722	0.238	0.185	-1.57	0.122
			25	0.222	0.274	1	-0.753	1.2
			28	-0.944*	0.212	0.004	-1.7	-0.193
		4	8	1.22*	0.178	p<.001	0.59	1.86
			11	0.944	0.266	0.051	-0.002	1.89
			14	0.167	0.148	1	-0.36	0.693
			17	0.111	0.126	1	-0.338	0.56
			21	0.889*	0.249	0.049	0.003	1.78
			24	0.056	0.169	1	-0.544	0.656
			25	1*	0.208	0.001	0.261	1.74
			28	-0.167	0.138	1	-0.656	0.323
		8	11	-0.278	0.244	1	-1.15	0.591
			14	-1.06*	0.169	p<.001	-1.66	-0.457
			17	-1.11*	0.162	p<.001	-1.69	-0.536
			21	-0.333	0.203	0.994	-1.05	0.387
			24	-1.17*	0.134	p<.001	-1.64	-0.691
			25	-0.222	0.204	1	-0.948	0.504
			28	-1.39*	0.133	p<.001	-1.86	-0.917
		11	14	-0.778	0.248	0.146	-1.66	0.103
			17	-0.833*	0.232	0.045	-1.66	-0.009
			21	-0.056	0.317	1	-1.18	1.07
			24	-0.889*	0.256	0.062	-1.8	0.02
			25	0.056	0.316	1	-1.07	1.18
			28	-1.11*	0.232	0.001	-1.94	-0.287
		14	17	-0.056	0.139	1	-0.551	0.44
			21	0.722	0.241	0.206	-0.135	1.58
			24	-0.111	0.159	1	-0.678	0.455
			25	0.833*	0.222	0.030	0.043	1.62
			28	-0.333	0.138	0.615	-0.823	0.156
		17	21	0.778	0.254	0.174	-0.124	1.68
			24	-0.056	0.178	1.000	-0.689	0.578
			25	0.889*	0.230	0.021	0.073	1.71
			28	-0.278	0.155	0.979	-0.829	0.273
		21	24	-0.833*	0.220	0.026	-1.62	-0.052
			25	0.111	0.321	1	-1.03	1.25
			28	-1.056*	0.219	0.001	-1.83	-0.279
		24	25	0.944*	0.210	0.003	0.199	1.69
			28	-0.222	0.136	0.995	-0.71	0.263
		25	28	-1.167*	0.201	p<.001	-1.88	-0.452

Based on marginal means

* The mean difference is significant at the

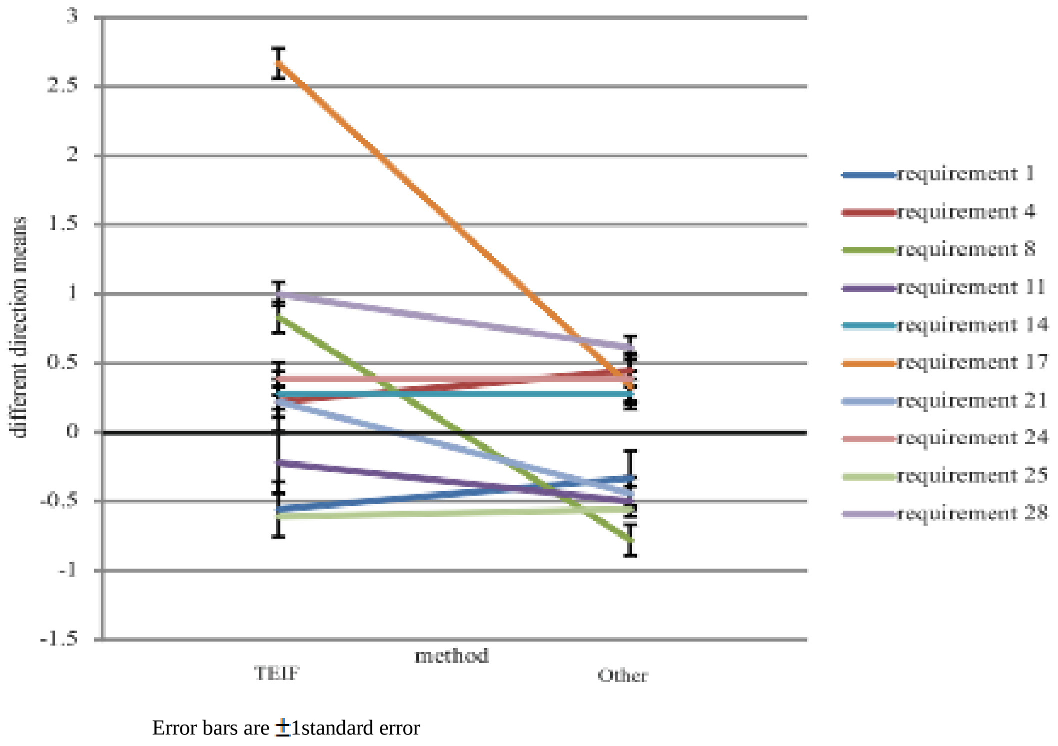


Figure 9-34 Profile graph of simple simple main effects for measure direction at each level of *method* for differential B-C

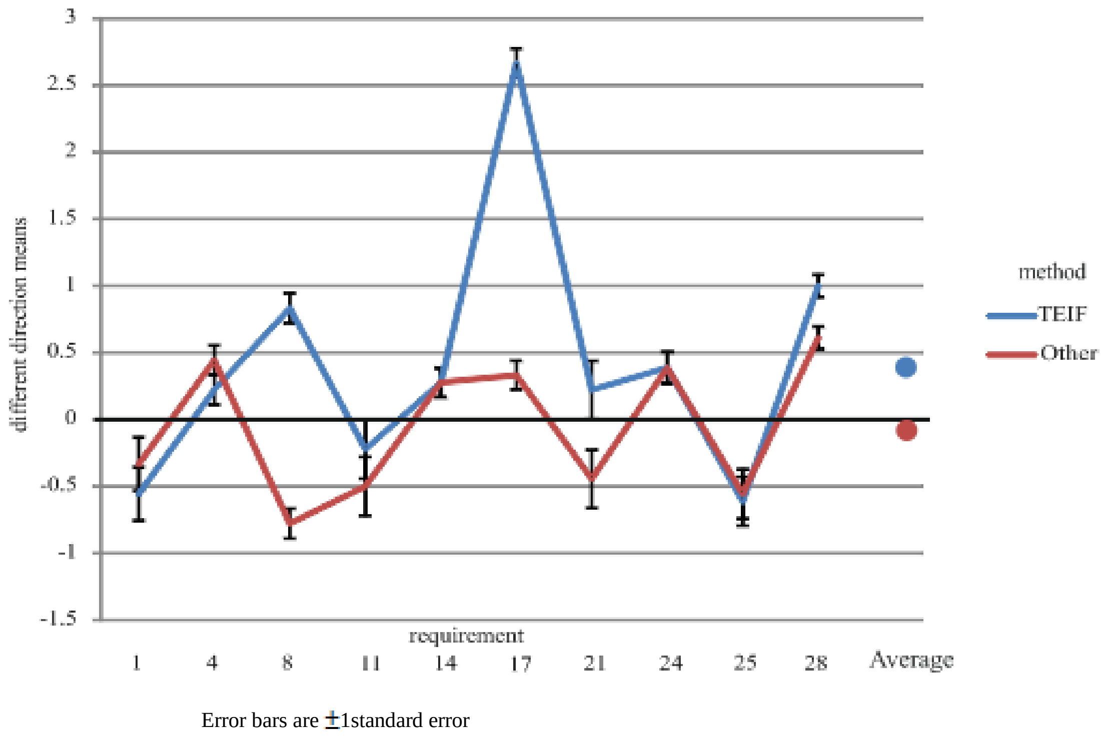


Figure 9-35 Profile graph of simple simple main effects for *requirement* on measure direction at each level of *method* for differential B-C

4) Summary of results for differential B-C

The measure amount for differential B-C for the TEIF Method was closer to the experts only for requirement 8 compared to the Other Methods, whereas the Other Methods were closer to the experts for requirements 1, 4, and 17 compared to the TEIF Method. All other requirements were not significantly different. The measure direction for differential B-C for the TEIF Method was closer to the experts' direction for requirements 8, 17, 21, and 28 compared to the Other Methods.

9.4.4 Exploring differential requirement pairs for measures amount and direction comparison results

Chi-square was used to test the TEIF Method was significantly different than the Other Methods for the number of significantly different requirement pairs for measures amount and direction for differentials A-B, A-C, and B-C.

The analysis showed that the TEIF Method was only significantly different from the Other Methods for the number of significantly different requirement pairs for differential A-B for measure direction (Table 9-100).

Table 9-100 Number of significantly differential pairs for measures amount and direction for differentials A-B, A-C, and B-C

differential	TEIF Method		Other Method		Chi-Square	df	P Value
	Number of significant pair	Number of not significant pair	Number of significant pair	Number of not significant pair			
Measure amount							
A-B	16	29	19	26	0.421	1	0.517
A-C	*requirement*method* was not significant						
B-C	20	25	19	26	0.045	1	0.832
Measure direction							
A-B	11	34	16	29	26.4	1	<0.001
A-C	17	28	21	24	0.729	1	0.393
B-C	18	27	16	29	0.189	1	0.664

9.4.4.1 Test of association between significance requirement pairs for TEIF Method and Other Methods pair differences

Chi-square was also used to test the association between significance of the TEIF Method and the Other Methods pair differences. Table 9-101 shows the number of significant differences between the two elements of a pair for all 45 possible pairs.

For example, for differential A-B, 15 were significantly different for both methods, 25 pairs were not significantly different for both methods, and only five pairs were significantly different for one method but not the other.

A significant chi-square shows a strong association between the pair differences and method, such that the same pair tends to be significantly different for both methods or not significantly different for both methods, and only a few pairs did not follow this tendency. The TEIF Method and the Other Methods showed significant association for differential A-B and B-C on measure amount, and differential A-C on measure direction, but did not show such significant association for differential A-B or B-C on measure direction.

Table 9-101 Number of significant and non-significant pairs per method

Differential	TEIF sig Other sig	TEIF sig Other not sig	TEIF not sig Other sig	TEIF not sig Other not sig	Chi-square	df	P value
Measure amount							
A-B	15	1	4	25	13.82	1	<0.001
A-C	*requirement*method* was not significant						
B-C	14	6	5	20	11.39	1	<0.001
Measure direction							
A-B	6	5	10	24	2.29	1	0.13
A-C	16	1	5	23	24.72	1	<0.001
B-C	9	9	7	20	2.73	1	0.098

9.4.4.2 Differential and Method effects for each requirement

Following the significant *requirement*differential*method* third-order interaction, the simple effects of *requirement* and *method* at each level of *differential* were analysed. A multivariate repeated measure two-way analysis of variance with one within subject factor (*differential)* and one between subject factors (*method*) was carried out, for each of ten requirements. The two measures were (a) direction (b) amount.

9.4.4.2.1 Differential and Method effects for requirement 1

Table 9-102 shows the results of multivariate tests. The second-order simple interaction effect of *differential*method* for requirement 1 was significant as suggested by Roy's Largest Root. While the offer multivariate statistics (Pillai's Trace, Wilks'

Lambda, and Hotelling's Trace) were not significant at α=0.05, it was decided to explore the interaction of indicated by the significant of Roy's Largest Root. This indicates that the mean ratings of *differential* depend on *method* and the mean ratings of *method* depend on *differential* for requirement 1. Therefore, the simple simple main effects of *differential* and *method* were not considered further (

Table 0-58 and Table 0-59, Appendix K).

Table 9-102 Multivariate of *differential*method* for requirement 1

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Differential	Pillai's Trace	.521	12	4	136	p<.001
	Wilks' Lambda	.487	14.5[c]	4	134	p<.001
	Hotelling's Trace	1.04	17.1	4	132	p<.001
	Roy's Largest Root	1.02	34.7[d]	2	68	p<.001
Differential*method	Pillai's Trace	.109	1.96	4	136	.104
	Wilks' Lambda	.891	1.99[c]	4	134	.100
	Hotelling's Trace	.122	2.01	4	132	.096
	Roy's Largest Root	.121	4.12[d]	2	68	.020

a. Design: Intercept + Method
Within Subjects Design: Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-103 shows the univariate tests. The second-order simple interaction effects of *differential*method* for requirement 1 was significant for measure amount, but not for measure direction using both Greenhouse-Geisser and Huynh-Feldt adjustments. The full table is shown in Table 0-60, Appendix K.

Table 9-103 Univariate tests of *differential*method* for requirement 1

Source	**Measure**		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Differential * Method	Direction	Sphericity Assumed	2.06	2	1.03	1.86	.164
		Greenhouse-Geisser	2.06	1.42	1.44	1.86	.176
		Huynh-Feldt	2.06	1.53	1.36	1.86	.174
		Lower-bound	2.06	1	2.06	1.86	.182
	Amount	Sphericity Assumed	38.9	2	19.4	4.04	.022
		Greenhouse-Geisser	38.9	1.53	25.5	4.04	.033
		Huynh-Feldt	38.9	1.63	23.9	4.04	.030
		Lower-bound	38.9	1	38.9	4.04	.052
Error(differential)	Direction	Sphericity Assumed	37.6	68	.553		
		Greenhouse-Geisser	37.6	48.4	.776		
		Huynh-Feldt	37.6	51.4	.731		
		Lower-bound	37.6	34	1.11		
	Amount	Sphericity Assumed	328	68	4.82		
		Greenhouse-Geisser	328	51.9	6.32		
		Huynh-Feldt	328	55.4	5.91		
		Lower-bound	328	34	9.63		

The following syntax '/EMMEANS' (IBM, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Differential*Method) COMPARE(Differential) ADJ(SIDAK)

/EMMEANS=TABLES(Differential*Method) COMPARE(Method) ADJ(SIDAK)

*1) Marginal means of differential*method for requirement 1*

Table 9-104 shows the marginal mean of *differential*method* on measures amount and direction for requirement 1 with the associated standard errors.

Table 9-104 Marginal means of *differential*method* on measures amount and direction for requirement 1

Measure	Differential	Method	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Direction	A-B	TEIF	-.333	.188	-.715	.049
		Other	-.722	.188	-1.1	-.340
	A-C	TEIF	-.667	.114	-.899	-.434
		Other	-1.000	.114	-1.23	-.768
	B-C	TEIF	-.556	.200	-.962	-.149
		Other	-.333	.200	-.739	.073
Amount	A-B	TEIF	4.5	.525	3.43	5.57
		Other	5.83	.525	4.77	6.9
	A-C	TEIF	6.5	.527	5.43	7.57
		Other	7.28	.527	6.21	8.35
	B-C	TEIF	3.56	.543	2.45	4.66
		Other	2.11	.543	1.01	3.21

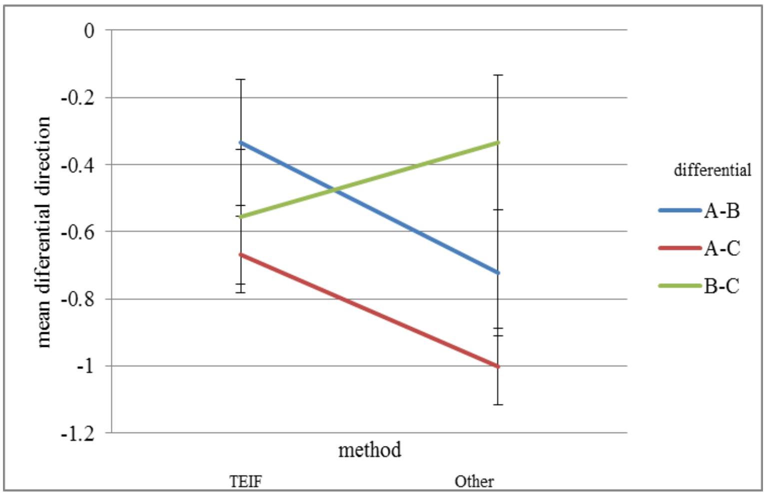
2) Simple simple main effects of differential at each level of method for requirement 1

Table 9-105 shows the multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 1. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects (p<0.001) for the TEIF Method and the Other Methods for requirement 1. This indicates that differentials A-B, A-C, and B-C were different for the TEIF Method and the Other Methods at requirement 1. Figure 9-36 and Figure 9-37 illustrate these results.

Table 9-105 Multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 1

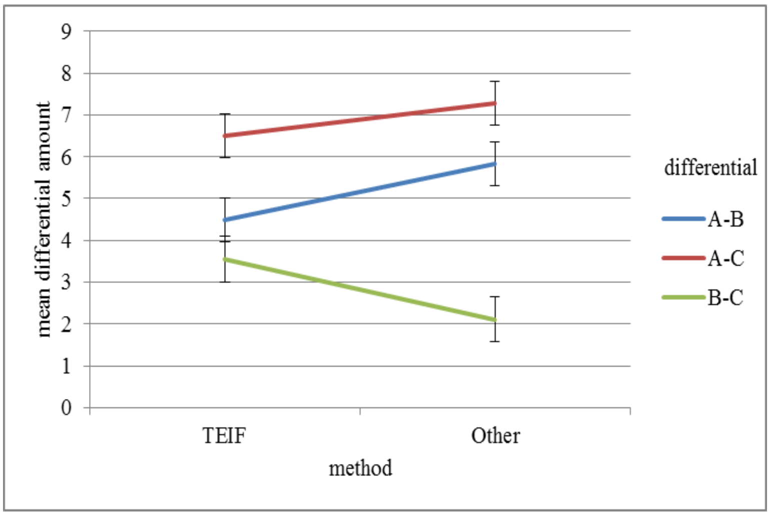
Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.522	8.45[a]	4	31	p<.001
	Wilks' lambda	.478	8.45[a]	4	31	p<.001
	Hotelling's trace	1.09	8.45[a]	4	31	p<.001
	Roy's largest root	1.09	8.45[a]	4	31	p<.001
Other	Pillai's trace	.735	21.5[a]	4	31	p<.001
	Wilks' lambda	.265	21.5[a]	4	31	p<.001
	Hotelling's trace	2.777	21.5[a]	4	31	p<.001
	Roy's largest root	2.777	21.5[a]	4	31	p<.001

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic



Error bars are ±1standard error

Figure 9-36 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 1 on measure direction



Error bars are ±1standard error

Figure 9-37 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 1 on measure amount

Table 9-106 shows the results of pairwise comparisons for differentials A-B, A-C, and B-C, using measures direction and amount for requirement 1. There were significant differences for:

- the TEIF Method at requirement 1 between differentials A-B and A-C, and A-C and B-C, on measure amount
- the Other Methods for differentials A-B and A-C, A-B and B-C, and A-C and B-C, on measure amount
- the Other Methods at requirement 1 between differentials A-C and B-C on measure direction

However, there were no significant differences for:

- the TEIF Method at requirements 1 between differentials A-B and A-C, A-B and B-C, and A-C and B-C, on measure direction
- the TEIF Method at requirements 1 between differentials A-B and B-C, on measure amount
- the Other Methods at requirements 1 between differentials A-B and A-C, and A-B and B-C, on measure direction

Table 9-106 Pairwise comparisons between differentials and methods for measures direction and amount for requirement 1

Measure	Method	(I) Differential	(J) Differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	TEIF	A-B	A-C	0.333	0.212	0.332	-0.2	0.867
			B-C	0.222	0.317	0.866	-0.573	1.02
		A-C	B-C	-0.111	0.197	0.924	-0.606	0.384
	Other	A-B	A-C	0.278	0.212	0.487	-0.256	0.811
			B-C	-0.389	0.317	0.54	-1.18	0.406
		A-C	B-C	-.667*	0.197	0.005	-1.16	-0.172
Amount	TEIF	A-B	A-C	-2*	0.552	0.003	-3.39	-0.614
			B-C	0.944	0.903	0.661	-1.32	3.21
		A-C	B-C	2.94*	0.697	0.001	1.19	4.7
	Other	A-B	A-C	-1.44*	0.552	0.039	-2.83	-0.058
			B-C	3.72*	0.903	0.001	1.46	5.99
		A-C	B-C	5.17*	0.697	0	3.42	6.92

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

3) *Simple simple main effects of method at each level of differential for requirement 1*

Table 9-107 shows the multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 1. The significant value for multivariate test as suggested by Pillai's trace was used. There were no significant simple simple main effects of differentials A-B, A-C, and B-C for the TEIF Method or for the Other Methods at requirement 1. This indicates that the TEIF Method was not different from the Other Methods on measures direction and amount for differentials A-B, A-C, and B-C at requirement 1.

Table 9-107 Multivariate tests of simple simple main effect of *method* at each level of *differential* for requirement 1

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.089	1.6[a]	2	33	.216
	Wilks' lambda	.911	1.6[a]	2	33	.216
	Hotelling's trace	.097	1.6[a]	2	33	.216
	Roy's largest root	.097	1.6[a]	2	33	.216
A-C	Pillai's trace	.113	2.11[a]	2	33	.137
	Wilks' lambda	.887	2.11[a]	2	33	.137
	Hotelling's trace	.128	2.11[a]	2	33	.137
	Roy's largest root	.128	2.11[a]	2	33	.137
B-C	Pillai's trace	.094	1.72[a]	2	33	.195
	Wilks' lambda	.906	1.72[a]	2	33	.195
	Hotelling's trace	.104	1.72[a]	2	33	.195
	Roy's largest root	.104	1.72[a]	2	33	.195

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

9.4.4.2.2 Differential and Method effects for requirement 4

Table 9-108 shows the results of multivariate tests. The second-order simple interaction effect of *differential*method* for requirement 4 was significant as suggested by Roy's Largest Root. While the offer multivariate statistics (Pillai's Trace, Wilks' Lambda, and Hotelling's Trace) were not significant at α=0.05, it was decided to explore the interaction of indicated by the significant of Roy's Largest Root. This indicates that the mean ratings of *differential* depend on *method* and the mean ratings of *method* depend on *differential* for requirement 4. Therefore, the simple main effects of *differential* (Table 9-108) and *method* were not considered further (Table 0-61, Appendix K).

Table 9-108 Multivariate tests of *differential*method* for requirement 4

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Differential	Pillai's Trace	.367	7.65	4	136	p<.001
	Wilks' Lambda	.648	8.1[c]	4	134	p<.001
	Hotelling's Trace	.518	8.54	4	132	p<.001
	Roy's Largest Root	.465	15.8[d]	4	68	p<.001
Differential * Method	Pillai's Trace	.112	2.02	4	136	.095
	Wilks' Lambda	.888	2.05[c]	4	134	.092
	Hotelling's Trace	.126	2.07	4	132	.088
	Roy's Largest Root	.123	4.19[d]	2	68	.019

a. Design: Intercept + Method
Within Subjects Design: Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-109 shows the univariate tests. The second-order simple interaction effects of *differential*method* for requirement 4 was significant on measure direction, but not for measure amount using Lower-bound adjustment. The full table is shown in

Table 0-62, Appendix K.

Table 9-109 Univariate tests of *differential*method* for requirement 4

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential * Method	Direction	Sphericity Assumed	3.57	2	1.79	4.19	.019
		Greenhouse-Geisser	3.57	1.9	1.83	4.19	.020
		Huynh-Feldt	3.57	2	1.79	4.19	.019
		Lower-bound	3.57	1	3.57	4.19	.049
	Amount	Sphericity Assumed	15.7	2	7.84	2.52	.088
		Greenhouse-Geisser	15.7	1.79	8.77	2.52	.094
		Huynh-Feldt	15.7	1.94	8.1	2.52	.090
		Lower-bound	15.7	1	15.9	2.52	.121
Error(differential)	Direction	Sphericity Assumed	29	68	.427		
		Greenhouse-Geisser	29	66	.438		
		Huynh-Feldt	29	68	.427		
		Lower-bound	29	34	.854		
	Amount	Sphericity Assumed	211	68	3.11		
		Greenhouse-Geisser	211	60.8	3.48		
		Huynh-Feldt	211	65.8	3.21		
		Lower-bound	211	34	6.22		

The following syntax '/EMMEANS' (IBM, 2001)was used to test simple simple main effects:

/EMMEANS=TABLES(Differential*Method)COMPARE(Differential) ADJ(SIDAK)

/EMMEANS=TABLES(Differential*Method)COMPARE(Method) ADJ(SIDAK)

1) *Marginal means of differential*method for requirement 4*

Table 9-110 shows the marginal means of *differential*method* for measures amount and direction for requirement 4 with the associated standard errors.

Table 9-110 Marginal means of *differential*method* for measures amount and direction for requirement 4

Measure	Differential	Method	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Direction	A-B	TEIF	.056	.195	-.340	.451
		Other	-.611	.195	-1.01	-.215
	A-C	TEIF	-.333	.173	-.685	.018
		Other	-.611	.173	-.962	-.260
	B-C	TEIF	.222	.111	-.004	.448
		Other	.444	.111	.219	.67
Amount	A-B	TEIF	3.11	.408	2.28	3.94
		Other	3.67	.408	2.84	4.5
	A-C	TEIF	3.22	.403	2.4	4.04
		Other	3.17	.403	2.35	3.99
	B-C	TEIF	2.67	.502	1.65	3.69
		Other	1.39	.502	.369	2.41

2) *Simple simple main effects of differential at each level of method for requirement 4*

Table 9-111 shows the multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 4. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects for the TEIF Method ($p<0.05$) and the Other Methods ($p<0.001$) at requirement 4. This indicates that the differentials A-B, A-C, and B-C were different for the TEIF Method and the Other Methods at requirement 4. Figure 9-38 and Figure 9-39 illustrate these results.

Table 9-111 Multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 4

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.308	3.45[a]	4	31	.019
	Wilks' lambda	.692	3.45[a]	4	31	.019
	Hotelling's trace	.445	3.45[a]	4	31	.019
	Roy's largest root	.445	3.45[a]	4	31	.019
Other	Pillai's trace	.601	11.7[a]	4	31	p<.001
	Wilks' lambda	.399	11.7[a]	4	31	p<.001
	Hotelling's trace	1.51	11.7[a]	4	31	p<.001
	Roy's largest root	1.51	11.7[a]	4	31	p<.001

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

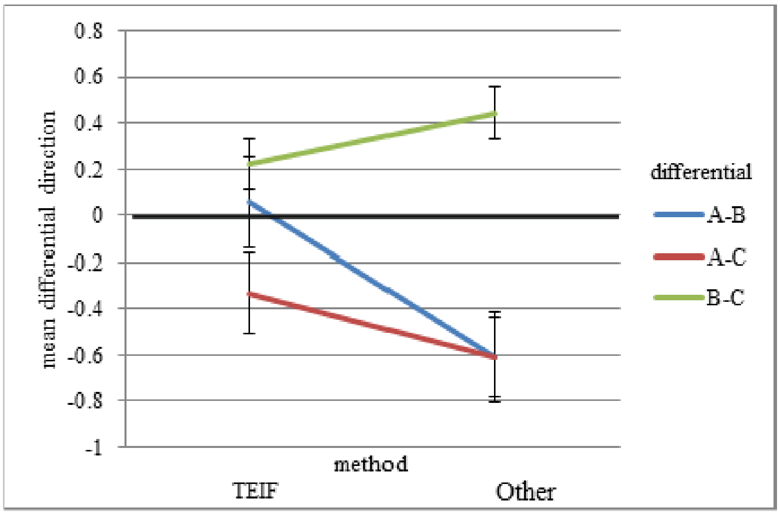


Figure 9-38 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 4 on measure direction

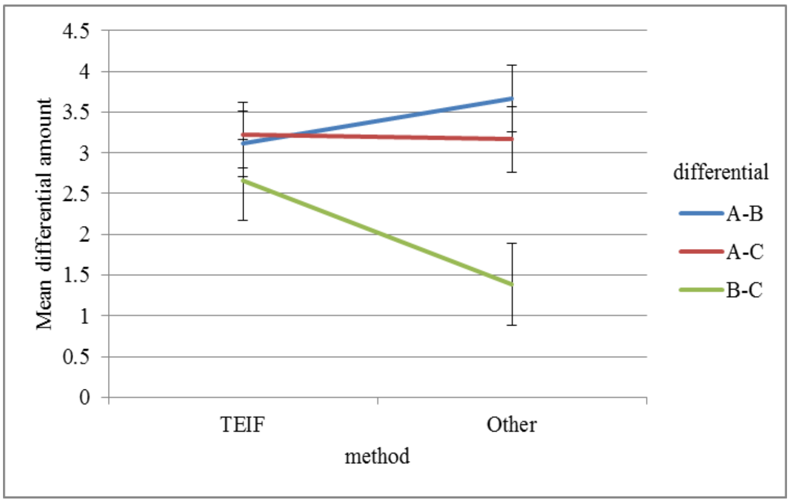


Figure 9-39 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 4 on measure amount

Table 9-112 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C, using measures direction and amount for requirement 4 at each level of method. There were significant differences for:

- the TEIF Method at requirement 4 between differentials A-C and B-C, on measure direction
- the Other Methods at requirement 4 between differentials A-B and B-C, and A-C and B-C, on both measures direction and amount

However, there were no significant differences for:

- the TEIF Method at requirements 4 between differentials A-B and A-C, and A-B and B-C, on measure direction
- the TEIF Method at requirement 4 between differentials A-B and A-C, A-B and B-C, and A-C and B-C, on measure amount
- the Other Methods at requirements 4 between differentials A-B and A-C, on both measures direction and amount

Table 9-112 Pairwise comparisons between differentials using measure direction for requirement 4 at each level of *method*

Measure	Method	(I) Differential	(J) Differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	TEIF	A-B	A-C	.389	.215	.219	-.151	.929
			B-C	-.167	.234	.860	-.754	.420
		A-C	B-C	-.556*	.204	.030	-1.07	-.044
	Other	A-B	A-C	.000	.215	1.000	-.54	.540
			B-C	-1.06*	.234	p<.001	-1.64	-.469
		A-C	B-C	-1.06*	.204	p<.001	-1.57	-.544
Amount	TEIF	A-B	A-C	-.111	.524	.995	-1.43	1.21
			B-C	.444	.545	.806	-.925	1.81
		A-C	B-C	.556	.681	.805	-1.15	2.27
	Other	A-B	A-C	.500	.524	.722	-.817	1.82
			B-C	2.28*	.545	.001	.908	3.65
		A-C	B-C	1.78*	.681	.039	.069	3.49

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

3) *Simple simple main effects of method at each level of differential for requirement 4*

Table 9-113 shows the multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 4. The significant value for multivariate test as suggested by Pillai's trace was used. There were no significant simple simple main effects of differentials A-B, A-C, and B-C for the TEIF Method or for the Other Methods at requirement 4. This indicates that the TEIF Method was not different from the Other Methods on both measures direction and amount for differentials A-B, A-C, and B-C at requirement 4.

Table 9-113 Multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 4

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.154	3.01[a]	2	33	.063
	Wilks' lambda	.846	3.01[a]	2	33	.063
	Hotelling's trace	.182	3.01[a]	2	33	.063
	Roy's largest root	.182	3.01[a]	2	33	.063
A-C	Pillai's trace	.096	1.75[a]	2	33	.189
	Wilks' lambda	.904	1.75[a]	2	33	.189
	Hotelling's trace	.106	1.75[a]	2	33	.189
	Roy's largest root	.106	1.75[a]	2	33	.189
B-C	Pillai's trace	.090	1.63[a]	2	33	.211
	Wilks' lambda	.910	1.63[a]	2	33	.211
	Hotelling's trace	.099	1.63[a]	2	33	.211
	Roy's largest root	.099	1.63[a]	2	33	.211

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

9.4.4.2.3 Differential and Method effects for requirement 8

Table 9-114 shows the results of multivariate tests. The second-order simple interaction effect of *differential*method* for requirement 8 was significant (p<0.001) as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* depend on *method* and the mean ratings of *method* depend on *differential*. Therefore, the simple main effects of *differential* (Table 9-114) and *method* were not considered further (Table 9-83, Appendix K).

Table 9-114 Multivariate tests of *differential*method* for requirement 8

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Differential	Pillai's Trace	.903	28	4	136	p<.001
	Wilks' Lambda	.115	65.5[c]	4	134	p<.001
	Hotelling's Trace	7.58	125	4	132	p<.001
	Roy's Largest Root	7.56	257[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.708	18.6	4	136	p<.001
	Wilks' Lambda	.292	28.5[c]	4	134	p<.001
	Hotelling's Trace	2.42	40	4	132	p<.001
	Roy's Largest Root	2.42	82[d]	2	68	p<.001

a. Design: Intercept + Method
Within Subjects Design: Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-115 shows the univariate tests. The second-order simple interaction effects of *differential*method* for requirement 8 was significant difference on both measures amount and direction using Lower-bound adjustment. The full table is shown in Table 0-64, Appendix K.

Table 9-115 Univariate tests of *differential*method* for requirement 8

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential * Method	Direction	Sphericity Assumed	24.9	2	12.4	79.9	p<.001
		Greenhouse-Geisser	24.9	1.94	12.9	79.9	p<.001
		Huynh-Feldt	24.9	2	12.4	79.9	p<.001
		Lower-bound	24.9	1	24.9	79.9	p<.001
	Amount	Sphericity Assumed	360	2	180	40.3	p<.001
		Greenhouse-Geisser	360	1.65	219	40.3	p<.001
		Huynh-Feldt	360	1.77	204	40.3	p<.001
		Lower-bound	360	1	360	40.3	p<.001
Error(differential)	Direction	Sphericity Assumed	10.6	68	.156		
		Greenhouse-Geisser	10.6	66	.161		
		Huynh-Feldt	10.6	68	.156		
		Lower-bound	10.6	34	.312		
	Amount	Sphericity Assumed	304	68	4.47		
		Greenhouse-Geisser	304	56	5.43		
		Huynh-Feldt	304	60.2	5.05		
		Lower-bound	304	34	8.94		

The following syntax '/EMMEANS' (IBM, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Differential*Method)COMPARE(Differential) ADJ(SIDAK)

/EMMEANS=TABLES(Differential*Method) COMPARE(Method) ADJ(SIDAK)

1) *Marginal mean of differential*method for requirement 8*

Table 9-116 shows the marginal mean of measures direction and amount for *differential* and *method* for requirement 8 with the associated standard errors.

Table 9-116 Marginal mean of measures direction and amount for *differential* and *method* for requirement 8

Measure	Differential	Method	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Direction	A-B	TEIF	.500	.118	.260	.740
		Other	-.667	.118	-.906	-.427
	A-C	TEIF	.056	.090	-.127	.238
		Other	.667	.090	.484	.849
	B-C	TEIF	.833	.112	.607	1.06
		Other	-.778	.112	-1	-.551
Amount	A-B	TEIF	8.33	.760	6.79	9.88
		Other	13.2	.760	11.7	14.8
	A-C	TEIF	2.5	.345	1.8	3.2
		Other	.611	.345	-.090	1.31
	B-C	TEIF	7.17	.794	5.55	8.78
		Other	13.7	.794	12.1	15.3

2) *Simple simple main effects of differential at each level of method for requirement 8*

Table 9-117 shows the multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 8. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects for the TEIF Method (p<0.001) and the Other Methods (p<0.001) for requirement 8. This indicates that the differentials A-B, A-C, and B-C mean ratings were different for the TEIF Method and the Other Methods at requirement 8. Figure 9-40 and Figure 9-41 illustrate these results.

Table 9-117 Multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 8

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.815	34.2[a]	4	31	p<.001
	Wilks' lambda	.185	34.2[a]	4	31	p<.001
	Hotelling's trace	4.41	34.2[a]	4	31	p<.001
	Roy's largest root	4.41	34.174[a]	4	31	p<.001
Other	Pillai's trace	.908	76.3[a]	4	31	p<.001
	Wilks' lambda	.092	76.3[a]	4	31	p<.001
	Hotelling's trace	9.84	76.3[a]	4	31	p<.001
	Roy's largest root	9.84	76.3[a]	4	31	p<.001

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

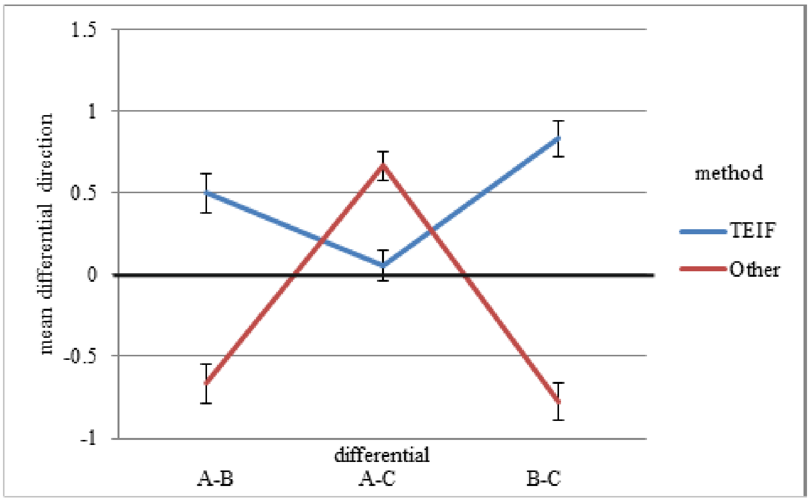


Figure 9-40 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 8 on measure direction

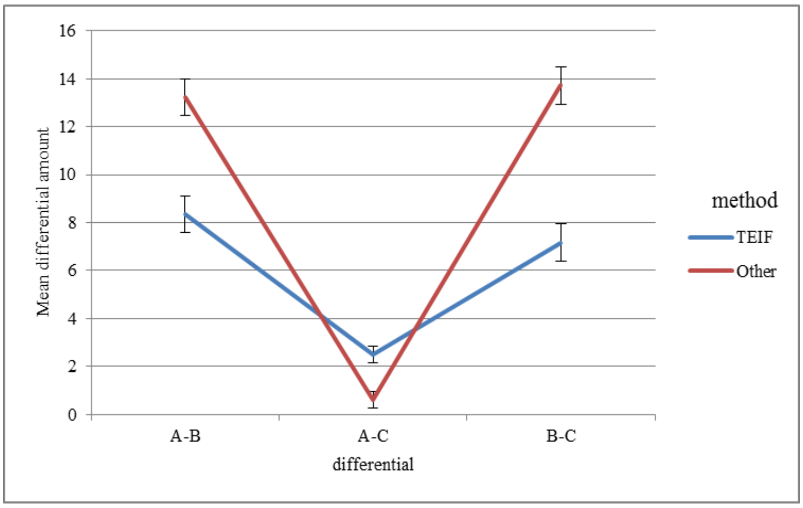


Figure 9-41 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 8 on measure amount

Table 9-118 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C, using measure direction for requirement 8 at each level of *method*. There were significant differences for:

- the TEIF Method at requirement 8 between differentials A-B and A-C, A-B and B-C, and A-C and B-C on measure direction
- the Other Methods at requirement 8 between differentials A-B and A-C, and A-C and B-C, on measure direction
- the TEIF Method at requirement 8 between differentials A-B and A-C, and A-C and B-C, on measure amount

- the Other Methods at requirement 8 between differentials A-B and A-C, and A-C and B-C, on measure amount

However, there were no significant differences for:

- the Other Methods at requirement 8 between differentials A-B and B-C, on measure direction
- the TEIF Method at requirement 8 between differentials A-B and B-C, on measure amount
- the Other Method at requirement 8 between differentials A-B and B-C, on measure amount

Table 9-118 Pairwise comparisons between differentials at each level of *method* on measures direction and amount for requirement 8

Measure	**Method**	**(I) Differential**	**(J) Differential**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence Interval for Difference[b]**	
							Lower Bound	**Upper Bound**
Direction	TEIF	A-B	A-C	.444*	.143	.011	.086	.803
			B-C	-.333*	.126	.037	-.651	-.016
		A-C	B-C	-.778*	.125	.000	-1.09	-.464
	Other	A-B	A-C	-1.33*	.143	.000	-1.69	-.975
			B-C	.111	.126	.768	-.206	.429
		A-C	B-C	1.44*	.125	.000	1.13	1.8
Amount	TEIF	A-B	A-C	5.83*	.776	.000	3.88	7.78
			B-C	1.17	.516	.088	-.129	2.46
		A-C	B-C	-4.67*	.788	.000	-6.65	-2.69
	Other	A-B	A-C	12.6*	.776	.000	10.7	14.6
			B-C	-.500	.516	.712	-1.8	.796
		A-C	B-C	-13.1*	.788	.000	-15.1	-11.1

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

3) *Simple simple main effects of method at each level of differential for requirement 8*

Table 9-119 shows the multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 8. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects of *method* for differentials A-B, A-C, and B-C at requirement 8. This indicates that the TEIF Method was different from the Other Methods on measures direction and amount for differentials A-B, A-C, and B-C at requirement 8. Figure 9-42 and Figure 9-43 illustrate these results.

Table 9-119 Multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 8

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.591	23.8[a]	2	33	p<.001
	Wilks' lambda	.409	23.8[a]	2	33	p<.001
	Hotelling's trace	1.44	23.8[a]	2	33	p<.001
	Roy's largest root	1.44	23.8[a]	2	33	p<.001
A-C	Pillai's trace	.431	12.5[a]	2	33	p<.001
	Wilks' lambda	.569	12.5[a]	2	33	p<.001
	Hotelling's trace	.756	12.5[a]	2	33	p<.001
	Roy's largest root	.756	12.5[a]	2	33	p<.001
B-C	Pillai's trace	.756	51.2[a]	2	33	p<.001
	Wilks' lambda	.244	51.2[a]	2	33	p<.001
	Hotelling's trace	3.11	51.2[a]	2	33	p<.001
	Roy's largest root	3.11	51.2[a]	2	33	p<.001

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

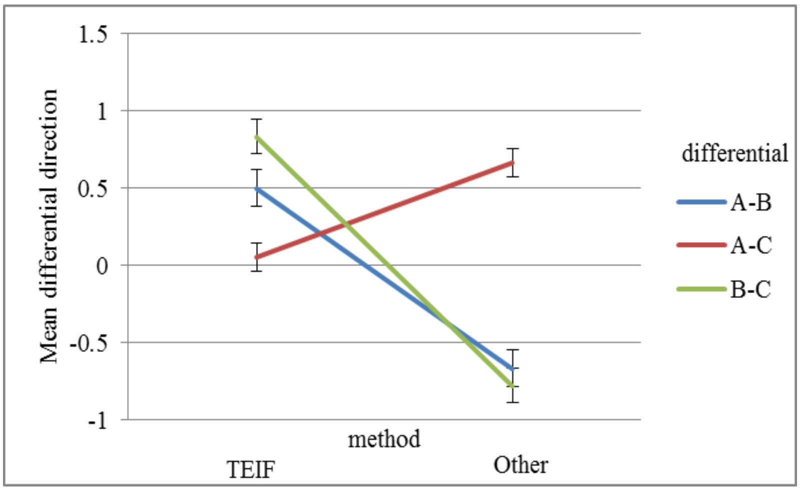


Figure 9-42 Profile graph of simple main effects of *method* at each level of *differential* for requirement 8 on measure direction

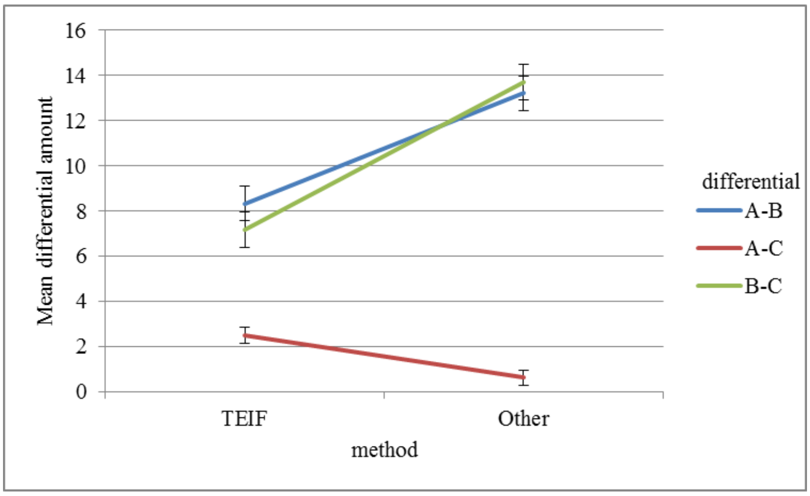


Figure 9-43 Profile graph of simple main effects of *method* at each level of *differential* for requirement 8 on measure amount

9.4.4.2.4 Differential and Method effects for requirement 11

Table 9-120 shows the results of multivariate tests. The second-order interaction effect of *differential*method* for requirement 11 was not significant as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* do not depend on *method* and the mean ratings of *method* do not depend on *differential*. Therefore, the simple main effects of *differential* and *method* were considered further.

The simple main effect of differential was significant (p<0.001) as suggested by Pillai's Trace as shown in Table 9-120, whereas the simple main effect of *method* was not significant as suggested by Pillai's Trace as shown in Table 9-121.

Table 9-120 Multivariate tests for requirement 11

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Differential	Pillai's Trace	.290	5.76	4	136	p<.001
	Wilks' Lambda	.711	6.23[c]	4	134	p<.001
	Hotelling's Trace	.405	6.69	4	132	p<.001
	Roy's Largest Root	.403	13.7[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.043	.749	4	136	.561
	Wilks' Lambda	.957	.739[c]	4	134	.567
	Hotelling's Trace	.044	.729	4	132	.574
	Roy's Largest Root	.031	1.05[d]	2	68	.356

a. Design: Intercept + Method
Within Subjects Design: differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-121 Multivariate tests of simple main effect of *method* for requirement 11

Method	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Pillai's trace	.046	.787[a]	2	33	.463
Wilks' lambda	.954	.787[a]	2	33	.463
Hotelling's trace	.048	.787[a]	2	33	.463
Roy's largest root	.048	.787[a]	2	33	.463

Each F tests the multivariate effect of Method. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Table 9-122 shows the results of Mauchly's sphericity test of *differential* for each of measure direction and amount. These tests indicate that the simple main effects of both measures direction and amount do not violate the sphericity assumption (Field, 2013).

Table 9-122 Mauchly's test of sphericity of *differential* for each of measure direction and amount

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Differential	Direction	.866	4.74	2	.093	.882	.954	.5
	Amount	.921	2.73	2	.255	.926	1	.5

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: differential
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-123 shows the univariate tests. The simple main effect of *differential* for requirement 11 was significant (p<0.001) for measure direction, but was not for measure amount. The full table is shown in Table 0-65, Appendix K.

Table 9-123 Univariate tests of simple main effect of *differential* for requirement 11

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	12.5	2	6.23	13.7	p<.001
		Greenhouse-Geisser	12.5	1.76	7.1	13.7	p<.001
		Huynh-Feldt	12.5	1.91	6.56	13.7	p<.001
		Lower-bound	12.5	1	12.5	13.7	.001
	Amount	Sphericity Assumed	21.9	2	11	2.98	.058
		Greenhouse-Geisser	21.9	1.85	12	2.98	.062
		Huynh-Feldt	21.9	2	11	2.98	.058
		Lower-bound	21.9	1	21.9	2.98	.093
Error(differential)	Direction	Sphericity Assumed	31.2	68	.459		
		Greenhouse-Geisser	31.2	60	.520		
		Huynh-Feldt	31.2	64.9	.481		
		Lower-bound	31.2	34	.917		
	Amount	Sphericity Assumed	250	68	3.68		
		Greenhouse-Geisser	250	63	3.97		
		Huynh-Feldt	250	68	3.68		
		Lower-bound	250	34	7.36		

Table 9-124 shows the results of pairwise comparisons of differentials A-B, A-C, and B-C using measure direction for requirement 11 over all methods. There were significant differences for requirement 11 between differentials A-B and A-C, and A-C and B-C, on measure direction. However, there was no significant difference for requirement 11 between differentials A-B and B-C, on measure direction. Figure 9-44 and Figure 9-45 illustrate these results. The full table is shown in Table 0-66, Appendix K.

Table 9-124 Pairwise comparisons of simple main effects between differentials for requirement 11

Measure	(I) differential	(J) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Direction	A-B	A-C	-.722*	.170	p<.001	-1.15	-.295
		B-C	-1	.127	1	-.320	.320
	A-C	B-C	.722*	.177	.001	.278	1.17

Based on estimated marginal means
*. The mean difference is significant at the .05 level.

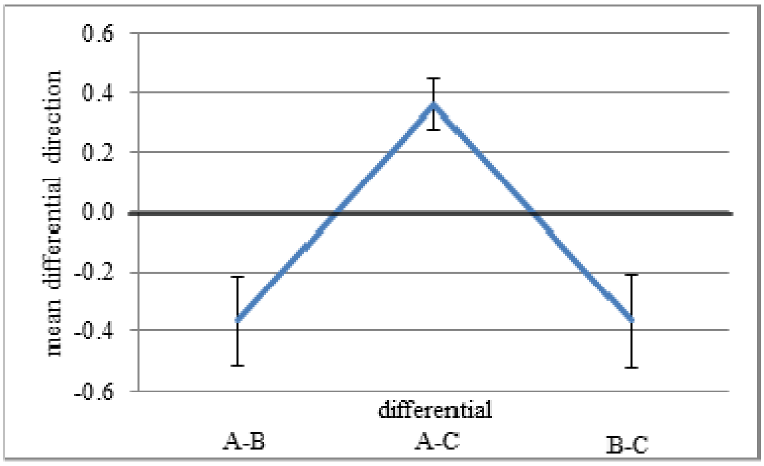


Figure 9-44 Profile graph of simple main effects of *differential* for requirement 11 on measure direction

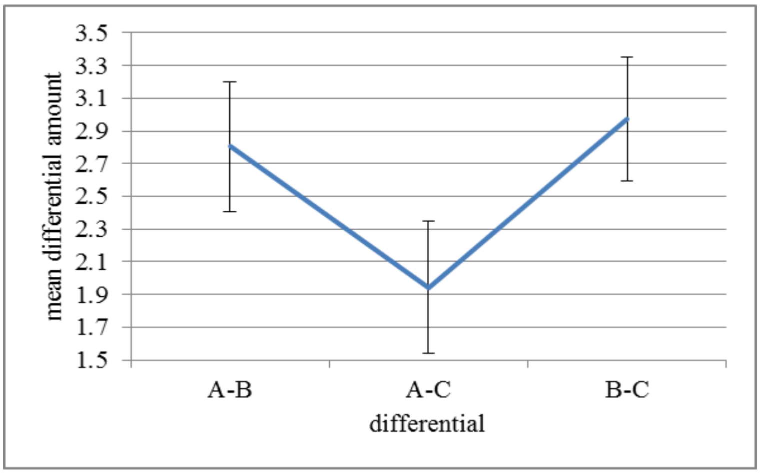


Figure 9-45 Profile graph of simple main effects of *differential* for requirement 11 on measure amount

9.4.4.2.5 Differential and Method effects for requirement 14

Table 9-125 shows the results of multivariate tests. The second-order interaction effect of *differential*method* for requirement 14 was not significant as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* do not depend on *method* and the mean ratings of *method* do not depend on *differential* for requirement 14. Therefore, the simple main effects of *differential* and *method* were considered further.

The simple main effect of *differential* was significant (p<0.001) as suggested by Pillai's Trace as shown in Table 9-125, whereas the simple main effect of *method* was not significant as suggested by Pillai's Trace as shown in Table 9-126

Table 9-125 Multivariate tests for requirement 14

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Differential	Pillai's Trace	.415	8.91	4	136	p<.001
	Wilks' Lambda	.597	9.84[c]	4	134	p<.001
	Hotelling's Trace	.653	10.8	4	132	p<.001
	Roy's Largest Root	.619	21[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.027	.462	4	136	.764
	Wilks' Lambda	.973	.456[c]	4	134	.768
	Hotelling's Trace	.027	.451	4	132	.772
	Roy's Largest Root	.023	.768[d]	2	68	.468

a. Design: Intercept + Method
Within Subjects Design: differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-126 Multivariate tests of simple main effect of *method* for requirement 14

Method	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Pillai's trace	.109	2.02[a]	2	33	.148
Wilks' lambda	.891	2.02[a]	2	33	.148
Hotelling's trace	.123	2.02[a]	2	33	.148
Roy's largest root	.123	2.02[a]	2	33	.148

Each F tests the multivariate effect of Method. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Table 9-127 shows the results of Mauchly's sphericity test of *differential* for each of measure direction and amount. These tests indicate that the simple main effects of both measures direction and amount do not violate the sphericity assumption (Field, 2013).

Table 9-127 Mauchly's sphericity test of *differential* for each of measure direction and amount

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Differential	Direction	.917	2.86	2	.239	.923	1	.5
	Amount	.906	3.24	2	.197	.914	.992	.5

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: differential
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-128 shows the univariate tests. The simple main effects of *differential* for requirement 14 were significant (p<0.001) on both measures direction and amount. The full table is shown in Table 0-67, Appendix K.

Table 9-128 Univariate tests of simple main effects of *differential* for requirement 14

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	19.5	2	9.75	20.8	p<.001
		Greenhouse-Geisser	19.5	1.847	10.6	20.8	p<.001
		Huynh-Feldt	19.5	2	9.75	20.8	p<.001
		Lower-bound	19.5	1	19.5	20.8	p<.001
	Amount	Sphericity Assumed	197	2	98.3	11	p<.001
		Greenhouse-Geisser	197	1.83	107.6	11	p<.001
		Huynh-Feldt	197	1.98	99.1	11	p<.001
		Lower-bound	197	1	196.7	11	.002
Error(differential)	Direction	Sphericity Assumed	31.8	68	.468		
		Greenhouse-Geisser	31.8	62.8	.507		
		Huynh-Feldt	31.8	68	.468		
		Lower-bound	31.8	34	.936		
	Amount	Sphericity Assumed	607	68	8.92		
		Greenhouse-Geisser	607	62.2	9.76		
		Huynh-Feldt	607	67.5	8.99		
		Lower-bound	607	34	17.8		

Table 9-129 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C using measure direction for requirement 14 over all methods. There were significant differences for requirement 14 between differentials A-B and B-C, and A-C and B-C, on both measures direction and amount. Figure 9-46 and Figure 9-47 illustrate these results.

Table 9-129 Pairwise comparisons of simple main effects of *differential* using measures amount and direction for requirement 14

Measure	(I) differential	(J) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Direction	A-B	A-C	.250	.163	.351	-.159	.659
		B-C	-.750*	.179	.001	-1.2	-.300
	A-C	B-C	-1*	.139	p<.001	-1.35	-.652
Amount	A-B	A-C	-.111	.657	.998	-1.76	1.54
		B-C	2.81*	.804	.004	.786	4.83
	A-C	B-C	2.92*	.640	p<.001	1.31	4.52

Based on estimated marginal means
*. The mean difference is significant at the .05 level.

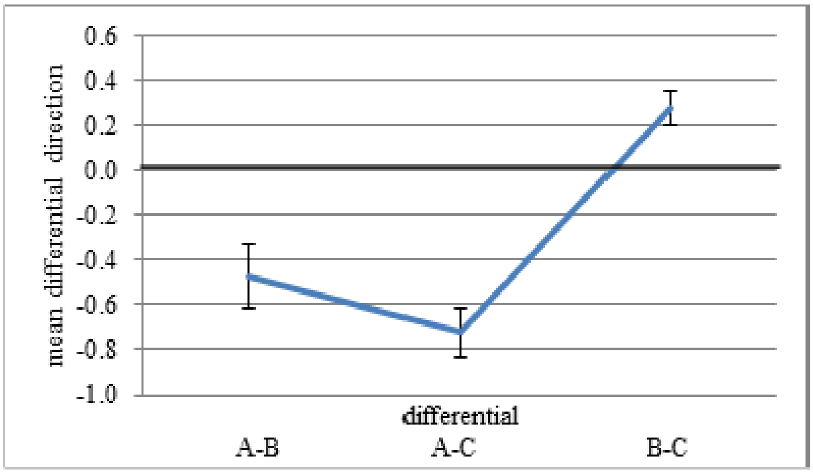


Figure 9-46 Profile graph of simple main effects of *differential* for requirement 14 on measure direction

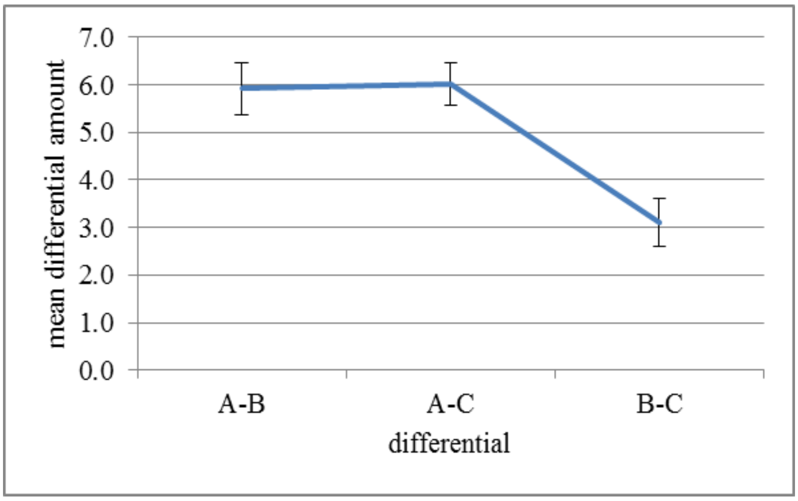


Figure 9-47 Profile graph of simple main effects of *differential* for requirement 14 on measure amount

9.4.4.2.6 Differential mean ratings for requirement 17

Table 9-130 shows the results of multivariate tests. The second-order interaction effect of *differential*method* for requirement 17 was not significant as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* do not depend on *method* and the mean ratings of *method* do not depend on *differential* for requirement 17. Therefore, the simple main effects of *differential* and *method* were considered further.

The simple main effect of *differential* was significant (p<0.001) as suggested by Pillai's Trace as shown in Table 9-130, whereas the simple main effect of *method* was not significant as suggested by Pillai's Trace as shown in Table 9-131.

Table 9-130 Multivariate tests of *differential*method* for requirement 17

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Differential	Pillai's Trace	.556	13.1	4	136	p<.001
	Wilks' Lambda	.504	13.7[c]	4	134	p<.001
	Hotelling's Trace	.863	14.2	4	132	p<.001
	Roy's Largest Root	.691	23.5[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.069	1.21	4	136	.309
	Wilks' Lambda	.932	1.2[c]	4	134	.316
	Hotelling's Trace	.071	1.2	4	132	.324
	Roy's Largest Root	.041	1.4[d]	2	68	.253

a. Design: Intercept + Method
Within Subjects Design: differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-131 Multivariate tests of simple main effect of *method* for requirement 17

Method	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Pillai's trace	.034	.577[a]	2	33	.567
Wilks' lambda	.966	.577[a]	2	33	.567
Hotelling's trace	.035	.577[a]	2	33	.567
Roy's largest root	.035	.577[a]	2	33	.567

Each F tests the multivariate effect of Method. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Table 9-132 shows the results of Mauchly's sphericity test of *differential* for each of measure direction and amount. These tests indicate that the simple main effects of both measures direction and amount have violated this assumption. The Lower-bound significance value is used because it is the most conservative (Field, 2013).

Table 9-132 Mauchly's test of sphericity for requirement 17 on each measure

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Differential	Direction	.713	11.2	2	.004	.777	.831	.5
	Amount	.716	11	2	.004	.779	.834	.5

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: differential
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-133 shows the univariate tests. The simple main effect of *differential* for requirement 17 were significant differences (p<0.001) on both measures direction and amount using Lower-bound adjustment. The full table is shown in Table 0-68, Appendix K.

Table 9-133 Univariate tests of simple main effect of *differential* on each measure for requirement 17

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	19.2	2	9.62	23.5	p<.001
		Greenhouse-Geisser	19.2	1.55	12.4	23.5	p<.001
		Huynh-Feldt	19.2	1.66	11.6	23.5	p<.001
		Lower-bound	19.2	1	19.2	23.5	p<.001
	Amount	Sphericity Assumed	195	2	97.3	18.7	p<.001
		Greenhouse-Geisser	195	1.56	125	18.7	p<.001
		Huynh-Feldt	195	1.67	117	18.7	p<.001
		Lower-bound	195	1	195	18.7	p<.001
Error(differential)	Direction	Sphericity Assumed	27.9	68	.41		
		Greenhouse-Geisser	27.9	52.8	.527		
		Huynh-Feldt	27.9	56.6	.493		
		Lower-bound	27.9	34	.819		
	Amount	Sphericity Assumed	355	68	5.22		
		Greenhouse-Geisser	355	53	6.7		
		Huynh-Feldt	355	56.7	6.26		
		Lower-bound	355	34	10.4		

Table 9-134 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C, using measure direction for requirement 17 over all methods. There were significant differences for requirement 17 between differentials A-B and A-C, A-B and B-C, and A-C and B-C, on measures direction, and were significant between differentials A-B and B-C, and A-C and B-C, on measure amount. Figure 9-48 and Figure 9-49 illustrate these results.

Table 9-134 Pairwise comparisons of *differential* using measures amount and direction for requirement 17

Measure	(I) differential	(J) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Direction	A-B	A-C	.417*	.128	.008	.095	.738
		B-C	-.611*	.187	.007	-1.081	-.142
	A-C	B-C	-1.03*	.130	p<.001	-1.355	-.701
Amount	A-B	A-C	-.333	.404	.800	-1.348	.682
		B-C	2.67*	.656	.001	1.021	4.313
	A-C	B-C	3*	.525	p<.001	1.680	4.320

Based on estimated marginal means
*. The mean difference is significant at the

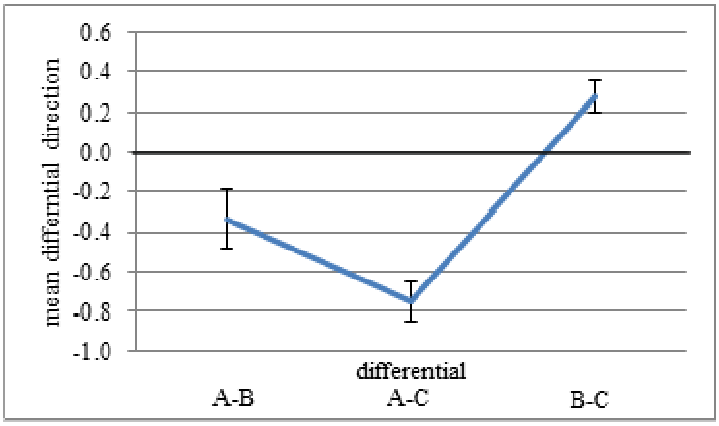


Figure 9-48 Profile graph of simple main effects of *differential* for requirement 17 on measure direction

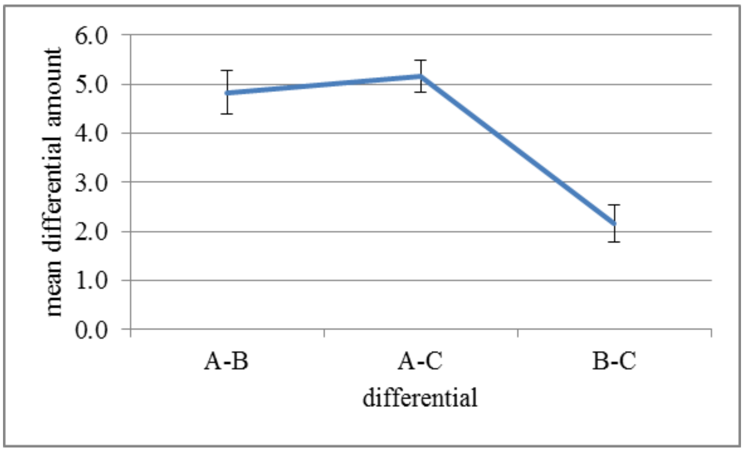


Figure 9-49 Profile graph of simple main effects of *differential* for requirement 17 on measure amount

9.4.4.2.7 Differential mean ratings for requirement 21

Table 9-135 shows the results of multivariate tests. The second-order interaction effect of *differential*method* for requirement 21 was not significant as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* do not depend on *method* and the mean ratings of *method* do not depend on *differential* for requirement 21. Therefore, the simple main effects of *differential* and *method* were considered further.

The simple main effect of *differential* was significant (p<0.001) as suggested by Pillai's Trace as shown in Table 9-135, whereas the simple main effect of *method* was not significant as suggested by Pillai's Trace as shown in Table 9-136.

Table 9-135 Multivariate tests of *differential*method* for requirement 21

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Differential	Pillai's Trace	.264	5.17	4	136	.001
	Wilks' Lambda	.745	5.31[c]	4	134	.001
	Hotelling's Trace	.330	5.44	4	132	p<.001
	Roy's Largest Root	.287	9.76[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.039	.672	4	136	.612
	Wilks' Lambda	.962	.664[c]	4	134	.618
	Hotelling's Trace	.040	.656	4	132	.624
	Roy's Largest Root	.030	1.02[d]	2	68	.366

a. Design: Intercept + Method
Within Subjects Design: differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-136 Multivariate tests of simple main effects of *method* for requirement 21

Method	**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Pillai's trace	.031	.535[a]	2	33	.59
Wilks' lambda	.969	.535[a]	2	33	.59
Hotelling's trace	.032	.535[a]	2	33	.59
Roy's largest root	.032	.535[a]	2	33	.59

Each F tests the multivariate effect of Method. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Table 9-137 shows the results of Mauchly's sphericity test of *differential* for each of measure direction and amount. The significance values of these tests indicate that the simple main effects of *differential* on measure amount do not violate the sphericity assumption, but the simple main effects of *differential* on measure direction has violated this assumption. Therefore the Lower-bound significance value is used for *differential* on measure direction because it is the most conservative (Field, 2013).

Table 9-137 Mauchly's test of sphericity of *differential* for requirement 21

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Differential	Direction	.437	27.3	2	p<.001	.64	.673	.5
	Amount	.935	2.21	2	.332	.939	1	.5

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept + Method
Within Subjects Design: differential
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-138 shows the univariate tests. The simple main effect of *differential* for requirement 21 was significant (p<0.001) on measure amount, but was not significant on measure direction as suggested by Lower-bound. The full table is shown in Table 0-69, Appendix K.

Table 9-138 Univariate tests of simple main effects of *differential* on measures amount and direction for requirement 21

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	1.56	2	.778	1.97	.147
		Greenhouse-Geisser	1.56	1.28	1.22	1.97	.164
		Huynh-Feldt	1.56	1.35	1.16	1.97	.163
		Lower-bound	1.56	1	1.56	1.97	.169
	Amount	Sphericity Assumed	60.2	2	30.1	7.12	.002
		Greenhouse-Geisser	60.2	1.88	32	7.12	.002
		Huynh-Feldt	60.2	2	30.1	7.12	.002
		Lower-bound	60.2	1	60.2	7.12	.012
Error(differential)	Direction	Sphericity Assumed	26.8	68	.394		
		Greenhouse-Geisser	26.8	43.5	.616		
		Huynh-Feldt	26.8	45.8	.586		
		Lower-bound	26.8	34	.789		
	Amount	Sphericity Assumed	287	68	4.22		
		Greenhouse-Geisser	287	63.9	4.5		
		Huynh-Feldt	287	68	4.22		
		Lower-bound	287	34	8.45		

Table 9-139 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C, using measure amount for requirement 21 over all methods. There were significant differences for requirement 21 between differentials A-B and A-C, and A-B and B-C, on measure amount, but there were not significant between differentials A-C and B-C. Figure 9-50 illustrates these results. The full table is shown in Table 0-70, Appendix K.

Table 9-139 Pairwise comparisons of *differential* on measure amount for requirement 21

Measure	(I) differential	(J) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Amount	A-B	A-C	1.58*	.501	.010	.326	2.84
		B-C	1.58*	.526	.015	.263	2.9
	A-C	B-C	.000	.421	1	-1.06	1.06

Based on estimated marginal means
*. The mean difference is significant at the
b. Adjustment for multiple comparisons: Sidak.

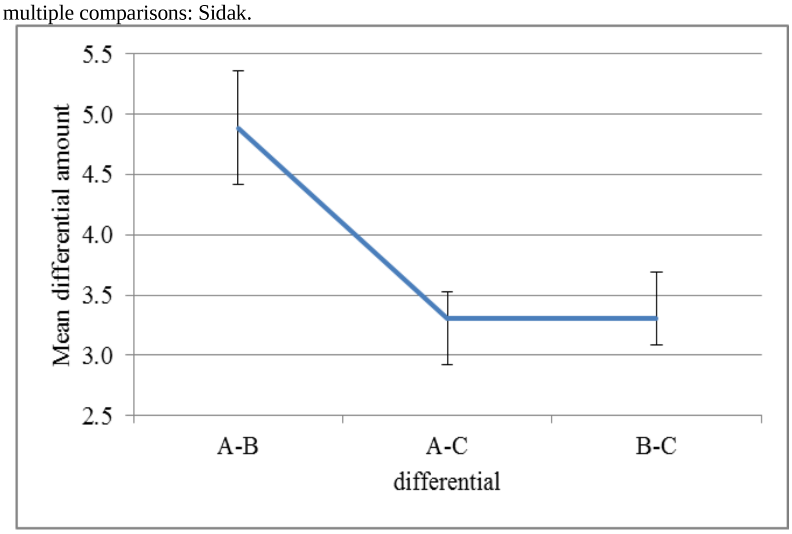


Figure 9-50 Profile graph of simple main effects of *differential* for requirement 21 on measure amount

9.4.4.2.8 Differential mean ratings for requirement 24

Table 9-140 shows the results of multivariate tests. The second-order simple interaction effect of *differential*method* for requirement 24 was significant as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* depend on *method* and the mean ratings of *method* depend on *differential*. Therefore, the simple simple main effects of *differential* and *method* were not considered further (Table 0-71, Appendix K).

Table 9-140 Multivariate tests of *differential* for requirement 24

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Differential	Pillai's Trace	.857	25.5	4	136	p<.001
	Wilks' Lambda	.149	53.3[c]	4	134	p<.001
	Hotelling's Trace	5.67	93.5	4	132	p<.001
	Roy's Largest Root	5.66	193[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.157	2.89	4	136	.024
	Wilks' Lambda	.848	2.87[c]	4	134	.025
	Hotelling's Trace	.173	2.85	4	132	.026
	Roy's Largest Root	.123	4.18[d]	2	68	.019

a. Design: Intercept + Method
Within Subjects Design: Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-141 shows the univariate tests. The second-order simple interaction effect of *differential*method* for requirement 24 was significant on measure direction ($p<0.05$) using both Greenhouse-Geisser and Huynh-Feldt adjustments, but was not significant for measure amount. The full table is shown in Table 0-72, Appendix K.

Table 9-141 Univariate tests of *differential*method* for requirement 24 on each measure

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential * Method	Direction	Sphericity Assumed	1.19	2	.593	4	.023
		Greenhouse-Geisser	1.19	1.63	.728	4	.031
		Huynh-Feldt	1.19	1.75	.678	4	.028
		Lower-bound	1.19	1	1.19	4	.054
	Amount	Sphericity Assumed	37.5	2	18.7	2.22	.117
		Greenhouse-Geisser	37.5	1.64	22.9	2.22	.127
		Huynh-Feldt	37.5	1.76	21.3	2.22	.124
		Lower-bound	37.5	1	37.5	2.22	.146
Error(differential)	Direction	Sphericity Assumed	10.1	68	.148		
		Greenhouse-Geisser	10.1	55.4	.182		
		Huynh-Feldt	10.1	59.5	.169		
		Lower-bound	10.1	34	.296		
	Amount	Sphericity Assumed	575	68	8.5		
		Greenhouse-Geisser	575	55.7	10.3		
		Huynh-Feldt	575	59.9	9.6		
		Lower-bound	575	34	16.9		

The following syntax '/EMMEANS' (SPSS, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Differential*Method) COMPARE(Differential) ADJ(SIDAK)

/EMMEANS=TABLES(Differential*Method) COMPARE(Method) ADJ(SIDAK)

*1) Marginal mean of differential*method for requirement 24*

Table 9-142 shows the marginal means of *differential*method* on measures amount and direction for requirement 24 with the associated standard errors.

Table 9-142 Marginal means of *differential*method* for requirement 24

Measure	Differential	Method	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Direction	A-B	TEIF	-.444	.152	-.754	-.135
		Other	-.889	.152	-1.2	-.579
	A-C	TEIF	-.389	.166	-.725	-.052
		Other	-.833	.166	-1.17	-.497
	B-C	TEIF	.389	.118	.149	.629
		Other	.389	.118	.149	.629
Amount	A-B	TEIF	12.8	.946	10.9	14.7
		Other	14.5	.946	12.6	16.4
	A-C	TEIF	13.6	1.03	11.5	15.7
		Other	13.4	1.03	11.3	15.5
	B-C	TEIF	2.5	.603	1.27	3.73
		Other	1.39	.603	.163	2.62

2) Simple simple main effects of differential at each level of method for requirement 24

Table 9-143 shows the multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 24. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects (p<0.001) for the TEIF Method and the Other Methods for requirement 24. This indicates that differentials A-B, A-C, and B-C were different for the TEIF Method and the Other Methods at requirement 24. Figure 9-51 and Figure 9-52 illustrate these results.

Table 9-143 Multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 24

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.810	33.[a]	4	31	p<.001
	Wilks' lambda	.190	33[a]	4	31	p<.001
	Hotelling's trace	4.26	33[a]	4	31	p<.001
	Roy's largest root	4.26	33[a]	4	31	p<.001
Other	Pillai's trace	.851	44.1[a]	4	31	p<.001
	Wilks' lambda	.149	44.1[a]	4	31	p<.001
	Hotelling's trace	5.69	44.1[a]	4	31	p<.001
	Roy's largest root	5.69	44.1[a]	4	31	p<.001

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

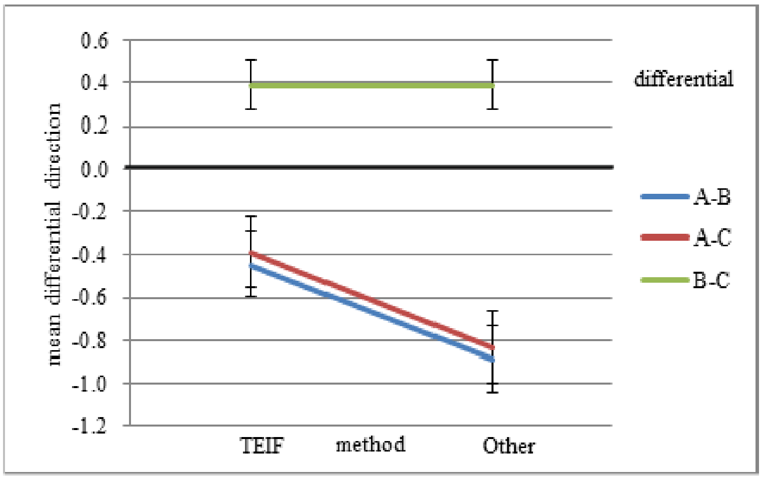


Figure 9-51 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 24 on measure direction

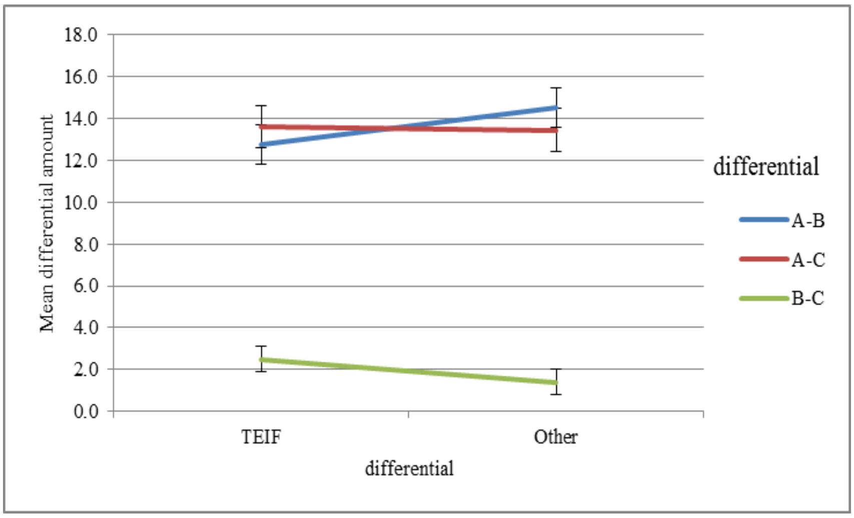


Figure 9-52 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 24 on measure amount

Table 9-144 shows the results of pairwise of comparisons between differentials A-B, A-C, and B-C, using measures direction and amount for requirement 24. There were significant differences for:

- the TEIF Method at requirement 24 between differentials A-B and B-C, and A-C and B-C, on both measures direction and amount
- the Other Methods at requirement 24 between differentials A-B and B-C, and A-C and B-C, on both measures direction and amount

However, there were no significant differences for:

- the TEIF Method at requirement 24 between differentials A-B and A-C, on both measures direction and amount
- the Other Methods at requirement 24 between differentials A-B and A-C, on both measures direction and amount

Table 9-144 Pairwise comparisons between methods and differentials using measures direction and amount for requirement 24

Measure	**Method**	**(I) Differential**	**(J) Differential**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**[b]	**95% Confidence Interval for Difference**[b]	
							Lower Bound	**Upper Bound**
Direction	TEIF	A-B	A-C	-.056	.098	.923	-.302	.191
			B-C	-.833*	.129	.000	-1.16	-.511
		A-C	B-C	-.778*	.152	.000	-1.16	-.395
	Other	A-B	A-C	-.056	.098	.923	-.302	.191
			B-C	-1.28*	.129	.000	-1.6	-.955
		A-C	B-C	-1.22*	.152	.000	-1.61	-.839
Amount	TEIF	A-B	A-C	-.833	.743	.610	-2.7	1.031
			B-C	10.3*	.975	.000	7.83	12.7
		A-C	B-C	11.1*	1.15	.000	8.23	14
	Other	A-B	A-C	1.06	.743	.416	-.809	2.92
			B-C	13.1*	.975	.000	10.7	15.6
		A-C	B-C	12.1*	1.15	.000	9.18	15

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

3) *Simple simple main effects of method at each level of differential for requirement 24*

Table 9-145 shows the multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 24. The significant value for multivariate test as suggested by Pillai's trace was used. There was only a significant simple simple main effect for differential A-C at requirement 24, but not for differentials A-C, and B-C. This indicates that the TEIF Method was different from the Other Methods for differential A-C, but was not different for differentials A-B and B-C at requirement 24. Figure 9-53 and Figure 9-54 illustrate these results.

Table 9-145 Multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 24

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.114	2.12[a]	2	33	.137
	Wilks' lambda	.886	2.12[a]	2	33	.137
	Hotelling's trace	.128	2.12[a]	2	33	.137
	Roy's largest root	.128	2.12[a]	2	33	.137
A-C	Pillai's trace	.247	5.42[a]	2	33	.009
	Wilks' lambda	.753	5.42[a]	2	33	.009
	Hotelling's trace	.329	5.42[a]	2	33	.009
	Roy's largest root	.329	5.42[a]	2	33	.009
B-C	Pillai's trace	.075	1.35[a]	2	33	.274
	Wilks' lambda	.925	1.35[a]	2	33	.274
	Hotelling's trace	.082	1.35[a]	2	33	.274
	Roy's largest root	.082	1.35[a]	2	33	.274

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

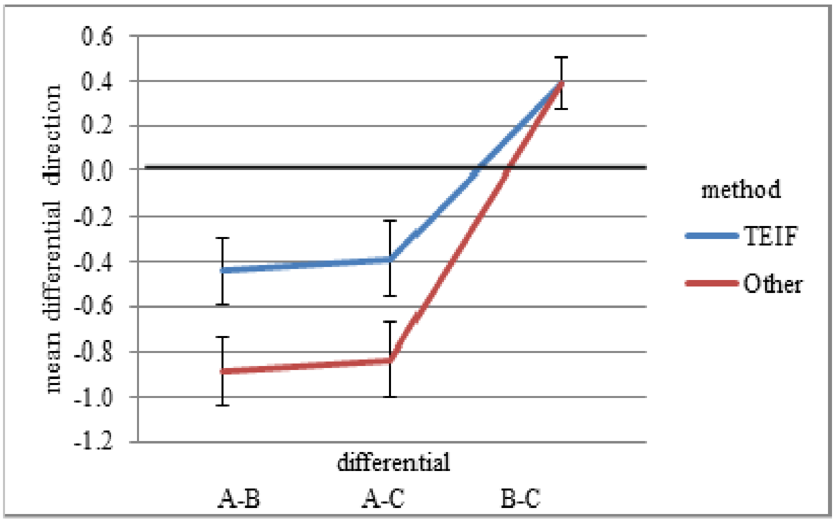


Figure 9-53 Profile graph of simple simple main effect of *method* at each level of *differential* for requirement 21 on measure direction

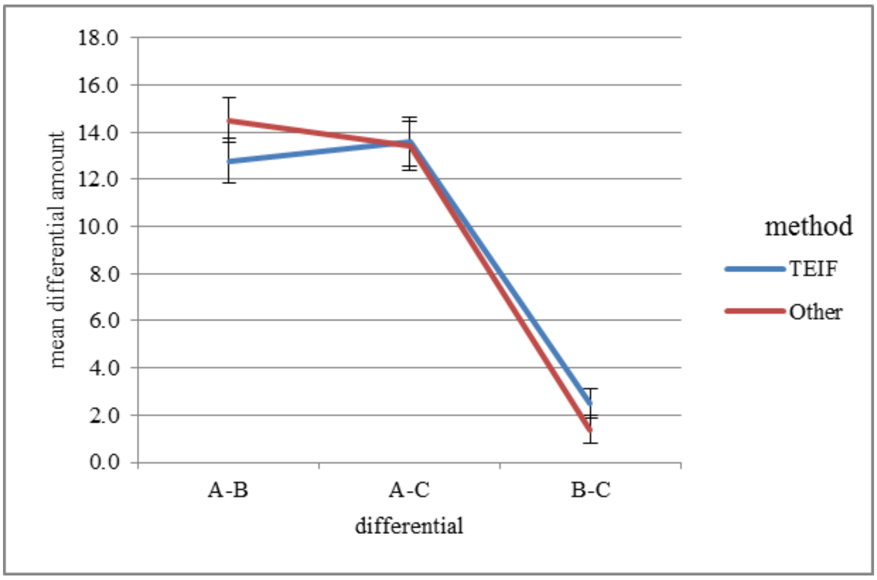


Figure 9-54 Profile graph of simple simple main effect of *method* at each level of *differential* for requirement 21 on measure amount

9.4.4.2.9 Differential mean ratings for requirement 25

Table 9-146 shows the results of multivariate tests. The second-order interaction effect of *differential*method* for requirement 25 was not significant as suggested by Pillai's Trace. This indicates that the mean ratings of *differential* do not depend on *method* and the mean ratings of *method* do not depend on *differential* for requirement 25. Therefore, the simple main effects of *differential* and *method* were considered further. The simple main effect of *differential* was significant (p<0.001) as suggested by Pillai's Trace as shown in Table 9-146, whereas the simple main effect of *method* was not significant as shown in Table 9-147.

Table 9-146 Multivariate of *differential*method* for requirement 25

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Differential	Pillai's Trace	.749	20.4	4	136	p<.001
	Wilks' Lambda	.253	33.1[c]	4	134	p<.001
	Hotelling's Trace	2.94	48.5	4	132	p<.001
	Roy's Largest Root	2.94	99.9[d]	2	68	p<.001
Differential * Method	Pillai's Trace	.075	1.33	4	136	.261
	Wilks' Lambda	.925	1.32[c]	4	134	.265
	Hotelling's Trace	.080	1.31	4	132	.268
	Roy's Largest Root	.066	2.23[d]	2	68	.116

a. Design: Intercept + Method
Within Subjects Design: differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-147 Multivariate tests of simple main effect of *method* for requirement 25

Method	Value	F	Hypothesis df	Error df	Sig.
Pillai's trace	.008	.141[a]	2	33	.869
Wilks' lambda	.992	.141[a]	2	33	.869
Hotelling's trace	.009	.141[a]	2	33	.869
Roy's largest root	.009	.141[a]	2	33	.869

Each F tests the multivariate effect of Method. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Table 9-148 shows the results of Mauchly's sphericity test of *differential* for each of measure direction and amount. The significance values of these tests indicate that the simple main effect of *differential* on measure direction has accepted the assumption, but the simple main effect of *differential* on measure amount has violated this assumption. The Lower-bound significance value was used for *differential* on measure amount because it is the most conservative (Field, 2013).

Table 9-148 Mauchly's sphericity test of *differential* for requirement 25

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Differential	Direction	.867	4.7	2	.095	.883	.955	.500
	Amount	.771	8.57	2	.014	.814	.874	.500

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.

Table 9-149 shows the univariate tests. The simple main effect of *differential* for requirement 25 was significant on both measures direction and amount ($p<0.001$). The full table is shown in Table 0-73, Appendix K.

Table 9-149 Univariate tests of simple main effect of *differential* for requirement 25

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	32.7	2	16.4	53.5	p<.001
		Greenhouse-Geisser	32.7	1.77	18.5	53.5	p<.001
		Huynh-Feldt	32.7	1.91	17.1	53.5	p<.001
		Lower-bound	32.7	1	32.7	53.5	p<.001
	Amount	Sphericity Assumed	1032	2	516	99.9	p<.001
		Greenhouse-Geisser	1032	1.63	634	99.9	p<.001
		Huynh-Feldt	1032	1.75	590	99.9	p<.001
		Lower-bound	1032	1	1032	99.9	p<.001
Error(differential)	Direction	Sphericity Assumed	20.8	68	.306		
		Greenhouse-Geisser	20.8	60	.347		
		Huynh-Feldt	20.8	65	.321		
		Lower-bound	20.8	34	.612		
	Amount	Sphericity Assumed	351	68	5.17		
		Greenhouse-Geisser	351	55	6.35		
		Huynh-Feldt	351	59.5	5.91		
		Lower-bound	351	34	10.33		

Table 9-150 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C using both measures direction and amount for requirement 25. There were significant for requirement 25 between differentials A-B and A-C, and A-B and B-C, on both measures direction and amount, but there were not significant between differentials A-C and B-C, on both measures direction and amount. Figure 9-55 and Figure 9-56 illustrate these results.

Table 9-150 Pairwise comparisons beween *differential* using both measures direction and amount for requirement 25

Measure	(I) differential	(J) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Direction	A-B	A-C	1.14*	.146	p<.001	.773	1.51
		B-C	1.19*	.137	p<.001	.851	1.54
	A-C	B-C	.056	.105	.936	-.208	.319
Amount	A-B	A-C	-6.28*	.602	p<.001	-7.79	-4.77
		B-C	-6.81*	.591	p<.001	-8.29	-5.32
	A-C	B-C	-.528	.387	.453	-1.5	.445

Based on estimated marginal means
*. The mean difference is significant at the
b. Adjustment for multiple comparisons: Sidak.

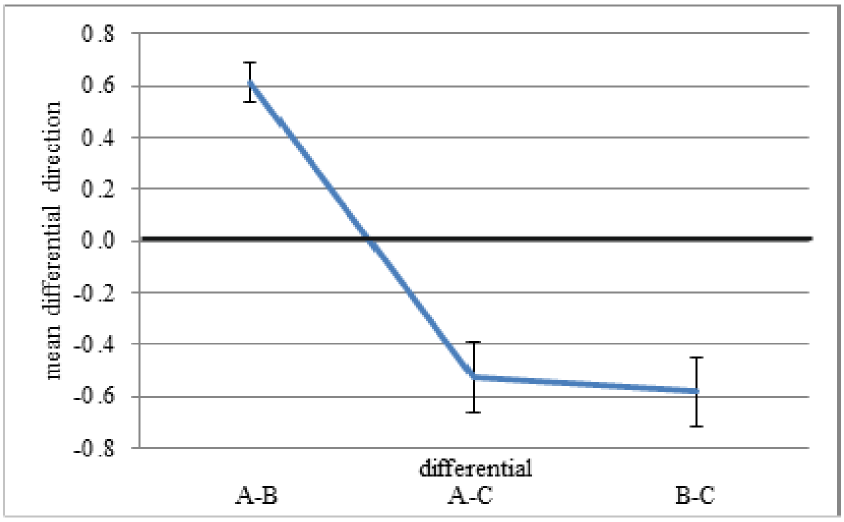


Figure 9-55 Profile graph of simple main effects of *differential* for requirement 25 on measure direction

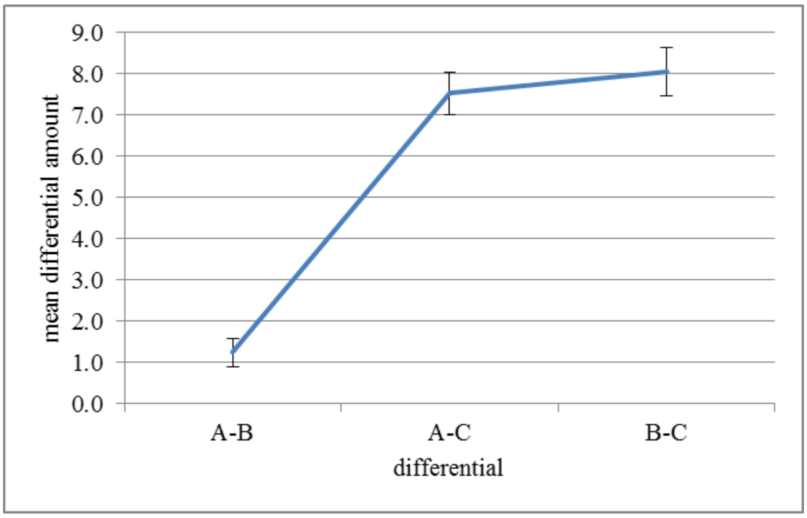


Figure 9-56 Profile graph of simple main effects of *method* for requirement 25 on measure amount

9.4.4.2.10 Differential mean ratings for requirement 28

Table 9-151 shows the results of multivariate tests. The second-order simple interaction effect of *differential*method* for requirement 28 was significant as suggested by Roy's Largest Root. While the offer multivariate statistics (Pillai's Trace, Wilks' Lambda, and Hotelling's Trace) were not significant at α=0.05, it was decided to explore the interaction of indicated by the significant of Roy's Largest Root. This indicates that the mean ratings of *differential* depend on *method* and the mean ratings of *method* depend on *differential* for requirement 28. Therefore, the simple simple main effects of *differential* and *method* were not considered further.

Table 9-151 Multivariate tests of *differential*method* for requirement 28

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Differential	Pillai's Trace	.151	2.77	4	136	.030
	Wilks' Lambda	.850	2.84c	4	134	.027
	Hotelling's Trace	.177	2.91	4	132	.024
	Roy's Largest Root	.174	5.91d	2	68	.004
Differential * Method	Pillai's Trace	.120	2.18	4	136	.075
	Wilks' Lambda	.880	2.21c	4	134	.071
	Hotelling's Trace	.136	2.24	4	132	.068
	Roy's Largest Root	.132	4.5d	2	68	.015

a. Design: Intercept + Method
Within Subjects Design: Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-152 shows the univariate tests. The second-order simple interaction effects of *differential*method* for requirement 28 was significant on measure direction ($p<0.05$), but was not significant for measure amount using Lower-bound adjustments. The full table is shown in Table 0-74, Appendix K.

Table 9-152 Univariate tests of *differential*method* at each measure for requirement 28

Source	**Measure**		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Differential * Method	Direction	Sphericity Assumed	.907	2	.454	4.5	.015
		Greenhouse-Geisser	.907	1.71	.532	4.5	.020
		Huynh-Feldt	.907	1.82	.494	4.5	.017
		Lower-bound	.907	1	.907	4.5	.041
	Amount	Sphericity Assumed	25	2	12.5	2.95	.059
		Greenhouse-Geisser	25	1.34	18.6	2.95	.081
		Huynh-Feldt	25	1.42	17.6	2.95	.078
		Lower-bound	25	1	25	2.95	.095
Error(differential)	Direction	Sphericity Assumed	6.85	68	.101		
		Greenhouse-Geisser	6.85	58	.118		
		Huynh-Feldt	6.85	62.5	.110		
		Lower-bound	6.85	34	.202		
	Amount	Sphericity Assumed	288	68	4.24		
		Greenhouse-Geisser	288	45.7	6.31		
		Huynh-Feldt	288	48.3	5.97		
		Lower-bound	288	34	8.48		

The following syntax '/EMMEANS' (SPSS, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Differential*Method)COMPARE(Differential) ADJ(SIDAK)

/EMMEANS=TABLES(Differential*Method) COMPARE(Method) ADJ(SIDAK)

*1) Marginal mean of differential*method for requirement 28*

Table 9-153 shows the marginal means of *differential*method* on measures amount and direction for requirement 28 with the associated standard errors.

Table 9-153 Marginal means of *differential*method* for requirement 28 on measures amount and direction

Measure	**Differential**	**Method**	**Mean**	**Std. Error**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Direction	A-B	TEIF	.611	.118	.371	.851
		Other	.611	.118	.371	.851
	A-C	TEIF	.611	.118	.371	.851
		Other	.611	.118	.371	.851
	B-C	TEIF	1	.084	.830	1.17
		Other	.611	.084	.441	.781
Amount	A-B	TEIF	2.44	.739	.942	3.95
		Other	1.33	.739	-.169	2.84
	A-C	TEIF	2.44	.793	.833	4.06
		Other	1.61	.793	.000	3.22
	B-C	TEIF	.000	.359	-.730	.730
		Other	1.06	.359	.326	1.79

2) Simple simple main effects of differential at each level of method for requirement 28

Table 9-154 shows the multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 28. The significant value for multivariate test as suggested by Pillai's trace was used. There was a significant simple simple main effects (p<0.001) for the TEIF Method, but not for the Other Methods at requirement 28. This indicates that differentials A-B, A-C, and B-C were different for the TEIF Method but not for the Other Methods at requirement 28. Figure 9-57 and Figure 9-58 illustrate these results.

Table 9-154 Multivariate tests of simple simple main effects of *differential* at each level of *method* for requirement 28

Method		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
TEIF	Pillai's trace	.286	3.1[a]	4	31	.029
	Wilks' lambda	.714	3.1[a]	4	31	.029
	Hotelling's trace	.400	3.1[a]	4	31	.029
	Roy's largest root	.400	3.1[a]	4	31	.029
Other	Pillai's trace	.076	.634[a]	4	31	.642
	Wilks' lambda	.924	.634[a]	4	31	.642
	Hotelling's trace	.082	.634[a]	4	31	.642
	Roy's largest root	.082	.634[a]	4	31	.642

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

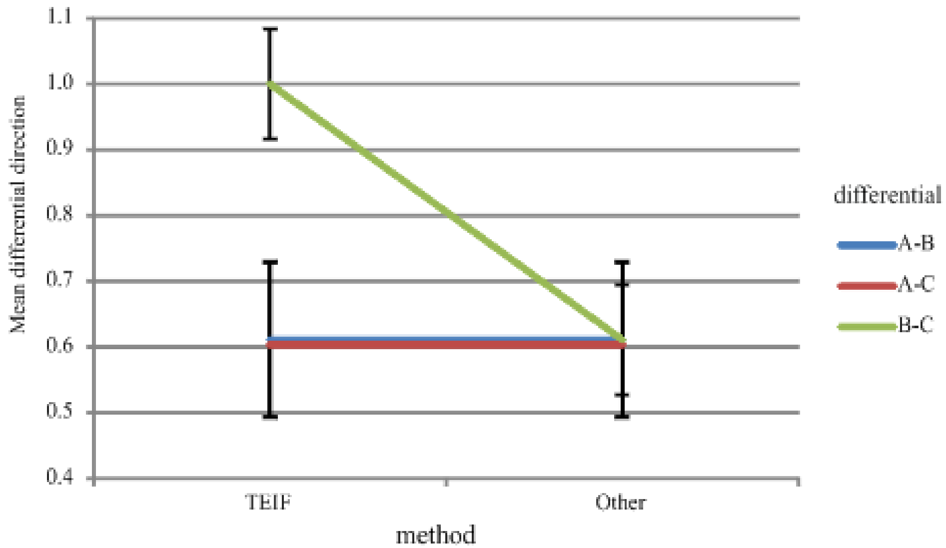


Figure 9-57 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 28 on measure direction

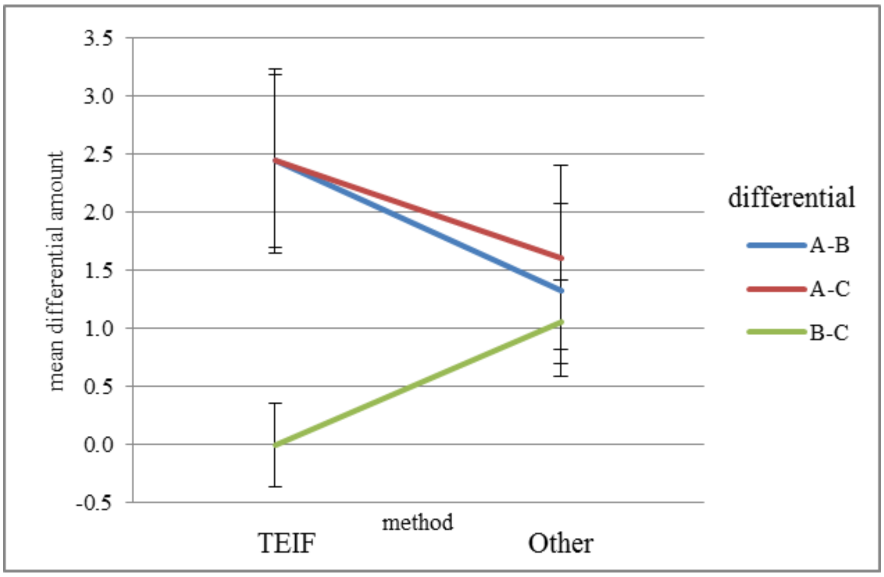


Figure 9-58 Profile graph of simple simple main effects of *differential* at each level of *method* for requirement 28 on measure amount

Table 9-155 shows the results of pairwise comparisons between differentials and methods, using measures direction and amount for requirement 28. There were significant for the TEIF Method at requirement 28 between differentials A-B and B-C, and A-C and B-C, on both measures amount and direction.

However, there were no significant differences of pairwise comparisons for the TEIF Method at requirements 28 between differentials A-B and A-C, on both measures amount and direction.

Table 9-155 Pairwise comparisons between *method* and *differential* using measures direction and amount for requirement 28

Measure	**Method**	**(I) Differential**	**(J) Differential**	**Mean Difference (I-J)**	**Std. Error**	**Sig.**[b]	**95% Confidence Interval for Difference**[b]	
							Lower Bound	**Upper Bound**
Direction	TEIF	A-B	A-C	.000	.081	1	-.203	.203
			B-C	-.389*	.116	.006	-.681	-.097
		A-C	B-C	-.389*	.116	.006	-.681	-.097
Amount	TEIF	A-B	A-C	.000	.391	1	-.982	.982
			B-C	2.44*	.838	.019	.339	4.55
		A-C	B-C	2.44*	.746	.007	.570	4.32

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

3) *Simple simple main effects of method at each level of differential for requirement 28*

Table 9-156 shows the multivariate tests of simple simple main effects of *method* at each level of *differential* for requirement 28. The significant value for multivariate test as suggested by Pillai's trace was used. There was only a significant simple simple main effect for differential B-C at requirement 28, but were not significant simple simple main effects for differentials A-B and A-C. This indicates that the TEIF Method was different from the Other Methods for differential B-C, but they were not different for differentials A-B and A-C, at requirement 28. Figure 9-59 and Figure 9-60 illustrate these results.

Table 9-156 Multivariate tests of method for requirement 28

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.077	1.38[a]	2	33	.265
	Wilks' lambda	.923	1.38[a]	2	33	.265
	Hotelling's trace	.084	1.38[a]	2	33	.265
	Roy's largest root	.084	1.38[a]	2	33	.265
A-C	Pillai's trace	.039	.678[a]	2	33	.515
	Wilks' lambda	.961	.678[a]	2	33	.515
	Hotelling's trace	.041	.678[a]	2	33	.515
	Roy's largest root	.041	.678[a]	2	33	.515
B-C	Pillai's trace	.241	5.25[a]	2	33	.01
	Wilks' lambda	.759	5.25[a]	2	33	.01
	Hotelling's trace	.318	5.25[a]	2	33	.01
	Roy's largest root	.318	5.25[a]	2	33	.01

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

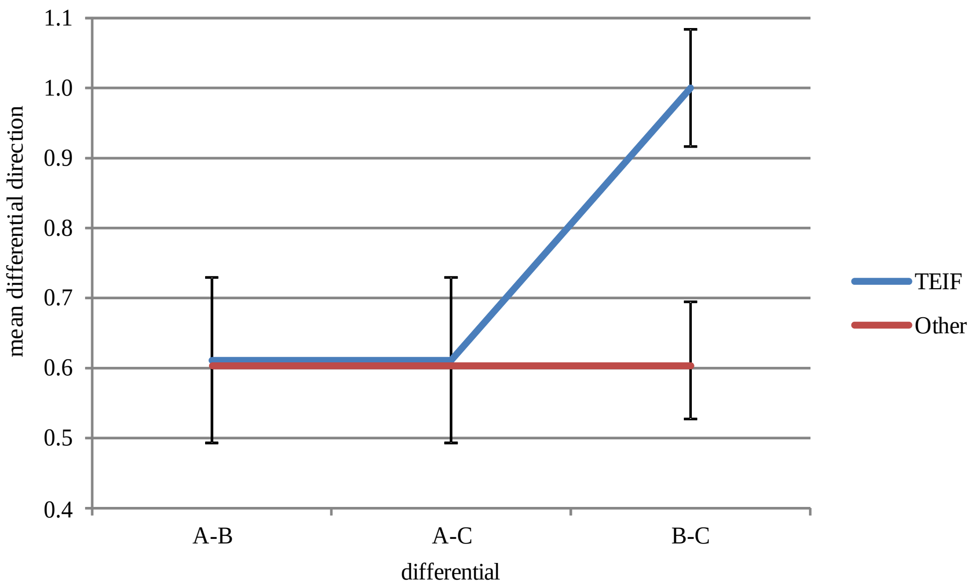


Figure 9-59 Profile graph of simple simple main effects of *method* at each level of *differential* for requirement 28 on measure direction

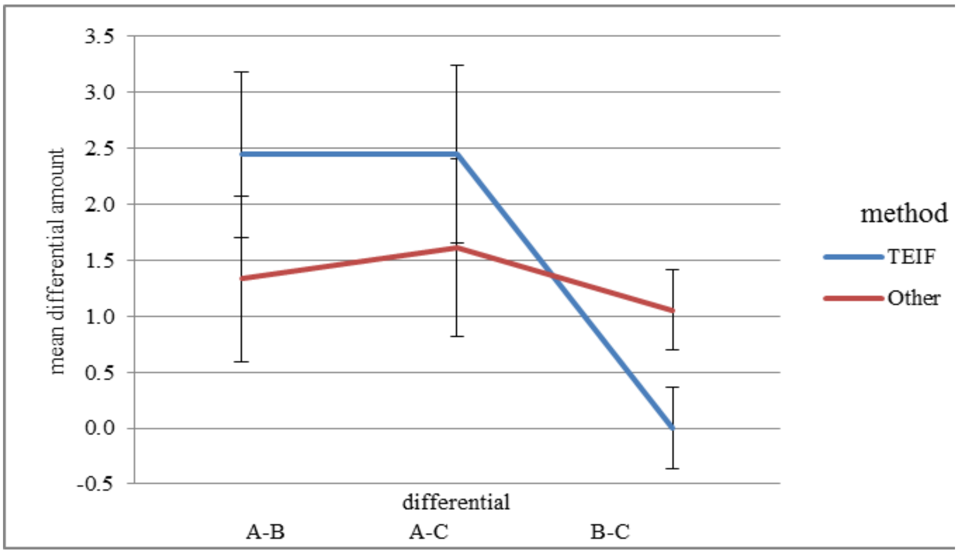


Figure 9-60 simple simple main effects of *method* at each level of *differential* for requirement 28 on measure amount

9.4.4.2.11 Exploring Differential and Method effects for each requirement

Chi-square was used to test whether the TEIF Method was significantly different than the Other Methods for the number of significant *differential* pairs (A-B and A-C, A-B and B-C, A-C and B-C) for measures amount and direction for each *requirement*.

The analysis showed that the TEIF Method was not significantly different than the Other Methods for the number of significant *differential* pairs (A-B and A-C, A-B and B-C, A-C and B-C) for measures amount and direction for each *requirement.*

Table 9-157 Differential and Method effects for each requirement

differential	TEIF Method		Other Method		Chi-Square	df	P Value
	Number of significant pair	Number of not significant pair	Number of significant pair	Number of not significant pair			
Measure amount							
Requirement 1	2	1	3	0			
Requirement 4	0	3	2	1			
Requirement 8	2	1	2	1			
Requirement 11	*differential*method* was not significant						
Requirement 14							
Requirement 17							
Requirement 21							
Requirement 24	2	1	2	1			
Requirement 25							
Requirement 28	2	1	0	3			
Total	8	7	9	6	0.278	1	0.598
Measure direction							
Requirement 1	0	3	1	2			
Requirement 4	1	2	2	1			
Requirement 8	3	0	2	1			
Requirement 11	*differential*method* was not significant						
Requirement 14							
Requirement 17							
Requirement 21							
Requirement 24	2	1	2	1			
Requirement 25	*differential*method* was not significant						
Requirement 28	2	1	0	3			
Total	8	7	7	8	0.268	1	0.605

9.4.4.2.12 Testing of association between significance of differential pairs for each requirement

Due to the small numbers the Fisher Exact test (Roscoe, 1975) was used to test the association between the significance of the TEIF Method and the Other Methods differential pair differences.

Table 9-158 Number of significant and non-significant pairs for each requirement

Differential	TEIF sig Other sig	TEIF sig Other not sig	TEIF not sig Other sig	TEIF not sig Other not sig	Fisher Exact Test	P value
Measure amount						
Requirement 1	2	0	1	0		
Requirement 4	0	0	2	1		
Requirement 8	2	0	0	1		
Requirement 11	*differential*method* was not significant					
Requirement 14						
Requirement 17						
Requirement 21						
Requirement 24	2	0	0	1		
Requirement 25	*differential*method* was not significant					
Requirement 28	0	2	0	1		
Total	6	2	3	4		0.315
Measure direction						
Requirement 1	0	0	1	2		
Requirement 4	1	0	1	1		
Requirement 8	2	1	0	0		
Requirement 11	*differential*method* was not significant					
Requirement 14						
Requirement 17						
Requirement 21						
Requirement 24	2	0	0	1		
Requirement 25	*differential*method* was not significant					
Requirement 28	0	2	0	1		
Total	5	3	2	5		0.315

9.4.4.2.13 Summary of differential and method effects for each requirement

There were significant differences for:

Requirement 1 for:

- TEIF Method for measure amount between differentials A-B and A-C, and A-C and B-C
- Other Method for measure amount between differentials A-B and A-C, A-B and B-C and A-C and B-C and for direction between differentials A-C and B-C

Requirement 4 for:

- the TEIF Method between differentials A-C and B-C on measure direction
- the Other Methods between differentials A-B and B-C, and A-C and B-C on both measures direction and amount

Requirement 8 for:

- the TEIF Method between differentials A-B and A-C, A-B and B-C, A-C and B-C on measure direction
- the Other Methods between differentials A-B and A-C, and A-C and B-C on measure direction
- the TEIF Method for differentials A-B and A-C and A-C and B-C on measure amount
- the Other Methods for differentials A-B and A-C and A-C and B-C on measure amount

Requirement 11 for:

- between differentials A-B and A-C, and A-C and B-C on measure direction over all methods

Requirement 14 for:

- between differentials A-B and B-C, and A-C and B-C, on both measures direction and amount over all methods

Requirement 17 for:

- between differentials A-B and A-C, A-B and B-C, and A-C and B-C on measures direction, and between differentials A-B and B-C, and A-C and B-C on measure amount over all methods

Requirement 21 for:

- between differentials A-B and A-C, and A-B and B-C on measure amount over all methods

Requirement 24 for:

- the TEIF Method between differentials A-B and B-C, and A-C and B-C on both measures direction and amount
- the Other Methods between differentials A-B and B-C, and A-C and B-C on both measures direction and amount
- differential A-C between TEIF Method and the Other Methods on both measures

Requirement 25:

- between differentials A-B and A-C, and A-B and B-C on both measures direction and amount

Requirement 28 for:

- the TEIF Method between differentials A-B and B-C, and A-C and B-C on both measures direction and amount
- differential B-C between the TEIF Method and the Other Methods on both measures

9.4.5 Methods differential closer to expert

Following the significant *requirement*differential*method* third-order interaction, the simple interaction effects of *requirement* and *differential* at each level of *method* were analysed. A multivariate repeated measure two-way analysis of variance with two within subject factors *(requirement)* and (*differential)* was carried out, for each of methods. The two measures were (a) direction and (b) amount.

9.4.5.1 TEIF Method differential closer to expert

Table 9-159 shows the results of multivariate tests. The second-order simple interaction effect of *requirement*differential* for the TEIF Method was significant as suggested by Pillai's Trace. This indicates that the mean ratings of *requirement* depend on *differential* and the mean ratings of *differential* depend on *requirement*. Although the main effects of *requirement* and *differential* were significant, they were not considered further as they were involved in the significant second-order simple interaction effect. The full table is shown in Table 0-75, Appendix K.

Table 9-159 Multivariate tests of *requirement*differential* for TEIF Method

Within Subjects Effect		**Value**	**F**	**Hypothesis df**	**Error df**	**Sig.**
Requirement * Differential	Pillai's Trace	.898	13.8	36	612	p<.001
	Wilks' Lambda	.254	16.7[c]	36	610	p<.001
	Hotelling's Trace	2.34	19.8	36	608	p<.001
	Roy's Largest Root	2.05	34.8[d]	18	306	p<.001

a. Design: Intercept
Within Subjects Design: Requirement + Differential + Requirement * Differential
b. Tests are based on averaged variables.
c. Exact statistic d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-160 shows that the Mauchly's sphericity test for *requirement* differential* for the TEIF Method shows a violation of the assumption of sphericity. Therefore Lower-bound adjustment to significance was used for *requirement*differential* because it is the most conservative (Field, 2013).

Table 9-160 Mauchly's test of sphericity of *requirement*differential* for TEIF Method

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Requirement	Direction	.008	66.8	44	.021	.575	.856	.111
	Amount	.004	77.2	44	.002	.496	.695	.111
Differential	Direction	.753	4.54	2	.104	.802	.873	.500
	Amount	.679	6.2	2	.045	.757	.815	.500
Requirement * Differential	Direction	.000	.	170	.	.401	.725	.056
	Amount	.000	.	170	.	.413	.764	.056

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept
Within Subjects Design: Requirement + Differential + Requirement * Differential
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-161 shows the univariate tests. The second-order simple interaction effect of *requirement*differential* for the TEIF Method was significant for both measure amount and direction, using Lower-bound adjustment. This indicates that the effects of requirement depend on *differential,* and the effects of *differential* depend on *requirement,* for measures amount and direction. Although the main effects of both *method* and *requirement* were significant simple main effects, they were not considered further as they were involved in the significant second-order simple interaction effect. The full table is shown in Table 0-76, Appendix K.

Table 9-161 Univariate tests of *requirement*differential* for TEIF Method

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement * Differential	Direction	Sphericity Assumed	35.4	18	1.97	5.48	p<.001
		Greenhouse-Geisser	35.4	7.21	4.91	5.48	p<.001
		Huynh-Feldt	35.4	13.6	2.71	5.48	p<.001
		Lower-bound	35.4	1	35.4	5.48	.032
	Amount	Sphericity Assumed	2221	18	123	26	p<.001
		Greenhouse-Geisser	2221	7.43	299	26	p<.001
		Huynh-Feldt	2221	13.8	161	26	p<.001
		Lower-bound	2221	1	2221	26	p<.001
Error(Requirement*Differential)	Direction	Sphericity Assumed	110	306	.359		
		Greenhouse-Geisser	110	123	.897		
		Huynh-Feldt	110	222	.495		
		Lower-bound	110	17	6.47		
	Amount	Sphericity Assumed	1453	306	4.75		
		Greenhouse-Geisser	1453	126	11.5		
		Huynh-Feldt	1453	234	6.21		
		Lower-bound	1453	17	85.4		

The following syntax '/EMMEANS' (SPSS, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Requirement*Differential)COMPARE(Requirement)ADJ (SIDAK)

/EMMEANS=TABLES(Requirement*Differential)COMPARE(Differential)ADJ (SIDAK)

*1) Marginal means of requirement*differential*

Table 9-162 shows the marginal mean *requirement*differential* on measure direction for the TEIF Method with the associated standard errors.

Table 9-162 Marginal means of *requirement*differential* on measure direction for TEIF Method

Measure	Requirement	Differential	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Direction	1	A-B	-0.333	0.214	-0.785	0.118
		A-C	-0.667	0.162	-1.01	-0.326*
		B-C	-0.556	0.185	-0.945	-0.166*
	4	A-B	0.056	0.235	-0.441	0.552
		A-C	-0.333	0.198	-0.751	0.084
		B-C	0.222	0.101	0.009	0.435*
	8	A-B	0.5	0.121	0.244	0.756*
		A-C	0.056	0.056	-0.062	0.173
		B-C	0.833	0.121	0.577	1.09*
	11	A-B	-0.167	0.218	-0.626	0.293
		A-C	0.333	0.114	0.092	0.575*
		B-C	-0.222	0.236	-0.721	0.277
	14	A-B	-0.278	0.226	-0.754	0.199
		A-C	-0.611	0.183	-0.998	-0.224*
		B-C	0.278	0.109	0.049	0.507*
	17	A-B	-0.167	0.218	-0.626	0.293
		A-C	-0.722	0.158	-1.06	-0.389*
		B-C	0.222	0.101	0.009	0.435*
	21	A-B	-0.556	0.202	-0.981	-0.13*
		A-C	-0.667	0.114	-0.908	-0.425*
		B-C	-0.389	0.216	-0.845	0.067
	24	A-B	-0.444	0.202	-0.87	-0.019*
		A-C	-0.389	0.216	-0.845	0.067
		B-C	0.389	0.118	0.139	0.638*
	25	A-B	0.444	0.121	0.19	0.699*
		A-C	-0.444	0.217	-0.903	0.014
		B-C	-0.611	0.183	-0.998	-0.224*
	28	A-B	0.611	0.118	0.362	0.861*
		A-C	0.611	0.118	0.362	0.861*
		B-C	1	0	1	1*

Table 9-163 shows the marginal mean *requirement*differential* on measure amount for the TEIF Method with the associated standard errors.

Table 9-163 Marginal means of *requirement*differential* on measure amount for TEIF Method

Measure	Requirement	Differential	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Amount	1	A-B	4.5	0.487	3.47	5.53
		A-C	6.5	0.556	5.33	7.67
		B-C	3.56	0.71	2.06	5.05
	4	A-B	3.11	0.484	2.09	4.13
		A-C	3.22	0.502	2.16	4.28
		B-C	2.67	0.554	1.5	3.84
	8	A-B	8.33	0.605	7.06	9.61
		A-C	2.5	0.39	1.68	3.32
		B-C	7.17	0.715	5.66	8.68
	11	A-B	2.22	0.475	1.22	3.23
		A-C	1.72	0.419	0.84	2.61
		B-C	2.83	0.493	1.79	3.87
	14	A-B	5.17	0.829	3.42	6.92
		A-C	5.28	0.47	4.29	6.27
		B-C	2.89	0.641	1.54	4.24
	17	A-B	4.67	0.631	3.33	6
		A-C	5	0.443	4.07	6
		B-C	2.67	0.631	1.33	4
	21	A-B	4.83	0.437	3.91	5.76
		A-C	3.28	0.226	2.8	3.75
		B-C	2.67	0.428	1.76	3.57
	24	A-B	12.8	1.034	10.6	15
		A-C	13.6	1.169	11.1	16.1
		B-C	2.5	0.711	1	4
	25	A-B	1.89	0.588	0.648	3.13
		A-C	7.11	0.656	5.73	8.5
		B-C	8.44	0.853	6.65	10.2
	28	A-B	2.44	0.864	0.621	4.27
		A-C	2.44	0.864	0.621	4.27
		B-C	0	0	0	0

2) Simple simple main effects of requirement at each level of differential for TEIF Method

Table 9-164 shows the multivariate tests of simple simple main effects of *requirement* at each level of *differential* for the TEIF Method. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple main effects ($p<0.05$) for *requirement* at A-B, A-C, and B-C levels of *differential* for the TEIF Method. Figure 9-61 and Figure 9-62 illustrate these results.

Table 9-164 Multivariate tests of simple simple main effects of *requirement* at each level of *differential* for TEIF Method

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.999	166[a]	16	2	.006
	Wilks' lambda	.001	166[a]	16	2	.006
	Hotelling's trace	1329	166[a]	16	2	.006
	Roy's largest root	1329	166[a]	16	2	.006
A-C	Pillai's trace	1	937[a]	16	2	.001
	Wilks' lambda	.000	937[a]	16	2	.001
	Hotelling's trace	7495	937[a]	16	2	.001
	Roy's largest root	7495	937[a]	16	2	.001
B-C	Pillai's trace	.997	37.5[a]	16	2	.026
	Wilks' lambda	.003	37.5[a]	16	2	.026
	Hotelling's trace	300	37.5[a]	16	2	.026
	Roy's largest root	300	37.5[a]	16	2	.026

Each F tests the multivariate simple simple effects of Requirement within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

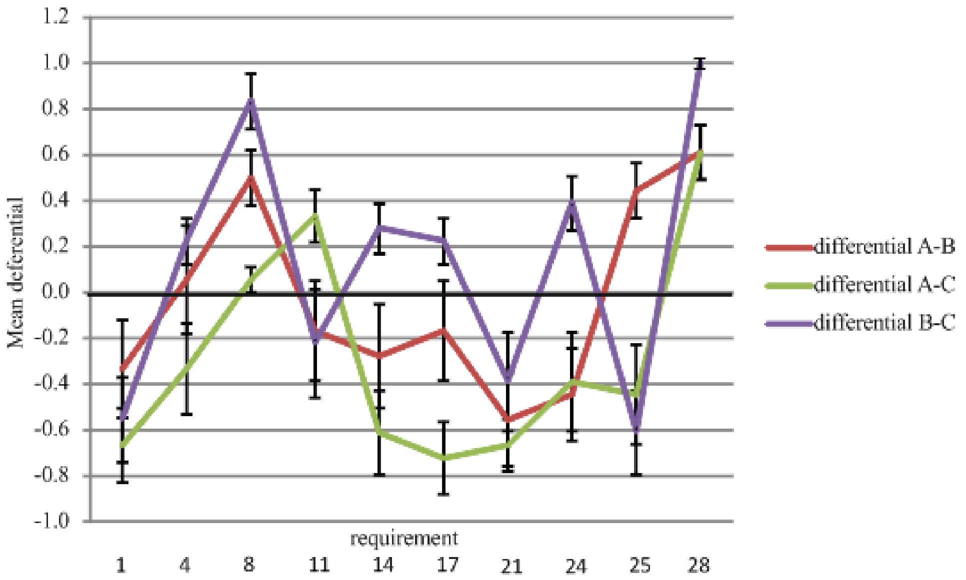


Figure 9-61 Profile graph of simple simple main effects of *differential* on measure direction for TEIF Method

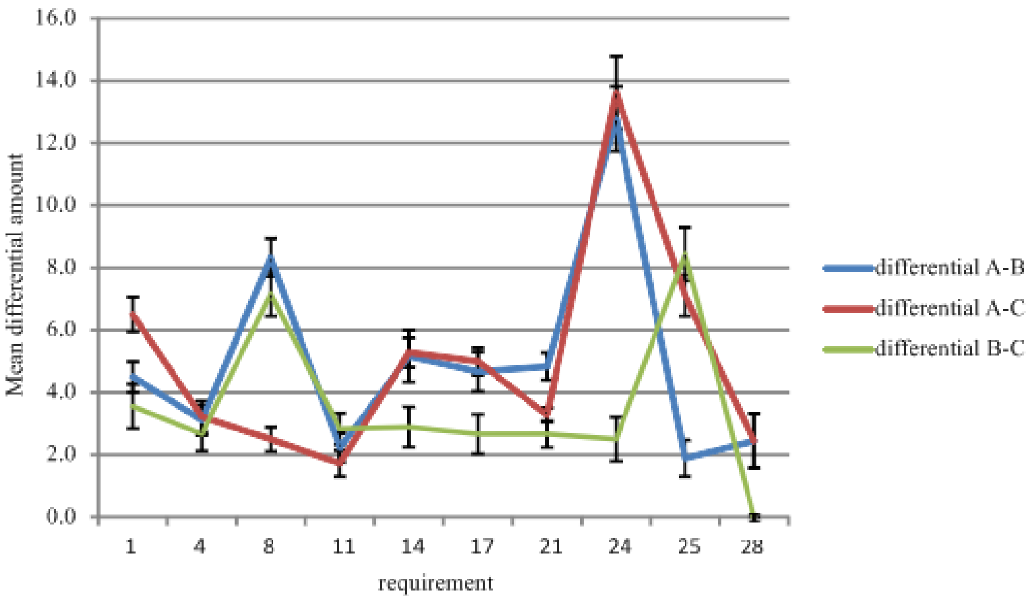


Figure 9-62 Profile graph of simple simple main effects of *differential* on measure direction for TEIF Method

Table 9-165 shows the results of pairwise comparisons of simple simple main effects between requirements using measure direction for differential A-B for the TEIF Method. There was a significant difference of direction for the TEIF Method for differential A-B between requirements 1 and 28, 8 and 21, 21 and 28, and 24 and 28.

However, there was no significant difference for measure direction for differential A-B for the TEIF Method between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 25, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 4 and 25, 4 and 28, 8 and 11, 8 and 14, 8 and 17, 8 and 24, 8 and 25, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 24, 14 and 25, 14 and 28, 17 and 21, 17 and 24, 17 and 25, 17 and 28, 21 and 24, 21 and 25, 24 and 25, and 25 and 28.

Table 9-165 Pairwise comparisons between requirements using measure direction for differential A-B for the TEIF Method

Measure	Differential	requirement		Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	A-B	1	4	-.389	.282	1	-1.49	.711
			8	-.833	.259	.203	-1.84	.177
			11	-.167	.305	1	-1.36	1.03
			14	-.056	.151	1	-.644	.533
			17	-.167	.259	1	-1.18	.844
			21	.222	.207	1	-.586	1.03
			24	.111	.179	1	-.587	.809
			25	-.778	.263	.327	-1.8	.248
			28	-.944*	.235	.040	-1.86	-.026
		4	8	-.444	.258	.993	-1.45	.565
			11	.222	.298	1	-.94	1.39
			14	.333	.229	1	-.56	1.23
			17	.222	.298	1	-.94	1.39
			21	.611	.216	.408	-.232	1.46
			24	.500	.271	.979	-.559	1.56
			25	-.389	.270	1	-1.44	.665
			28	-.556	.305	.983	-1.75	.635
		8	11	.667	.198	.152	-.107	1.44
			14	.778	.250	.249	-.198	1.75
			17	.667	.181	.079	-.039	1.37
			21	1.056*	.235	.015	.137	1.97
			24	.944	.262	.093	-.077	1.97
			25	.056	.171	1	-.612	.723
			28	-.111	.179	1	-.809	.587
		11	14	.111	.254	1	-.882	1.1
			17	0	.214	1	-.835	.835
			21	.389	.257	.999	-.616	1.39
			24	.278	.331	1	-1.02	1.57
			25	-.611	.282	.871	-1.71	.489
			28	-.778	.275	.407	-1.85	.295
		14	17	-.111	.212	1	-.940	.718
			21	.278	.158	.989	-.338	.894
			24	.167	.218	1	-.683	1.02
			25	-.722	.300	.720	-1.9	.451
			28	-.889	.267	.163	-1.9	.153
		17	21	.389	.200	.960	-.393	1.17
			24	.278	.253	1	-.711	1.27
			25	-.611	.293	.911	-1.76	.533
			28	-.778	.263	.327	-1.8	.248
		21	24	-.111	.212	1	-.940	.718
			25	-1	.280	.101	-2.09	.094
			28	-1.17*	.246	.008	-2.13	-.206
		24	25	-.889	.254	.117	-1.88	.104
			28	-1.06*	.206	.004	-1.86	-.252
		25	28	-.167	.167	1	-.818	.484

*. The mean difference is significant at the .05 level

Table 9-166 shows the results of pairwise comparison between requirements using measure direction for differential A-C for the TEIF Method. There was a significant difference for measure direction for differential A-C for the TEIF Method between requirements 1 and 8, 1 and 11, 1 and 28, 8 and 17, 8 and 21, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 14 and 28, 17 and 28, 21 and 28, 24 and 28, and 25 and 28.

However, there was no significant difference for measure direction for differential A-C for the TEIF Method between requirements 1 and 4, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 1 and 25, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 4 and 25, 4 and 28, 8 and 11, 8 and 14, 8 and 24, 8 and 25, 11 and 24, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 24, 14 and 25, 17 and 21, 17 and 24, 17 and 25, 21 and 24, 21 and 25, and 24 and 25.

Table 9-166 Pairwise comparisons between requirements using measure direction for differential A-C for the TEIF Method

Measure				Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	A-C	1	4	-.333	.280	1	-1.43	.760
			8	-.722*	.177	.035	-1.41	-.030
			11	-1*	.140	p<.001	-1.55	-.453
			14	-.056	.249	1	-1.08	.916
			17	.056	.189	1	-.683	.794
			21	0	.162	1	-.631	.631
			24	-.278	.311	1	-1.49	.937
			25	-.222	.286	1	-1.34	.896
			28	-1.28*	.211	.001	-2.1	-.454
		4	8	-.389	.183	.895	-1.11	.327
			11	-.667	.256	.566	-1.67	.332
			14	.278	.289	1	-.852	1.41
			17	.389	.270	1	-.665	1.44
			21	.333	.214	.999	-.502	1.17
			24	.056	.262	1	-.966	1.08
			25	.111	.279	1	-.977	1.2
			28	-.944	.249	.063	-1.92	.027
		8	11	-.278	.135	.925	-.807	.251
			14	.667	.198	.152	-.107	1.44
			17	.778*	.173	.014	.104	1.45
			21	.722*	.135	.002	.193	1.25
			24	.444	.232	.966	-.461	1.35
			25	.5	.232	.880	-.407	1.41
			28	-.556*	.121	.011	-1.03	-.085
		11	14	.944*	.221	.023	.081	1.81
			17	1.06*	.189	.001	.317	1.79
			21	1*	.162	p<.001	.369	1.63
			24	.722	.240	.299	-.215	1.66
			25	.778	.263	.327	-.248	1.8
			28	-.278	.158	.989	-.894	.338
		14	17	.111	.212	1	-.718	.940
			21	.056	.171	1	-.612	.723
			24	-.222	.236	1	-1.15	.701
			25	-.167	.202	1	-.956	.623
			28	-1.22*	.222	.002	-2.09	-.354
		17	21	-.056	.171	1	-.723	.612
			24	-.333	.243	1	-1.28	.614
			25	-.278	.300	1	-1.45	.895
			28	-1.33*	.229	.001	-2.23	-.440
		21	24	-.278	.253	1	-1.27	.711
			25	-.222	.236	1	-1.15	.701
			28	-1.28*	.177	p<.001	-1.97	-.586
		24	25	.056	.286	1	-1.06	1.17
			28	-1*	.243	.031	-1.95	-.053
		25	28	-1.06*	.249	.024	-2.03	-.084

*. The mean difference is significant at the .05 level

Table 9-167 shows the results of pairwise comparison between requirements using measure direction for differential B-C for the TEIF Method. There was a significant difference for measure direction for differential B-C for the TEIF Method between requirements 1 and 4, 1 and 8, 1 and 24, 1 and 28, 4 and 25, 4 and 28, 8 and 11, 8 and 17, 8 and 21, 8 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 28, 24 and 25, 24 and 28, and 25 and 28.

However, there was no significant difference for measure direction for differential B-C for the TEIF Method between requirements 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 25, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 14, 8 and 24, 8 and 28, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 11 and 25, 14 and 17, 14 and 21, 14 and 24, 17 and 21, 17 and 24, 21 and 24, and 21 and 25.

Table 9-167 Pairwise comparisons between requirements using measure direction for differential B-C for TEIF Method

Measure				Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	B-C	1	4	-.778*	.191	.034	-1.52	-.034
			8	-1.39*	.231	.001	-2.29	-.488
			11	-.333	.280	1	-1.43	.760
			14	-.833	.246	.146	-1.79	.127
			17	-.778	.222	.116	-1.65	.090
			21	-.167	.336	1	-1.48	1.15
			24	-.944*	.235	.040	-1.86	-.026
			25	.056	.274	1	-1.01	1.13
			28	-1.56*	.185	p<.001	-2.28	-.834
		4	8	-.611	.200	.278	-1.393	.171
			11	.444	.271	.997	-.613	1.5
			14	-.056	.127	1	-.552	.441
			17	0	.114	1	-.446	.446
			21	.611	.244	.648	-.343	1.57
			24	-.167	.185	1	-.890	.557
			25	.833*	.202	.031	.044	1.62
			28	-.778*	.101	p<.001	-1.17	-.384
		8	11	1.06*	.262	.038	.034	2.08
			14	.556	.185	.301	-.166	1.28
			17	.611*	.143	.023	.052	1.17
			21	1.22*	.222	.002	.354	2.09
			24	.444	.145	.273	-.122	1.01
			25	1.44*	.202	p<.001	.657	2.23
			28	-.167	.121	1	-.640	.307
		11	14	-.500	.259	.962	-1.51	.511
			17	-.444	.246	.984	-1.4	.514
			21	.167	.326	1	-1.11	1.44
			24	-.611	.257	.742	-1.62	.394
			25	.389	.335	1.	-.918	1.7
			28	-1.22*	.236	.003	-2.15	-.299
		14	17	.056	.098	1	-.328	.439
			21	.667	.256	.566	-.332	1.7
			24	-.111	.179	1	-.809	.587
			25	.889*	.212	.027	.060	1.7
			28	-.722*	.109	p<.001	-1.15	-.298
		17	21	.611	.244	.648	-.343	1.57
			24	-.167	.185	1	-.890	.557
			25	.833*	.202	.031	.044	1.62
			28	-.778*	.101	p<.001	-1.17	-.384
		21	24	-.778	.222	.116	-1.65	.090
			25	.222	.329	1	-1.06	1.51
			28	-1.39*	.216	p<.001	-2.23	-.545
		24	25	1*	.214	.010	.165	1.84
			28	-.611*	.118	.003	-1.07	-.149
		25	28	-1.61*	.183	p<.001	-2.33	-.895

*. The mean difference is significant at the .05 level

Table 9-168 shows the results of pairwise comparisons between requirements using measure amount for differential A-B for the TEIF Method. There was a significant difference for measure amount for the TEIF Method for differential A-B between requirements 1 and 8, 1 and 24, 4 and 8, 4 and 24, 8 and 11, 8 and 17, 8 and 21, 8 and 25, 8 and 28, 11 and 24, 14 and 24, 17 and 24, 21 and 24, 24 and 25, and 24 and 28.

However, there was no significant difference for measure amount for differential A-B for the TEIF Method between requirements 1 and 4, 1 and 11, 1 and 14, 1 and 17, 1 and 21,1 and 25, and 1 and 28, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 25, 4 and 28, 8 and 14, 8 and 24, 11 and 14, 11 and 17, 11 and 21, 11 and 25, 11 and 28, 14 and 17, 14 and 21, 14 and 25, 14 and 28, 17 and 21, 17 and 25, 17 and 28, 21 and 25, 21 and 28, and 25 and 28.

Table 9-168 Pairwise comparisons between requirements using measure amount for differential A-B for TEIF Method

Measure				Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Amount	A-B	1	4	1.39	.728	.968	-1.46	4.23
			8	-3.83*	.817	.009	-7.03	-.641
			11	2.28	.859	.532	-1.08	5.63
			14	-.667	.792	1	-3.76	2.43
			17	-.167	.678	1	-2.81	2.48
			21	-.333	.457	1	-2.12	1.45
			24	-8.28*	.889	p<.001	-11.8	-4.81
			25	2.61	.947	.456	-1.09	6.31
			28	2.06	1.002	.925	-1.86	5.97
		4	8	-5.22*	.693	p<.001	-7.93	-2.52
			11	.889	.582	.999	-1.39	3.16
			14	-2.06	.895	.795	-5.55	1.44
			17	-1.56	.720	.875	-4.37	1.25
			21	-1.72	.547	.233	-3.86	.414
			24	-9.67*	1.100	p<.001	-14	-5.37
			25	1.22	.730	.995	-1.63	4.07
			28	.667	1.163	1	-3.88	5.21
		8	11	6.11*	.766	p<.001	3.12	9.1
			14	3.17	.923	.133	-.436	6.77
			17	3.67*	.705	.003	.914	6.42
			21	3.5*	.776	.014	.468	6.53
			24	-4.44	1.336	.165	-9.66	.774
			25	6.44*	.971	p<.001	2.65	10.2
			28	5.89*	1.029	.001	1.87	9.91
		11	14	-2.94	1.027	.384	-6.96	1.07
			17	-2.44	.738	.169	-5.32	.436
			21	-2.61	.737	.107	-5.49	.267
			24	-10.6*	1.158	p<.001	-15.1	-6.03
			25	.333	.605	1	-2.03	2.7
			28	-.222	.969	1	-4	3.56
		14	17	.500	.912	1	-3.06	4.06
			21	.333	.741	1	-2.56	3.23
			24	-7.61*	1.06	p<.001	-11.8	-3.46
			25	3.28	1.2	.468	-1.4	7.95
			28	2.72	1.11	.686	-1.62	7.06
		17	21	-.167	.595	1.000	-2.49	2.16
			24	-8.11*	.925	p<.001	-11.7	-4.5
			25	2.78	1.08	.588	-1.43	6.99
			28	2.22	.877	.621	-1.2	5.65
		21	24	-7.94*	.934	p<.001	-11.6	-4.3
			25	2.94	.873	.150	-.463	6.35
			28	2.39	.967	.671	-1.39	6.17
		24	25	10.9*	1.38	p<.001	5.5	16.3
			28	10.3*	1.05	p<.001	6.23	14.4
		25	28	-.556	1.11	1.000	-4.89	3.78

*. The mean difference is significant at the .05 level.

Table 9-169 shows the results of pairwise comparisons between requirements using measure amount for differential A-C for the TEIF Method. There was a significant difference of measure amount for the TEIF Method for differential A-C between requirements 1 and 8, 1 and 11, 1 and 21, 1 and 24, 4 and 24, 4 and 25, 8 and 14, 8 and 17, 8 and 24, 8 and 25, 11 and 14, 11 and 17, 11 and 24, 11 and 25, 14 and 21, 14 and 24, 17 and 21, 17 and 24, 21 and 24, 21 and 25, 24 and 25, 24 and 28, and 25 and 28.

However, there was no significant difference for measure amount for differential A-C for the TEIF Method between requirements 1 and 4, 1 and 14, 1 and 17, 1 and 25, and 1 and 28, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 28, 8 and 11, 8 and 21, 8 and 28, 11 and 21, 11 and 28, 14 and 17, 14 and 25, 14 and 28, 17 and 25, 17 and 28, and 21 and 28.

Table 9-169 Pairwise comparisons between requirements using measure amount for differential A-C for TEIF Method

Measure	**(I)requirement**		**J(requirement)**	**Mean Difference (I-J)**	**Std. Error**	**Sig.[b]**	**95% Confidence Interval for Difference[b]**	
							Lower Bound	**Upper Bound**
Amount	A-C	1	4	3.28	.855	.058	-.060	6.62
			8	4*	.577	p<.001	1.75	6.26
			11	4.78*	.645	p<.001	2.26	7.3
			14	1.22	.717	.994	-1.58	4.02
			17	1.5	.579	.578	-.760	3.76
			21	3.22*	.502	p<.001	1.26	5.18
			24	-7.11*	1.46	.007	-12.8	-1.39
			25	-.611	.964	1	-4.38	3.15
			28	4.06	1.05	.053	-.030	8.14
		4	8	.722	.571	1	-1.51	2.95
			11	1.5	.809	.978	-1.66	4.66
			14	-2.06	.730	.416	-4.9	.794
			17	-1.78	.774	.794	-4.8	1.24
			21	-.056	.514	1	-2.06	1.95
			24	-10.4*	1.21	p<.001	-15.1	-5.65
			25	-3.89*	.762	.004	-6.87	-.912
			28	.778	1.03	1	-3.24	4.79
		8	11	.778	.645	1	-1.74	3.3
			14	-2.78*	.650	.023	-5.31	-.241
			17	-2.5*	.606	.031	-4.87	-.132
			21	-.778	.409	.969	-2.374	.818
			24	-11.1*	1.42	p<.001	-16.6	-5.58
			25	-4.61*	.687	p<.001	-7.29	-1.93
			28	.056	.880	1	-3.38	3.49
		11	14	-3.56*	.781	.013	-6.6	-.507
			17	-3.28*	.630	.003	-5.74	-.816
			21	-1.56	.519	.307	-3.58	.471
			24	-11.9*	1.4	p<.001	-17.3	-6.44
			25	-5.39*	.936	.001	-9.05	-1.73
			28	-.722	.976	1	-4.53	3.09
		14	17	.278	.593	1	-2.04	2.59
			21	2*	.464	.021	.186	3.81
			24	-8.33*	1.05	p<.001	-12.4	-4.25
			25	-1.83	.622	.335	-4.26	.597
			28	2.83	.923	.269	-.770	6.44
		17	21	1.72*	.426	.038	.057	3.39
			24	-8.61*	1.17	p<.001	-13.2	-4.06
			25	-2.11	.911	.781	-5.67	1.45
			28	2.56	.981	.568	-1.28	6.39
		21	24	-10.3*	1.22	p<.001	-15.1	-5.56
			25	-3.83*	.663	.001	-6.42	-1.24
			28	.833	.912	1	-2.73	4.4
		24	25	6.5*	1.15	.001	2.021	11
			28	11.2*	1.5	p<.001	5.51	16.9
		25	28	4.7*	1.02	.012	.698	8.64

*. The mean difference is significant at the .05 level.

Table 9-170 shows the results of pairwise comparisons between requirements using measure amount for differential B-C for the TEIF Method. There was a significant difference for measure amount for the TEIF Method for differential B-C between requirements 1 and 25, 1 and 28, 4 and 8, 4 and 25, 4 and 28, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 24, 8 and 28, 11 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 25, 21 and 28, 24 and 25, and 25 and 28.

However, there was no significant difference for measure amount for differential B-C for the TEIF Method between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 25, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 14 and 17, 14 and 21, 14 and 24, 17 and 21, 17 and 24, 21 and 24, and 24 and 28.

Table 9-170 Pairwise comparisons between requirements using measure amount for differential B-C for TEIF Method

Measure				Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Amount	B-C	1	4	.889	.588	.999	-1.41	3.19
			8	-3.61	1.12	.199	-7.98	.754
			11	.722	.699	1	-2.01	3.45
			14	.667	.893	1	-2.82	4.15
			17	.889	1.06	1	-3.04	4.82
			21	.889	.582	.999	-1.39	3.16
			24	1.06	1.16	1	-3.48	5.59
			25	-4.89*	1.1	.016	-9.19	-.585
			28	3.56*	.710	.005	.781	6.33
		4	8	-4.5*	.981	.012	-8.33	-.669
			11	-.167	.617	1	-2.58	2.24
			14	-.222	.508	1	-2.21	1.76
			17	0	.667	1	-2.6	2.6
			21	0	.492	1	-1.92	1.92
			24	.167	1.14	1	-4.29	4.62
			25	-5.78*	.850	p<.001	-9.1	-2.46
			28	2.67*	.554	.007	.502	4.83
		8	11	4.33*	.904	.008	.804	7.86
			14	4.28*	1.08	.046	.044	8.51
			17	4.5*	.772	.001	1.48	7.52
			21	4.5*	.919	.006	.911	8.09
			24	4.67*	.925	.004	1.05	8.28
			25	-1.28	1.15	1	-5.76	3.21
			28	7.17*	.715	p<.001	4.37	9.96
		11	14	-.056	.834	1	-3.31	3.2
			17	.167	.742	1	-2.73	3.06
			21	.167	.697	1	-2.55	2.89
			24	.333	1	1	-3.57	4.24
			25	-5.61*	1.16	.007	-10.14	-1.08
			28	2.83*	.493	.001	.907	4.76
		14	17	.222	.613	1	-2.17	2.62
			21	.222	.527	1	-1.84	2.28
			24	.389	1.14	1	-4.06	4.83
			25	-5.56*	.789	p<.001	-8.64	-2.48
			28	2.89*	.641	.014	.385	5.39
		17	21	0	.788	1	-3.08	3.08
			24	.167	1.06	1	-3.95	4.29
			25	-5.78*	.952	.001	-9.49	-2.06
			28	2.67*	.631	.025	.201	5.13
		21	24	.167	.919	1	-3.42	3.76
			25	-5.78*	.774	p<.001	-8.8	-2.76
			28	2.67*	.428	p<.001	.996	4.34
		24	25	-5.94*	.968	p<.001	-9.73	-2.16
			28	2.5	.711	.112	-.275	5.28
		25	28	8.44*	.853	p<.001	5.12	11.8

*. The mean difference is significant at the .05 level.

3) *Simple simple main effect of differential at each level of requirement*

Table 9-171 shows the multivariate tests of simple simple main effects of differentials A-B, A-C and B-C, at each level of *requirement*, for the TEIF Method. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple effects (p<0.05) for *differential* at requirements 1, 8, 14, 17, 21, 24, 25, and 28, for the TEIF Method. However, there were not significant effects for *differential* at requirements 4 and 11. Figure 9-63 and Figure 9-64 illustrate these results.

Table 9-171 Multivariate tests of simple simple main effects of *differential* at each level of *requirement*

Requirement		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.583	4.89[a]	4	14	.011
	Wilks' lambda	.417	4.89[a]	4	14	.011
	Hotelling's trace	1.4	4.89[a]	4	14	.011
	Roy's largest root	1.4	4.89[a]	4	14	.011
4	Pillai's trace	.440	2.75[a]	4	14	.071
	Wilks' lambda	.560	2.75[a]	4	14	.071
	Hotelling's trace	.786	2.75[a]	4	14	.071
	Roy's largest root	.786	2.75[a]	4	14	.071
8	Pillai's trace	.931	47.1[a]	4	14	p<.001
	Wilks' lambda	.069	47.1[a]	4	14	p<.001
	Hotelling's trace	13.5	47.1[a]	4	14	p<.001
	Roy's largest root	13.5	47.1[a]	4	14	p<.001
11	Pillai's trace	.278	1.35[a]	4	14	.301
	Wilks' lambda	.722	1.35[a]	4	14	.301
	Hotelling's trace	.385	1.35[a]	4	14	.301
	Roy's largest root	.385	1.35[a]	4	14	.301
14	Pillai's trace	.568	4.61[a]	4	14	.014
	Wilks' lambda	.432	4.61[a]	4	14	.014
	Hotelling's trace	1.32	4.61[a]	4	14	.014
	Roy's largest root	1.32	4.61[a]	4	14	.014
17	Pillai's trace	.879	25.5[a]	4	14	p<.001
	Wilks' lambda	.121	25.5[a]	4	14	p<.001
	Hotelling's trace	7.3	25.5[a]	4	14	p<.001
	Roy's largest root	7.3	25.5[a]	4	14	p<.001
21	Pillai's trace	.825	16.5[a]	4	14	p<.001
	Wilks' lambda	.175	16.5[a]	4	14	p<.001
	Hotelling's trace	4.72	16.5[a]	4	14	p<.001
	Roy's largest root	4.72	16.5[a]	4	14	p<.001
24	Pillai's trace	.919	39.6[a]	4	14	p<.001
	Wilks' lambda	.081	39.6[a]	4	14	p<.001
	Hotelling's trace	11.3	39.6	4	14	p<.001
	Roy's largest root	11.3	39.6[a]	4	14	p<.001
25	Pillai's trace	.845	19.1[a]	4	14	p<.001
	Wilks' lambda	.155	19.1[a]	4	14	p<.001
	Hotelling's trace	5.46	19.1[a]	4	14	p<.001
	Roy's largest root	5.46	19.1[a]	4	14	p<.001
28	Pillai's trace	.389	5.09[a]	2	16	.019
	Wilks' lambda	.611	5.09[a]	2	16	.019
	Hotelling's trace	.636	5.09[a]	2	16	.019
	Roy's largest root	.636	5.09[a]	2	16	.019

Each F tests the multivariate simple simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

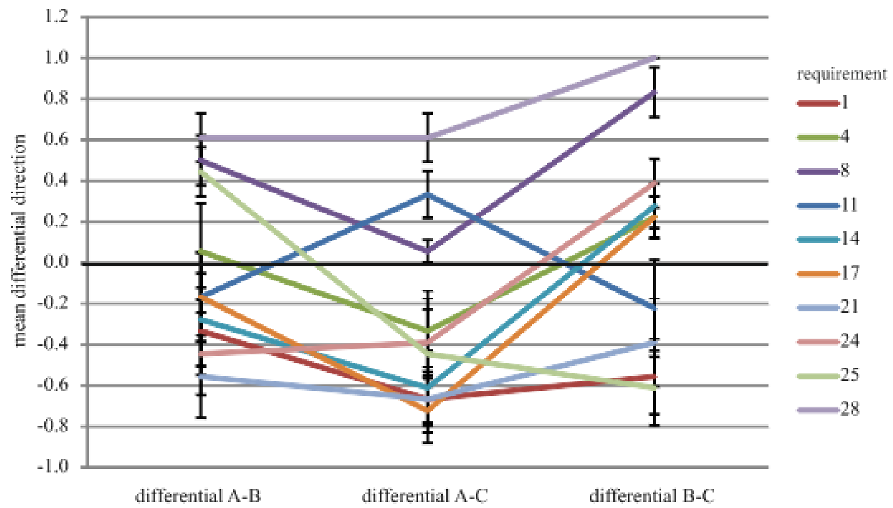


Figure 9-63 Profile graph of simple simple main effects of *requirement* at each level of *differential* on measure amount for TEIF Method

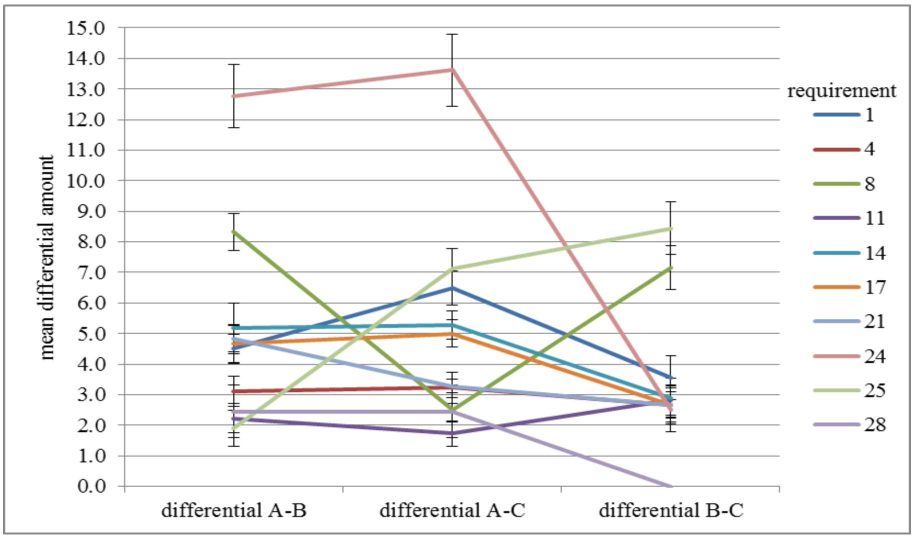


Figure 9-64 Profile graph of simple simple main effects of *requirement* at each level of *differential* on measure direction for TEIF Method

Table 9-172 shows the results of pairwise comparisons between differentials A-B, A-C, and B-C using measure direction at each level of *requirement* for the TEIF Method. There were significant differences on measure direction for:

- requirement 8 between differentials A-B and A-C, and A-C and B-C
- requirement 14 between differentials A-C and B-C
- requirement 17 between differentials A-B and A-C, and A-C and B-C
- requirement 24 between differentials A-B and B-C, and A-C and B-C
- requirement 25 between differentials A-B and A-C, and A-B and B-C
- requirement 28 between differentials A-B and B-C, and A-C and B-C

However, there was no significant difference for measure direction for:

- requirement 1 between differentials A-B and A-C, A-B and B-C, and A-C, and B-C
- requirement 8 between differentials A-B and B-C
- requirement 14 between differentials A-B and A-C, and A-B and B-C
- requirement 17 between differentials A-B and B-C
- requirement 21 between differentials A-B and A-C, A-B and B-C, and A-C and B-C
- requirement 24 between differentials A-B and A-C
- requirement 25 between differentials A-C and B-C
- requirement 28 between differentials A-B and A-C

Table 9-172 Pairwise comparisons between requirements at each level of *differential* using measure direction for TEIF Method

Measure				Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
							Lower Bound	Upper Bound
Direction	1	A-B	A-C	.333	.256	.506	-.343	1.01
			B-C	.222	.329	.881	-.648	1.09
		A-C	B-C	-.111	.179	.904	-.584	.362
	8	A-B	A-C	.444*	.121	.005	.125	.763
			B-C	-.333	.162	.156	-.761	.095
		A-C	B-C	-.778*	.129	p<.001	-1.12	-.436
	14	A-B	A-C	.333	.229	.414	-.272	.939
			B-C	-.556	.271	.159	-1.27	.161
		A-C	B-C	-.889*	.212	.002	-1.45	-.327
	17	A-B	A-C	.556*	.185	.024	.067	1.05
			B-C	-.389	.282	.459	-1.13	.357
		A-C	B-C	-.944*	.206	.001	-1.49	-.4
	21	A-B	A-C	.111	.179	.904	-.362	.584
			B-C	-.167	.121	.463	-.488	.154
		A-C	B-C	-.278	.211	.498	-.836	.28
	24	A-B	A-C	-.056	.127	.963	-.392	.281
			B-C	-.833*	.146	p<.001	-1.22	-.448
		A-C	B-C	-.778*	.173	.001	-1.23	-.321
	25	A-B	A-C	.889*	.227	.003	.288	1.49
			B-C	1.06*	.171	p<.001	.603	1.51
		A-C	B-C	.167	.167	.701	-.274	.608
	28	A-B	A-C	0	0	.	0	0
			B-C	-.389*	.118	.013	-.702	-.076
		A-C	B-C	-.389*	.118	.013	-.702	-.076

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Table 9-173 shows the results of pairwise comparisons between requirements at each level of *differential* using measure amount for the TEIF Method. There were significant differences on measure amount for:

- requirement 1 between differentials A-B and A-C, and A-C and B-C
- requirement 8 between differentials A-B and A-C, and A-C and B-C
- requirement 14 between differentials A-C and B-C

- requirement 17 between differentials A-C and B-C
- requirement 21 between differentials A-B and A-C, and A-B and B-C
- requirement 24 between differentials A-B and B-C, and A-C and B-C
- requirement 25 between differentials A-B and A-C, and A-B and B-C
- requirement 28 between differentials A-B and B-C, and A-C and B-C

However, there was no significant difference on measure direction for:

- requirement 1 between differentials A-B and B-C
- requirement 8 between differentials A-B and B-C
- requirement 14 between differentials A-B and A-C, and A-B and B-C
- requirement 17 between differentials A-B and A-C, and A-B and B-C
- requirement 21 between differentials A-C and B-C
- requirement 24 between differentials A-B and A-C
- requirement 25 between differentials A-C and B-C
- requirement 28 between differentials A-B and A-C

Table 9-173 Pairwise comparisons between requirements at each level of *differential* using measure amount for TEIF Method

Measure				**Mean Difference (I-J)**	**Std. Error**	**Sig.**[b]	**95% Confidence Interval for Difference**[b]	
							Lower Bound	**Upper Bound**
Amount	1	A-B	A-C	-2*	.621	.015	-3.64	-.356
			B-C	.944	1.02	.747	-1.76	3.65
		A-C	B-C	2.94*	.826	.007	.757	5.13
	8	A-B	A-C	5.83*	.538	p<.001	4.41	7.26
			B-C	1.17	.663	.262	-.588	2.92
		A-C	B-C	-4.67*	.728	p<.001	-6.59	-2.74
	14	A-B	A-C	-.111	.832	.999	-2.31	2.09
			B-C	2.28	1.06	.133	-.527	5.08
		A-C	B-C	2.39*	.742	.015	.426	4.35
	17	A-B	A-C	-.333	.572	.919	-1.85	1.18
			B-C	2	.993	.170	-.629	4.63
		A-C	B-C	2.33*	.878	.049	.009	4.66
	21	A-B	A-C	1.56*	.345	.001	.642	2.47
			B-C	2.17*	.638	.010	.478	3.86
		A-C	B-C	.611	.525	.595	-.778	2
	24	A-B	A-C	-.833	.912	.754	-3.25	1.58
			B-C	10.3*	1.1	p<.001	7.38	13.2
		A-C	B-C	11.1*	1.19	p<.001	7.95	14.3
	25	A-B	A-C	-5.22*	.862	p<.001	-7.5	-2.94
			B-C	-6.56*	.742	p<.001	-8.52	-4.59
		A-C	B-C	-1.33	.672	.179	-3.11	.444
	28	A-B	A-C	0	0	.	0	0
			B-C	2.44*	.864	.034	.158	4.73
		A-C	B-C	2.44*	.864	.034	.158	4.73

Based on estimated marginal means
*. The mean difference is significant at the .05 level.
b. Adjustment for multiple comparisons: Sidak.

4) Summary of differential mean ratings for TEIF Method

The mean ratings of measure direction for differential A-B for the TEIF Method were in the same direction as the expert ratings for four requirements (4, 8, 25, and 28) and the opposite direction for six requirements (1, 11, 14, 17, 21, and 24). These mean ratings were significantly different from zero with a confidence interval of 95%.

The mean ratings of measure direction for differential A-C for the TEIF Method were in the same direction as the expert ratings for three requirements (8, 11, and 28) and the opposite direction for seven requirements (1, 4, 14, 17, 21, 24, and 25). These mean ratings were significantly different from zero with a confidence interval of 95%.

The mean ratings of measure direction for differential B-C for the TEIF Method were in the same direction as the expert ratings for six requirements (4, 8, 14, 17, 24 and 28) and the opposite direction for four requirements (1, 11, 21, and 25). These mean ratings were significantly different from zero with a confidence interval of 95%.

The mean ratings of measure direction for differential A-B for the TEIF Method were significantly different from differential A-C for requirements 4, 8, 11, 14, 17, 21, 24, and 28, and from differential B-C for requirements 8, 14, 17, 24, 25, and 28. The mean ratings of measure direction for differential A-C for the TEIF Method were significantly different from differential A-B for requirements 1, 8, 11, 17, and 25.

The mean ratings on measure amount of requirements 8 and 24 for differential A-B for the TEIF Method were different from all other requirements. The mean rating for requirement 24 for differential A-C for the TEIF Method was different from all other requirements.

The mean rating for requirement 28 for differential B-C was the same as the experts. For all offer requirements and all offer differentials, the mean ratings on measure amount was significantly different from zero, i.e. agreement with the experts.

9.4.5.2 Other Methods differential closer to expert

Table 9-174 shows the results of multivariate tests. The second-order simple interaction effect of *requirement*differential* for the Other Methods was significant as suggested by Pillai's Trace. This indicates that the differential mean ratings of *requirement* depend on *differential* and the differential mean ratings of *differential* depend on *requirement* for measures amount and direction. Although the simple simple main effects of *requirement* and *differential* were significant, they were not considered further as they were involved in the significant second-order simple interaction effect. The full table is shown in Table 0-77, Appendix K.

Table 9-174 Multivariate tests of *requirement*differential* for Other Methods

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Requirement * Differential	Pillai's Trace	1.07	19.7	36	612	p<.001
	Wilks' Lambda	.166	24.7[c]	36	610	p<.001
	Hotelling's Trace	3.6	30.4	36	608	p<.001
	Roy's Largest Root	3.14	53.4[d]	18	306	p<.001

a. Design: Intercept
Within Subjects Design: Requirement + Differential + Requirement * Differential

b. Tests are based on averaged variables.

c. Exact statistic

d. The statistic is an upper bound on F that yields a lower bound on the significance level.

Table 9-175 shows that the Mauchly's sphericity test of *requirement*differential* for the Other Methods shows a violation of the assumption of sphericity. Therefore Lower-bound adjustment to significance was used for *requirement*differential* because it is the most conservative (Field, 2013).

Table 9-175 Mauchly's sphericity test of *requirement* differential* for Other Methods

Within Subjects Effect	Measure	Mauchly's W	Approx. Chi-Square	df	Sig.	Epsilon[b]		
						Greenhouse-Geisser	Huynh-Feldt	Lower-bound
Requirement	Direction	.005	73	44	.006	.488	.679	.111
	Amount	.007	68.8	44	.014	.560	.824	.111
Differential	Direction	.724	5.18	2	.075	.783	.849	.500
	Amount	.899	1.71	2	.425	.908	1	.500
Requirement * Differential	Direction	.000	.	170	.	.382	.669	.056
	Amount	.000	.	170	.	.342	.558	.056

Tests the null hypothesis that the error covariance matrix of the orthonormalized transformed dependent variables is proportional to an identity matrix.
a. Design: Intercept
Within Subjects Design: Requirement + Differential + Requirement * Differential
b. May be used to adjust the degrees of freedom for the averaged tests of significance. Corrected tests are displayed in the Tests of Within-Subjects Effects table.

Table 9-176 shows the univariate tests. The second-order simple interaction effects of *requirement*differential* for the Other Methods was significant (p<0.001) for both measures amount and direction, using Lower-bound adjustment. Although the simple simple main effects of both *method* and *requirement* were significant, they were not considered further as they were involved in the significant second-order simple interaction effect. The full table is shown in Table 0-78, Appendix K.

Table 9-176 Univariate tests of *requirement*differential* for Other Methods

Source	**Measure**		**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
Requirement * Differential	Direction	Sphericity Assumed	106	18	5.91	20	p<.001
		Greenhouse-Geisser	106	6.88	15.5	20	p<.001
		Huynh-Feldt	106	12	8.83	20	p<.001
		Lower-bound	106	1	106	20	p<.001
	Amount	Sphericity Assumed	4795	18	266	53.3	p<.001
		Greenhouse-Geisser	4795	6.16	778	53.3	p<.001
		Huynh-Feldt	4795	10.1	477	53.3	p<.001
		Lower-bound	4795	1	4795	53.3	p<.001
Error(Requirement*Differential)	Direction	Sphericity Assumed	90.3	306	.295		
		Greenhouse-Geisser	90.3	117	.772		
		Huynh-Feldt	90.3	205	.441		
		Lower-bound	90.3	17	5.31		
	Amount	Sphericity Assumed	1530	306	5		
		Greenhouse-Geisser	1530	105	14.6		
		Huynh-Feldt	1530	171	8.95		
		Lower-bound	1530	17	90		

The following syntax '/EMMEANS' (SPSS, 2001) was used to test simple simple main effects:

/EMMEANS=TABLES(Requirement*Differential)COMPARE(Requirement)ADJ (SIDAK)

/EMMEANS=TABLES(Requirement*Differential)COMPARE(Differential)ADJ (SIDAK)

*1) Marginal means of requirement*differential for the Other Methods*

Table 9-177 shows the marginal mean of *requirement*differential* on measure direction for each level of differentials A-B, A-C, and B-C for the Other Methods with the associated standard errors.

Table 9-178 shows the marginal means of *requirement*differential* on measure amount for each level of differentials A-B, A-C, and B-C for the Other Methods with the associated standard errors.

Table 9-177 Marginal mean of *requirement*differential* on measure direction for each level of *differential* for Other Methods

Measure	**Requirement**	**Differential**	**Mean**	**Std. Error**	**95% Confidence Interval**	
					Lower Bound	**Upper Bound**
Direction	1	A-B	-.722	.158	-1.06	-.389*
		A-C	-1	.000	-1	-1*
		B-C	-.333	.214	-.785	.118
	4	A-B	-.611	.143	-.913	-.309*
		A-C	-.611	.143	-.913	-.309*
		B-C	.444	.121	.190	.699*
	8	A-B	-.667	.114	-.908	-.425*
		A-C	.667	.114	.425	.908*
		B-C	-.778	.101	-.991	-.565*
	11	A-B	-.556	.202	-.981	-.130*
		A-C	.389	.118	.139	.638*
		B-C	-.500	.202	-.926	-.074*
	14	A-B	-.667	.181	-1.05	-.285*
		A-C	-.833	.121	-1.09	-.577*
		B-C	.278	.109	.049	.507*
	17	A-B	-.500	.202	-.926	-.074*
		A-C	-.778	.129	-1.05	-.505*
		B-C	.333	.114	.092	.575*
	21	A-B	-.389	.200	-.812	.034
		A-C	-.722	.158	-1.06	-.389*
		B-C	-.444	.217	-.903	.014
	24	A-B	-.889	.076	-1.05	-.728*
		A-C	-.833	.090	-1.02	-.643*
		B-C	.389	.118	.139	.638*
	25	A-B	.778	.101	.565	.991*
		A-C	-.611	.164	-.958	-.264*
		B-C	-.556	.185	-.945	-.166*
	28	A-B	.611	.118	.362	.861*
		A-C	.611	.118	.362	.861*
		B-C	.611	.118	.362	.861*

Table 9-178 Marginal means of *requirement*differential* on measure amount for each level of *differential* for Other Methods

Measure	Requirement	Differential	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
Amount	1	A-B	5.83	.562	4.65	7.02
		A-C	7.28	.497	6.23	8.33
		B-C	2.11	.290	1.5	2.72
	4	A-B	3.67	.313	3.01	4.33
		A-C	3.17	.271	2.6	3.74
		B-C	1.39	.444	.452	2.33
	8	A-B	13.22	.888	11.4	15.1
		A-C	.611	.293	-.007	1.23
		B-C	13.72	.866	11.9	15.6
	11	A-B	3.39	.637	2	4.73
		A-C	2.17	.687	.717	3.62
		B-C	3.11	.577	1.89	4.33
	14	A-B	6.67	.719	5.15	8.18
		A-C	6.78	.761	5.17	8.38
		B-C	3.33	.784	1.68	4.99
	17	A-B	5	.642	3.65	6.35
		A-C	5.33	.471	4.4	6.33
		B-C	1.67	.412	.797	2.54
	21	A-B	4.94	.838	3.18	6.71
		A-C	3.33	.379	2.53	4.13
		B-C	3.94	.639	2.6	5.29
	24	A-B	14.5	.849	12.7	16.3
		A-C	13.4	.875	11.6	15.3
		B-C	1.39	.472	.392	2.39
	25	A-B	.611	.363	-.154	1.38
		A-C	7.94	.798	6.26	9.63
		B-C	7.67	.780	6.02	9.31
	28	A-B	1.33	.589	.092	2.58
		A-C	1.61	.715	.103	3.12
		B-C	1.06	.508	-.016	2.13

1) *Simple simple main effect of requirement at each level of differential for the Other Methods*

Table 9-179 shows the multivariate tests of simple simple main effects of *requirement* at each level of differential A-B, A-C, and B-C for the Other Methods. The significant value for multivariate test as suggested by Pillai's trace was used. There was a significant simple simple main effect ($p<0.05$) for *requirement* at only differential A-B, but not for differentials A-C and B-C for the Other Methods. Figure 9-65 and Figure 9-66 illustrate these results.

Table 9-179 Multivariate tests of simple simple main effects of *requirement* at each level of *differential* for the Other Methods

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	1	953[a]	17	1	.025
	Wilks' lambda	.000	953[a]	17	1	.025
	Hotelling's trace	16207	953[a]	17	1	.025
	Roy's largest root	16207	953[a]	17	1	.025
A-C	Pillai's trace	1	160[a]	17	1	.062
	Wilks' lambda	.000	160[a]	17	1	.062
	Hotelling's trace	2716	160[a]	17	1	.062
	Roy's largest root	2716	160[a]	17	1	.062
B-C	Pillai's trace	.988	4.78[a]	17	1	.347
	Wilks' lambda	.012	4.78[a]	17	1	.347
	Hotelling's trace	81.2	4.78[a]	17	1	.347
	Roy's largest root	81.2	4.78[a]	17	1	.347

Each F tests the multivariate simple effects of requirement within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

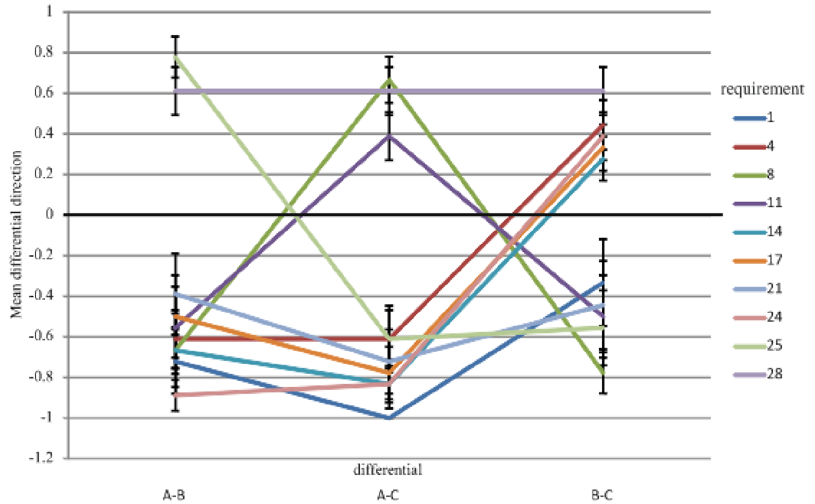


Figure 9-65 Profile graph of simple simple main effects of *requirement* at each level of *differential* on measure direction for the Other Methods

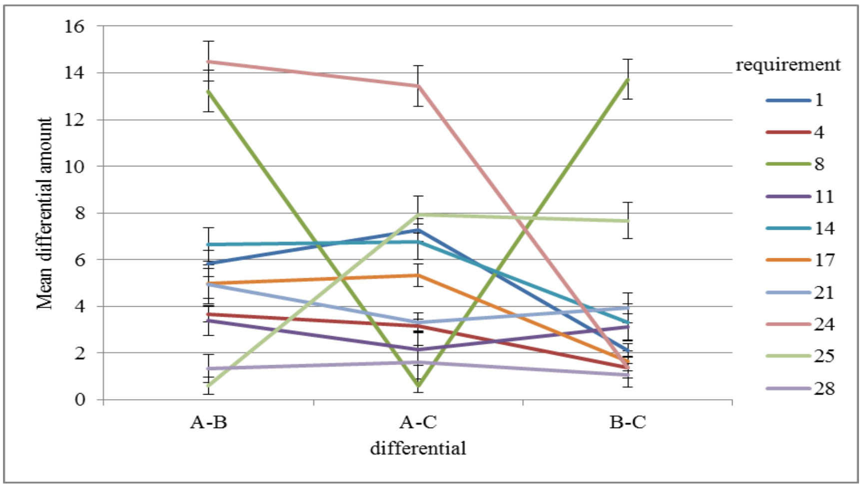


Figure 9-66 Profile graph of simple simple main effects of *requirement* at each level of *differential* on measure amount for the Other Methods

Table 9-180 shows the results of pairwise comparisons between requirements and differential A-B using measure direction for the Other Methods. There was a significant difference on measure direction for the Other Methods for differential A-B between requirements 1 and 25, 1 and 28, 4 and 25, 4 and 28, 8 and 25, 8 and 28, 11 and 25, 11 and 28, 14 and 25, 14 and 28, 17 and 25, 17 and 28, 21 and 25, 21 and 28, 24 and 25, and 24 and 28.

However, there was no significant difference for measure direction for differential A-B for the Other Methods between requirements 1 and 4, 1 and 8, 1 and 11, 1 and 14, 1 and 17, 1 and 21, 1 and 24, 4 and 8, 4 and 11, 4 and 14, 4 and 17, 4 and 21, 4 and 24, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 24, 11 and 14, 11 and 17, 11 and 21, 11 and 24, 14 and 17, 14 and 21, 14 and 24, 17 and 21, 17 and 24, 21 and 24, and 25 and 28.

Table 9-180 Pairwise comparisons between requirements and differential A-B using measure direction for the Other Methods

Measure	Differential	Requirement		Mean Difference (I-J)	Std. Error	Sig.b	95% Confidence Interval for Differenceb	
		(I)	(J)				Lower Bound	Upper Bound
Direction	A-B	1	4	-0.111	0.179	1	-0.809	0.587
			8	-0.056	0.206	1	-0.859	0.748
			11	-0.167	0.232	1	-1.073	0.74
			14	-0.056	0.206	1	-0.859	0.748
			17	-0.222	0.236	1	-1.15	0.701
			21	-0.333	0.291	1	-1.47	0.805
			24	0.167	0.185	1	-0.557	0.89
			25	-1.5*	0.202	0	-2.29	-0.711
			28	-1.33*	0.198	0	-2.11	-0.56
		4	8	0.056	0.171	1	-0.612	0.723
			11	-0.056	0.171	1	-0.723	0.612
			14	0.056	0.127	1	-0.441	0.552
			17	-0.111	0.212	1	-0.94	0.718
			21	-0.222	0.222	1	-1.09	0.646
			24	0.278	0.109	0.605	-0.146	0.702
			25	-1.39*	0.2	0	-2.17	-0.607
			28	-1.22*	0.222	0.002	-2.09	-0.354
		8	11	-0.111	0.241	1	-1.05	0.83
			14	0	0.181	1	-0.706	0.706
			17	-0.167	0.167	1	-0.818	0.484
			21	-0.278	0.177	0.999	-0.97	0.414
			24	0.222	0.101	0.852	-0.172	0.616
			25	-1.44*	0.145	0	-2.01	-0.878
			28	-1.28*	0.135	0	-1.81	-0.749
		11	14	0.111	0.196	1	-0.655	0.877
			17	-0.056	0.262	1	-1.08	0.966
			21	-0.167	0.294	1	-1.32	0.983
			24	0.333	0.198	0.995	-0.44	1.11
			25	-1.33*	0.229	0.001	-2.23	-0.44
			28	-1.17*	0.246	0.008	-2.13	-0.206
		14	17	-0.167	0.167	1	-0.818	0.484
			21	-0.278	0.24	1	-1.22	0.659
			24	0.222	0.129	0.993	-0.282	0.727
			25	-1.44*	0.185	0	-2.17	-0.723
			28	-1.28*	0.211	0.001	-2.1	-0.454
		17	21	-0.111	0.254	1	-1.1	0.882
			24	0.389	0.183	0.895	-0.327	1.11
			25	-1.28*	0.226	0.001	-2.16	-0.396
			28	-1.111*	0.196	0.001	-1.88	-0.345
		21	24	0.5	0.185	0.498	-0.223	1.22
			25	-1.17*	0.202	0.001	-1.96	-0.377
			28	-1*	0.229	0.018	-1.89	-0.107
		24	25	-1.67*	0.114	0	-2.11	-1.22
			28	-1.5*	0.146	0	-2.07	-0.931
		25	28	0.167	0.121	1	-0.307	0.64

* The mean difference is significant at the .05 level.

Table 9-181 shows the results of pairwise comparisons between requirements and differential A-B using measure amount for the Other Methods. There were significant differences on measure amount for the Other Method for differential A-B between requirements 1 and 4, 1 and 8, 1 and 24, 1 and 25, 1 and 28, 4 and 8, 4 and 14, 4 and 24, 4 and 25, 8 and 11, 8 and 14, 8 and 17, 8 and 21, 8 and 25, 8 and 28, 11 and 24, 11 and 25, 14 and 24, 14 and 25, 14 and 28, 17 and 24, 17 and 25, 17 and 28, 21 and 24, 21 and 25, 24 and 25, and 24 and 28.

However, there was no significant difference on measure amount for differential A-B for the Other Methods between requirements 1 and 11, 1 and 14, 1 and 17, 1 and 21, 4 and 11, 4 and 17, 4 and 21, 4 and 28, 8 and 24, 11 and 14, 11 and 17, 11 and 21, 11 and 28, 14 and 17, 14 and 21, 17 and 21, 21 and 28, and 25 and 28.

Table 9-181 Pairwise comparisons between requirements and differential A-B using measure amount for the Other Methods

Measure	**Differential**	**Requirement**		**Mean Difference (I-J)**	**Std. Error**	**Sig.b**	**95% Confidence Interval for Differenceb**	
		(I)	**(J)**				Lower Bound	Upper Bound
Amount	A-B	1	4	2.17*	0.5	0.02	0.214	4.12
			8	-7.39*	1.09	p<.001	-11.7	-3.12
			11	2.44	0.768	0.218	-0.554	5.44
			14	-0.833	0.845	1	-4.13	2.47
			17	0.833	0.883	1	-2.61	4.28
			21	0.889	1.15	1	-3.62	5.4
			24	-8.67*	1.11	p<.001	-13	-4.34
			25	5.22*	0.778	p<.001	2.19	8.26
			28	4.5*	0.612	p<.001	2.11	6.89
		4	8	-9.56*	0.971	p<.001	-13.4	-5.76
			11	0.278	0.709	1	-2.49	3.05
			14	-3*	0.637	0.009	-5.49	-0.514
			17	-1.33	0.681	0.956	-3.99	1.33
			21	-1.28	0.881	1	-4.72	2.16
			24	-10.8*	0.933	p<.001	-14.5	-7.19
			25	3.06*	0.58	0.003	0.791	5.32
			28	2.33	0.719	0.193	-0.473	5.14
		8	11	9.83*	1.2	p<.001	5.16	14.5
			14	6.56*	1.11	0.001	2.24	10.9
			17	8.22*	0.992	p<.001	4.35	12.1
			21	8.28*	0.828	p<.001	5.05	11.5
			24	-1.28	0.758	0.995	-4.24	1.68
			25	12.6*	0.984	p<.001	8.77	16.5
			28	11.9*	1.1	p<.001	7.61	16.2
		11	14	-3.3	1.08	0.292	-7.51	0.956
			17	-1.6	1.01	0.998	-5.54	2.32
			21	-1.556	1.15	1	-6.05	2.93
			24	-11.1*	1.075	p<.001	-15.3	-6.91
			25	2.78*	0.655	0.024	0.222	5.33
			28	2.06	0.769	0.517	-0.947	5.06
		14	17	1.67	0.647	0.589	-0.859	4.19
			21	1.72	1.11	0.999	-2.59	6.04
			24	-7.83*	0.797	p<.001	-11	-4.72
			25	6.06*	0.794	p<.001	2.96	9.16
			28	5.33*	0.993	0.002	1.45	9.21
		17	21	0.056	1.01	1	-3.87	3.98
			24	-9.5*	0.89	p<.001	-13	-6.02
			25	4.39*	0.637	p<.001	1.9	6.88
			28	3.67*	0.871	0.026	0.266	7.07
		21	24	-9.56*	1.01	p<.001	-13.5	-5.6
			25	4.33*	0.907	0.008	0.79	7.88
			28	3.61	1.18	0.271	-0.987	8.21
		24	25	13.9*	0.824	p<.001	10.7	17.1
			28	13.2*	1.09	p<.001	8.92	17.4
		25	28	-0.722	0.604	1	-3.08	1.64

* The mean difference is significant at the .05 level.

2) Simple simple main effects of differential at each level of requirement for the Other Methods

Table 9-182 shows the multivariate tests of simple simple main effects of differentials A-B, A-C, and B-C at each level of *requirement* for the Other Methods. The significant value for multivariate test as suggested by Pillai's trace was used. There were significant simple simple effects for *differential* at requirements 1, 4, 8, 11, 14, 17, 21, 24, and 25 but not for requirement 28 for the Other Methods. Figure 9-67 and Figure 9-68 illustrate these results.

Table 9-182 Multivariate tests of simple simple main effects of *differential* at each level of *requirement* for the Other Methods

Requirement		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.973	128[a]	4	14	p<.001
	Wilks' lambda	.027	128[a]	4	14	p<.001
	Hotelling's trace	36.5	128[a]	4	14	p<.001
	Roy's largest root	36.5	128[a]	4	14	p<.001
4	Pillai's trace	.786	12.8[a]	4	14	p<.001
	Wilks' lambda	.214	12.8[a]	4	14	p<.001
	Hotelling's trace	3.66	12.8[a]	4	14	p<.001
	Roy's largest root	3.66	12.8[a]	4	14	p<.001
8	Pillai's trace	.956	75.8[a]	4	14	p<.001
	Wilks' lambda	.044	75.8[a]	4	14	p<.001
	Hotelling's trace	21.7	75.8[a]	4	14	p<.001
	Roy's largest root	21.7	75.8[a]	4	14	p<.001
11	Pillai's trace	.541	4.12[a]	4	14	.021
	Wilks' lambda	.459	4.12[a]	4	14	.021
	Hotelling's trace	1.18	4.12[a]	4	14	.021
	Roy's largest root	1.18	4.12[a]	4	14	.021
14	Pillai's trace	.775	12.1[a]	4	14	p<.001
	Wilks' lambda	.225	12.1[a]	4	14	p<.001
	Hotelling's trace	3.45	13	4	14	p<.001
	Roy's largest root	3.45	13[a]	4	14	p<.001
17	Pillai's trace	.788	13[a]	4	14	p<.001
	Wilks' lambda	.212	13[a]	4	14	p<.001
	Hotelling's trace	3.71	13[a]	4	14	p<.001
	Roy's largest root	3.71	13[a]	4	14	p<.001
21	Pillai's trace	.496	3.44[a]	4	14	.037
	Wilks' lambda	.504	3.44[a]	4	14	.037
	Hotelling's trace	.983	3.44[a]	4	14	.037
	Roy's largest root	.983	3.44[a]	4	14	.037
24	Pillai's trace	.956	76.9[a]	4	14	p<.001
	Wilks' lambda	.044	76.9[a]	4	14	p<.001
	Hotelling's trace	22	76.9[a]	4	14	p<.001
	Roy's largest root	22	76.9[a]	4	14	p<.001
25	Pillai's trace	.824	16.3[a]	4	14	p<.001
	Wilks' lambda	.176	16.3[a]	4	14	p<.001
	Hotelling's trace	4.67	16.3[a]	4	14	p<.001
	Roy's largest root	4.67	16.3[a]	4	14	p<.001
28	Pillai's trace	.137	.554[a]	4	14	.700
	Wilks' lambda	.863	.554[a]	4	14	.700
	Hotelling's trace	.158	.554[a]	4	14	.700
	Roy's largest root	.158	.554[a]	4	14	.700

Each F tests the multivariate simple simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

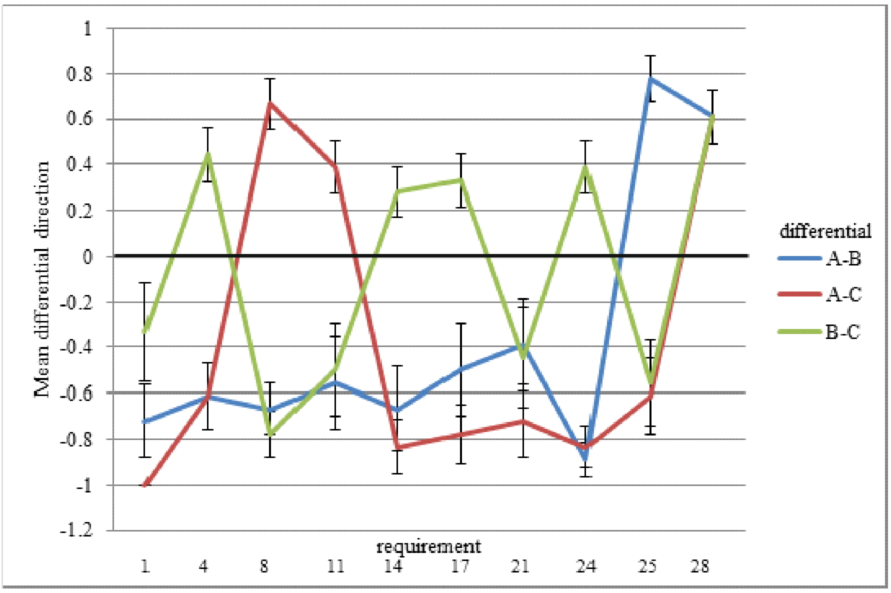


Figure 9-67 Profile graph of simple simple main effect of *differential* at each level of *requirement* on measure direction for the Other Methods

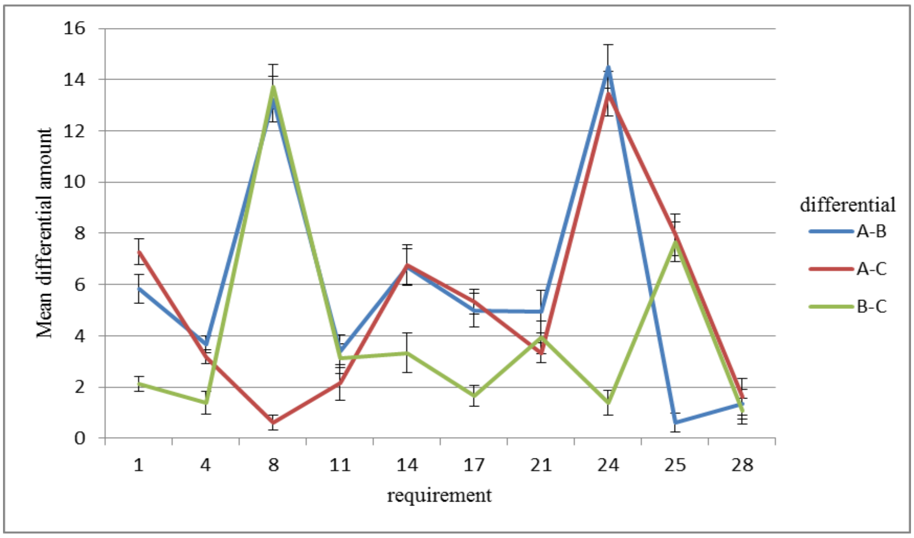


Figure 9-68 Profile graph of simple simple main effects of *differentials* at each level of *requirement* on measure amount for the Other Methods

Table 9-183 shows the results of pairwise comparisons between differentials and requirements using measure direction for the Other Methods. There were significant differences on measure direction for:

- requirement 1 between differentials A-C and B-C
- requirement 4 between differentials A-B and B-C, and A-C and B-C
- requirement 8 between differentials A-B and A-C, and A-C and B-C
- requirement 11 between differentials A-B and A-C, and A-C and B-C
- requirement 14 between differentials A-B and B-C, and A-C and B-C
- requirement 17 between differentials A-B and B-C, and A-C and B-C
- requirement 24 between differentials A-B and B-C, and A-C and B-C
- requirement 25 between differentials A-B and A-C, and A-B and B-C

However, there was no significant difference for measure direction for:

- requirement 1 between differentials A-B and A-C, A-B and B-C
- requirement 4 between differentials A-B and A-C
- requirement 8 between differentials A-B and B-C
- requirement 11 between differentials A-B and B-C
- requirement 14 between differentials A-B and A-C
- requirement 17 between differentials A-B and A-C
- requirement 21 between differentials A-B and A-C, A-B and B-C, and A-C and B-C
- requirement 24 between differentials A-B and A-C
- requirement 25 between differentials A-C and B-C

Table 9-183 Pairwise comparisons between differentials and requirements using measure direction for Other Methods

Measure	Requirement	Differential (I)	Differential (J)	Mean Difference (I-J)	Std. Error	Sig.b	95% Confidence Interval for Differenceb Lower Bound	Upper Bound
Direction	1	A-B	A-C	0.278	0.158	0.262	-0.14	0.695
			B-C	-0.389	0.304	0.522	-1.193	0.416
		A-C	B-C	-.667*	0.214	0.019	-1.233	-0.101
	4	A-B	A-C	0	0.181	1	-0.478	0.478
			B-C	-1.06*	0.206	p<.001	-1.6	-0.511
		A-C	B-C	-1.06*	0.206	p<.001	-1.6	-0.511
	8	A-B	A-C	-1.33*	0.162	p<.001	-1.761	-0.905
			B-C	0.111	0.076	0.414	-0.091	0.313
		A-C	B-C	1.44*	0.121	p<.001	1.125	1.763
	11	A-B	A-C	-.944*	0.221	0.002	-1.529	-0.36
			B-C	-0.056	0.056	0.701	-0.203	0.091
		A-C	B-C	.889*	0.227	0.003	0.288	1.49
	14	A-B	A-C	0.167	0.232	0.862	-0.448	0.781
			B-C	-.944*	0.235	0.003	-1.567	-0.322
		A-C	B-C	-1.11*	0.179	p<.001	-1.584	-0.638
	17	A-B	A-C	0.278	0.177	0.354	-0.191	0.747
			B-C	-.833*	0.246	0.01	-1.484	-0.183
		A-C	B-C	-1.11*	0.159	p<.001	-1.533	-0.689
	21	A-B	A-C	0.333	0.268	0.545	-0.376	1.043
			B-C	0.056	0.098	0.925	-0.204	0.315
		A-C	B-C	-0.278	0.3	0.748	-1.073	0.517
	24	A-B	A-C	-0.056	0.056	0.701	-0.203	0.091
			B-C	-1.28*	0.109	p<.001	-1.565	-0.99
		A-C	B-C	-1.22*	0.129	p<.001	-1.564	-0.88
	25	A-B	A-C	1.39*	0.183	p<.001	0.904	1.874
			B-C	1.33*	0.214	p<.001	0.767	1.899
		A-C	B-C	-0.056	0.127	0.963	-0.392	0.281

Based on estimated marginal means
* The mean difference is significant at the .05 level.
b Adjustment for multiple comparisons: Sidak.

Table 9-183 shows the results of pairwise comparisons between differentials and requirements using measure amount for the Other Methods. There were significant differences on measure direction for:

- requirement 1 between differentials A-B and A-C, A-B and B-C, A-C and B-C
- requirement 4 between differentials A-B and B-C, and A-C and B-C
- requirement 8 between differentials A-B and A-C, and A-C and B-C
- requirement 14 between differentials A-B and B-C, and A-C and B-C
- requirement 17 between differentials A-B and B-C, and A-C and B-C
- requirement 24 between differentials A-B and B-C, and A-C and B-C
- requirement 25 between differentials A-B and A-C, and A-B and B-C

However, there were no significant differences for measure direction for:

- requirement 4 between differentials A-B and A-C
- requirement 8 between differentials A-B and B-C

- requirement 11 between differentials A-B and A-C, A-B and B-C, A-C and B-C
- requirement 14 between differentials A-B and A-C
- requirement 17 between differentials A-B and A-C
- requirement 21 between differentials A-B and A-C, A-B and B-C, and A-C and B-C
- requirement 24 between differentials A-B and A-C
- requirement 25 between differentials A-C and B-C

Table 9-184 Pairwise comparisons between differentials and requirements using measure amount for Other Methods

Measure	**Requirement**	**Differential**		**Mean Difference (I-J)**	**Std. Error**	**Sig.b**	**95% Confidence Interval for Differenceb**	
		(I)	**(J)**				**Lower Bound**	**Upper Bound**
Amount	1	A-B	A-C	-1.44*	0.473	0.021	-2.7	-0.193
			B-C	3.72*	0.766	p<.001	1.69	5.75
		A-C	B-C	5.17*	0.538	p<.001	3.74	6.59
	4	A-B	A-C	0.5	0.437	0.609	-0.657	1.66
			B-C	2.28*	0.419	p<.001	1.17	3.39
		A-C	B-C	1.78*	0.613	0.03	0.154	3.4
	8	A-B	A-C	12.6*	0.957	p<.001	10.1	15.1
			B-C	-0.5	0.305	0.318	-1.31	0.308
		A-C	B-C	-13.1*	0.844	p<.001	-15.3	-10.9
	11	A-B	A-C	1.22	0.575	0.138	-0.299	2.7
			B-C	0.278	0.862	0.985	-2.01	2.56
		A-C	B-C	-0.944	0.664	0.435	-2.7	0.813
	14	A-B	A-C	-0.111	1.02	0.999	-2.8	2.58
			B-C	3.33*	1.21	0.04	0.131	6.54
		A-C	B-C	3.44*	1.04	0.013	0.686	6.2
	17	A-B	A-C	-0.333	0.572	0.919	-1.85	1.18
			B-C	3.33*	0.856	0.003	1.07	5.6
		A-C	B-C	3.67*	0.577	p<.001	2.14	5.2
	21	A-B	A-C	1.611	0.94	0.282	-0.876	4.1
			B-C	1	0.836	0.575	-1.21	3.21
		A-C	B-C	-0.611	0.657	0.745	-2.35	1.13
	24	A-B	A-C	1.056	0.521	0.166	-0.322	2.43
			B-C	13.1*	0.836	p<.001	10.9	15.32
		A-C	B-C	12.1*	1.098	p<.001	9.15	15
	25	A-B	A-C	-7.33*	0.84	p<.001	-9.56	-5.11
			B-C	-7.06*	0.92	p<.001	-9.49	-4.621
		A-C	B-C	0.278	0.386	0.861	-0.744	1.3

Based on estimated marginal means
* The mean difference is significant at the .05 level.
b Adjustment for multiple comparisons: Sidak.

3) Summary of differential mean ratings for the Other Methods

The mean ratings of measure direction for differential A-B for the Other Methods were in the same direction as the expert ratings for two requirements (25 and 28) and the opposite direction for eight requirements (1, 4, 8, 11, 14, 17, 21, and 24). These mean ratings were significantly different from zero with a confidence interval of 95%.

The mean ratings of measure direction for differential A-C for the Other Methods were in the same direction as the expert ratings for three requirements (8, 11, and 28) and the opposite direction for seven requirements (1, 4, 14, 17, 21, 24, and 25). These mean ratings were significantly different from zero with a confidence interval of 95%.

The mean ratings of measure direction for differential B-C for the Other Methods were in the same direction as the expert ratings for five requirements (4, 14, 17, 24, and 28) and the opposite direction for five requirements (1, 8, 11, 21, and 25). These mean ratings were significantly different from zero with a confidence interval of 95%.

The mean ratings of measure direction for differential A-B for the Other Methods were significantly different from differential A-C for requirements 1, 8, 11, 17, and 25. The mean ratings of measure direction for differential A-B for the Other Methods were significantly different from differential B-C for requirements 1, 4, 14, 17, 24, and 25. The mean ratings of measure direction for differential B-C for the Other Methods were significantly different from differential A-C for requirements 1, 4, 8, 11, 14, 17, 21, and 24.

The mean rating on measure amount for requirement 25 for differential A-B was closer to zero (i.e. agreement with the experts) than the other differentials A-C and B-C.

The mean rating on measure amount for requirement 8 for differential A-C for the Other Methods was closer to the zero (i.e. agreement with the experts) than the other differentials A-B and B-C.

The mean ratings on measure amount for requirements 1, 4, 14, 17, and 24 for differential B-C for the Other Methods were closer to the zero (i.e. agreement with the experts) than the other differentials A-B and A-C.

The mean rating on measure amount for requirement 25 for differential A-B was significantly different to the other differentials A-C and B-C.

The mean rating on measure amount for requirement 8 for differential A-C for the Other Methods was significantly different to the other differentials A-B and B-C.

The mean ratings on measure amount for requirements 1, 4, 14, 17, and 24 for differential B-C for the Other Methods were significantly different to the other differentials A-B and A-C.

9.4.5.3 Exploring Methods differential requirement pairs closer to expert results

Chi-square was used to test the TEIF Method was significantly different than the Other Methods for the number of significantly differential requirement pairs closer to the experts for measures amount and direction for each differential.

The analysis showed that the TEIF Method was significantly different than the Other Methods for the number of significantly differential requirement pairs for measures amount and direction for differential A-B (Table 9-185). *Requirement* was not significant for the Other Methods for differentials A-C and B-C for either measure.

Table 9-185 Number of significantly differential requirement pairs closer to the experts for measures amount and direction for each differential

differential	TEIF Method		Other Method		Chi-Square	df	P Value
	Number of significant pair	Number of not significant pair	Number of significant pair	Number of not significant pair			
Measure amount							
A-B	15	30	27	18	13.33	1	0.0003
A-C	23	22	*Requirement* was not significant for the Other Methods for *differentials* A-C and B-C.				
B-C	21	24					
Measure direction							
A-B	4	41	16	29	13.97	1	0.0002
A-C	14	31					
B-C	19	26					

9.4.5.4 Testing of association between significance of TEIF Method and Other Methods differential requirement pairs closer to experts

The Chi-square test was used to test the association between the significance of the TEIF Method and the Other Methods requirement pair differences. Table 9-186 shows the number of significant differences between the two elements of the pairs for all 45 possible pairs for differential A-B. The second order interaction of *requirement*method* was not significant for differentials A-C and B-C for either measure.

The significant result shows a strong association between the pair differences and pair differences and method for differential A-B, such that the same pair tends to be significantly different for both methods or not significantly different for both methods.

Table 9-186 Number of significant differences for *requirement*method* of the pairs for all 45 possible pairs for each *differential*

Differential	TEIF sig Other sig	TEIF sig Other not sig	TEIF not sig Other sig	TEIF not sig Other not sig	Chi-square	df	P value
Measure amount							
A-B	14	0	13	18	18.08	1	<.001
A-C	*requirement*method* was not significant						
B-C							
Measure direction							
A-B	3	1	13	28	33.73	1	<.001
A-C	*requirement*method* was not significant						
B-C							

9.5 Questions to participants following experimental tasks

Due to the limitation of the time that any one participant was able to spend on an experiment (because of user motivation and ethics committee guidelines), it was decided to ask participants to carry out only one task involving evaluation of requirements and only one task involving evaluation of technology solutions. Evaluation of requirements and solutions are important aspects of designing a technology solution but all participants were also asked after they had completed the tasks whether they thought the TEIF Method would also help with gathering requirements and designing technology solutions. Again, due to the limitation of the time that any one participant was able to spend on an experiment, the scenario used for the task involved communication and interactions in situations that only involved a person with a hearing impairment and so all participants were also asked after they had completed the tasks whether they thought the TEIF Method would also help with communication and interactions in situations involving people with other disabilities. The TEIF Method was designed to help improve a developer's awareness of interaction issues involving disabled people and their understanding of how environment context affects the accessibility of interactions and to provide a technology suggestions table to help with designing technology solutions. Participants were asked questions to check whether the TEIF Method helped in these ways.

9.5.1 Questions Related to Evaluate Requirements Task

The participants of the TEIF Method group were asked to complete question number 8 (Table 9-187) which helped answer the sub research question 3.1: Can developers use the TEIF Method to help with *evaluating requirements* when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Table 9-187 Purpose of question 8

Question	Purpose
Question 8: The TEIF Method helped you in TASK 1 to evaluate requirements.	To check whether the TEIF Method helped to evaluate requirements as additional evidence to the experimental results in answering sub research question 3.1.

Table 9-188 shows the mean rating of question 8. There was a significant difference greater than 3 ($p<0.001$) in mean ratings on question 8.

Table 9-188 Mean rating of question number 8

Question	N	Mean	Std. Deviation	Std. Error Mean
Question 8	18	4.5000	.70711	.16667

The one sample t-test statistic was used to help answer the sub research question 3.1 (Table 9-189).

Table 9-189 One-sample test of question number 8

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Question 8	9.0	17	p < 0.001	1.5	1.15	1.85

9.5.2 Questions Related to Evaluate Technology Solution Task

The participants of the TEIF Method group were asked to complete question number 9 (Table 9-190), which is related to sub research question 3.2. Table 9-190 shows the purpose of question number 9 and Table 9-191 shows the mean rating of question 9.

Table 9-190 Purpose of question number 9

Question	Purpose
Question 9: The TEIF Method helped you in TASK 2 to evaluate technology solution designs.	To check whether the TEIF Method helped to evaluate technology solution designs as additional evidence to the experimental results in answering sub research question 3.2.

Table 9-191 Mean rating of question number 9

Question	N	Mean	Std. Deviation	Std. Error Mean
Question9	18	4.28	.895	.211

The one sample t-test statistic was used to help answer the sub research question 3.2. There was a significant difference (p<0.001) between '3' and the mean rating on question 9 as shown in Table 9-192.

Table 9-192 One-sample test of question number 9

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Question 9	6.06	17	p < 0.001	1.28	.833	1.72

9.5.3 Questions Related to Hearing Impairment

The participants from the TEIF Method group were asked to complete the question numbers 5 to 7 as shown in Table 9-193.

Table 9-193 Purpose of question numbers 5-7

Question	Purpose
Question 5: The TEIF Method helped to improve your awareness of interaction issues involving hearing impaired people.	To check whether the TEIF Method helped improve awareness of interaction issues involving hearing impaired people as this is one of the ways the TEIF Method aimed to help developers with requirements and design. This helps answer the sub research question 4.1.
Question 6: The TEIF Method helped to improve your understanding of how environment context affects interaction when hearing impaired people are involved.	To check whether the TEIF Method helped improve understanding of how environment context affects interaction when hearing impaired people are involved as this is one of the ways the TEIF Method aimed to help developers with requirements and design. This helps answer the sub research question 4.2.
Question 7: The TEIF Method Technology Suggestions Table helped you to identify technology solutions to issues involving hearing impaired people.	To check whether the TEIF Method Technology Suggestions Table helped identify technology solutions to issues involving hearing impaired people as this is one of the ways the TEIF Method aimed to help developers with requirements and design. This helps answer the sub research question 4.3.

Table 9-194 shows the mean ratings of questions 5-7. The one sample t-test statistic was used to help answer research question 4. There was a significant difference between '3' (p<0.001) and the mean ratings on question 5-7 as shown in Table 9-195.

Table 9-194 Mean ratings question numbers 5-7

	N	Mean	Std. Deviation	Std. Error Mean
Question 5	18	4.44	.511	.12
Question 6	18	4.44	.705	.166
Question7	18	4.44	.616	.145

Table 9-195 One-sample t-test of questionnaire number 5-7

	Test Value = 3					
	t	**df**	**Sig. (2-tailed)**	**Mean Difference**	**95% Confidence Interval of the Difference**	
					Lower	**Upper**
Question 5	12	17	p<.001	1.44	1.19	1.7
Question 6	8.7	17	p<.001	1.44	1.09	1.8
Question 7	9.95	17	p<.001	1.44	1.14	1.75

9.5.4 Questions about gathering requirements, designing solutions and other disabilities

The participants from both methods groups were asked to complete question numbers 10-14 (Table 9-196).

Table 9-196 Purpose of question numbers 10-14

Question	**Purpose**
Question 10: You would find the TEIF Method you used for the evaluate requirements task helpful to gather requirements for technology solutions to interaction problems involving hearing impaired people.	To check whether the TEIF Method would be helpful to gather requirements for technology solutions to interaction problems involving hearing impaired people as Evaluate Requirement Task only involved evaluating requirements. This helps answer the sub research question 3.3.
Question 11: You would find the TEIF Method you used for the evaluate technology solution task helpful for designing technology solutions to interaction problems involving hearing impaired people.	To checks whether the TEIF Method would help in designing technology solutions to interaction problems involving hearing impaired people as Evaluate Technology Solution Task only involved evaluating designs. This helps answer the sub research question 3.4.
Question 12: You would find using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the part of the method you used for evaluate technology solution task.	To check whether the whole TEIF Method would be needed for designing technology solutions. This helps answer the sub research question 4.4.
Question 13: If information was also provided about other disabilities you would find the TEIF Method helpful in gathering requirements for technology solutions to interaction problems involving disabled people.	To check whether the TEIF Method could help in gathering requirements to interaction problems involving a wider range of disabilities than just hearing impairment. This helps answer sub research question 3.3.
Question 14: If information was also provided about other disabilities you would find the TEIF Method helpful for designing technology solutions to interaction problems involving disabled people.	To check whether the TEIF Method could help in designing technology solutions to interaction problems involving a wider range of disabilities than just hearing impairment. This helps answer sub research question 3.4.

Participants gave mean ratings between 4.28 and 4.5 for the five questions evaluating whether and how the TEIF Method helped where 5 meant they strongly agreed.

Table 9-197 shows the mean ratings on questions 10 -14 for each method as illustrated in Figure 9-69.

Table 9-197 Mean ratings of between two methods for questions 10-14

Qusetion	Method	N	Mean	Std. Deviation	Std. Error Mean
Question10	TEIF	18	4.56	.705	.166
	Other	18	4.5	.618	.146
Question11	TEIF	18	4.33	.907	.214
	Other	18	4.44	.705	.166
Question12	TEIF	18	4.61	.502	.118
	Other	18	4.5	.618	.146
Question13	TEIF	18	4.5	.618	.146
	Other	18	4.44	.511	.121
Question14	TEIF	18	4.17	.618	.146
	Other	18	4.33	.686	.162

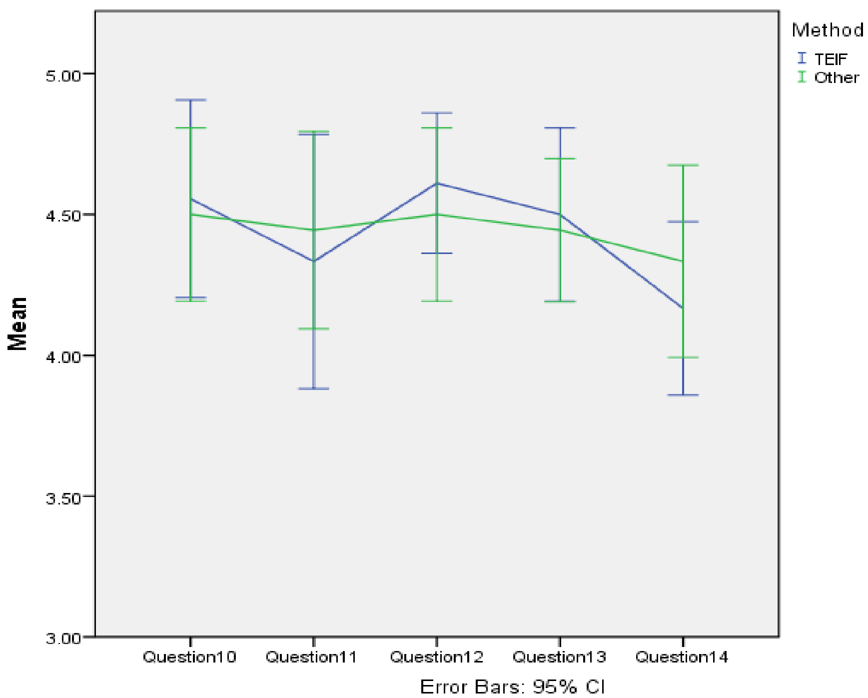


Figure 9-69 mean ratings of question numbers 10-14

The independent sample t-test statistic was used to help answer the sub research questions 3.3, 3.4, and 4.4. There were no significant differences on the mean ratings of questions 10 -14 between both two methods as shown in Table 9-198. Table 9-199 shows the overall mean ratings of participants on questions 10 -14.

Table 9-198 Independent samples t-test of question 10-14 between two methods

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Question10	Equal variances assumed	.137	.714	.251	34	.803	.056	.221	-.394	.505
	Equal variances not assumed			.251	33.4	.803	.056	.221	-.394	.505
Question11	Equal variances assumed	.817	.372	-.410	34	.684	-.111	.271	-.661	.439
	Equal variances not assumed			-.410	32	.684	-.111	.271	-.663	.441
Question12	Equal variances assumed	1.71	.200	.592	34	.558	.111	.188	-.27	.493
	Equal variances not assumed			.592	32.6	.558	.111	.188	-.27	.493
Question13	Equal variances assumed	1.17	.288	.294	34	.771	.056	.189	-.329	.44
	Equal variances not assumed			.294	32.8	.771	.056	.189	-.329	.44
Question14	Equal variances assumed	1.19	.283	-.766	34	.449	-.167	.218	-.609	.276
	Equal variances not assumed			-.766	33.640	.449	-.167	.218	-.609	.276

Table 9-199 Overall mean ratings of questionnaire numbers 10-14 for two methods

Question	N	Mean	Std. Deviation	Std. Error Mean
Question10	36	4.53	.654	.109
Question11	36	4.39	.803	.134
Question12	36	4.56	.558	.093
Question13	36	4.47	.56	.093
Question14	36	4.25	.65	.108

The one sample t-test was used to test whether the overall mean ratings were significantly greater than 3 ($p<0.001$) in the mean ratings on questions 10-14 as shown in Table 9-200 and illustrated in Figure 9-70.

Table 9-200 Overall one-sample t-test of question numbers 10-14

	Test Value = 3					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
Question10	14.02	35	p<.001	1.53	1.31	1.75
Question11	10.4	35	p<.001	1.39	1.12	1.66
Question12	16.7	35	p<.001	1.56	1.37	1.74
Question13	15.8	35	p<.001	1.47	1.28	1.66
Question14	11.6	35	p<.001	1.25	1.03	1.47

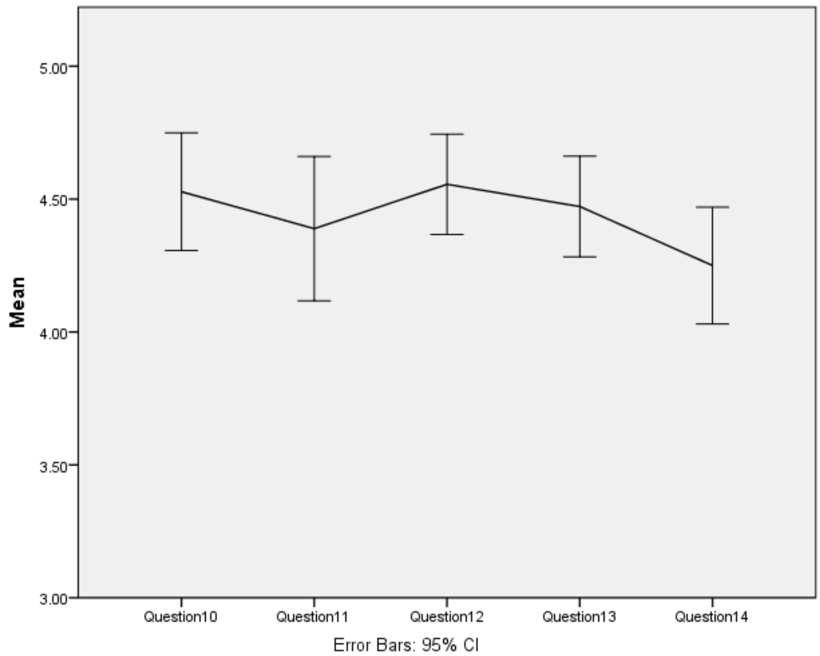


Figure 9-70 Profile graph of one-sample t-test of questionnaire numbers 10-14 for two methods

9.5.5 Participants' other comments about the usefulness or value of TEIF Method

Question 15 asked**: '**Do you have any other comments about the usefulness or value of the TEIF Method?'

Participants' comments included:

- It seemed very useful overall. What is the TEIF stand for? Mention only once so the participant forgot about it.
- About the technology suggestion table (Appendix K), I find some disagree with my intuition. Also searching through huge table is not easy to human eyes.
- I did not realise that the TEIF Method steps were difficult from the experiment tasks until I filled in the questionnaire.
- I would like to see an abstract outline of the TEIF Method. It is hard to tell what is in the TEIF Method, and what is specific to this example. The interaction types are good and were helpful.
- In the evaluate technology solutions task, for the technology solution scenario, it would be easier if the solutions present in the layout / prototype / dummy picture to show how the web / application look like such as the position of display captions, searching function etc.

- It is useful for double-checking requirement and design. Well done.
- It is an interesting method but needs to be tried with other disabilities as well.
- Excellent idea
- The technology suggestion table should suggest how well each technology meets each requirement by giving some levels e.g. high, medium, and low.
- It involves all needs and requirements for hearing impaired people.
- The method can be helpful once it was described by someone.

Chapter 10 Discussion

This chapter discusses the research questions in the context of the results of the expert validation and review presented in chapter 6 and discussed in chapter 7, and the results of the user experiments presented in chapter 9. Section 10.1 discusses research question 1 which concerns the TEIF while section 10.2 discusses research question 2, which is about the development of the TEIF Method. Section 10.3 discusses research question 3 which addresses the use of the TEIF Method by developers. Section 10.3.1 discusses sub research question 3.1 which concerns the evaluation of requirements, section 10.3.2 discusses sub research question 3.2 which is about the evaluation of technology solutions, section 10.3.7 discusses sub research question 3.3 which addresses gathering requirements and section 10.3.8 discusses sub research question 3.4 which concerns designing solutions. Research question 4 investigates the ways the TEIF Method helps developers and is discussed in section 10.4. Section 10.4.1 discusses sub research question 4.1 which investigates awareness of interaction issues. Section 10.4.2 discusses sub research question 4.2 which is concerned with understanding of environmental context. Section 10.4.3 discusses sub research question 4.3 which addresses the use of the technology suggestions table for identifying solutions. Section 10.4.4 discusses sub research question 4.4 which compares the use of the whole TEIF Method with just the part involving the technology suggestions table. Section 10.5 discusses any issues participants found with the TEIF Method in the experiment. The limitations of the research are discussed in section 10.6.

10.1 Research question 1

Research question 1: Can the TEIF be developed regarding disabled people interacting with people, technologies, and objects?

This was answered by an expert validation and review of TEIF (discussed in detail in chapter 7) which showed that the TEIF was successfully validated by three developer experts, and one HCI Professor.

As shown in Table 6-3, the TEIF table was successfully validated and as a result of the comments the following changes were made:

- A clarification of the meaning of the word ‘Objects’ in the TEIF context
- The ‘examples’ sub-heading was changed to ‘Explanations and examples’
- People being aware of other interactions (e.g. between other people or between other people and technology or other people and objects) was added as a sub-component
- The identity of an object was added to the sub-component ‘Property’
- Clarification why a robotic device triggered by the person walking past it talking to them would be a P-T-P interaction rather than a T-P interaction
- More information provided about the purpose of the TEIF

10.2 Research question 2

Research question 2: Can the TEIF Method be developed building on this TEIF to help design technology solutions for disabled people interacting with people, technologies, and objects?

This was answered by an expert validation and review of the TEIF Method (discussed in detail in chapter 7) which showed that the TEIF Method was successfully validated by three developer experts, three accessibility experts and one HCI professor and the following improvements made following the experts’ suggestions:

- More detail provided in scenario in order to be able to answer requirement questions
- Improved wording of the questions, multiple choices, answers, and explanations
- Grammar / spelling / re-wording changes to the technology suggestion tables and links provided to more sources.
- The scenario technology solution was improved.
- The numbering and re-ordering of actions in Mobile Web Interaction Diagram was improved, presenting concurrent as well as sequential actions.

- Login and logout functions were added to the Use Case Diagram.
- More information was provided for the technology solution and explanation.
- The TEIF Method was broken down into easier smaller steps.
- The professor's comment that the technology suggestions table could rate how well a technology meets the requirement rather than just showing a tick or cross had been considered when the table was being developed but it was decided that this would really involve the very extensive involvement of both accessibility experts and users and it would be best to first see how developers coped with the existing table with its binary classification. Refinement into a more nuanced multi-level classification could be future work after completion of the PhD.
- The professor's suggestion that the TEIF Method could be used as an index for case based solutions was considered a good idea for future work after the completion of the PhD.

For the user evaluation experiment, due to time limitations the Mobile Web Interaction Diagram and Use Case Diagram were not shown to participants.

10.3 Research question 3

Research question 3: Can developers use the TEIF Method to help with the software development process when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Four aspects of the software development process were explored with the following sub research questions:

Sub research question 3.1: focussed on evaluating requirements; Can developers use the TEIF Method to help with evaluating requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.2: focussed on evaluating technology solutions; Can developers use the TEIF Method to help with evaluating technology solutions when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.3: focussed on gathering requirements; Can developers use the TEIF Method to help with gathering requirements when designing technology solutions to interactions for disabled people with people, technologies, and objects?

Sub research question 3.4: focussed on designing technology solutions; Can developers use the TEIF Method to help with designing technology solutions to interactions for disabled people with people, technologies, and objects?

To help answer sub research questions 3.1 and 3.2 an experiment was carried out involving 36 experienced developers evaluating requirements and technology solutions. There was no significant difference between the TEIF Method and the Other Method groups in terms of the number of years of practical experience designing software and experience in designing technology solutions for disabled people (section 9.1) and so the groups were well balanced in this respect.

Half the participants used the TEIF Method and the other half used whatever other methods they would normally have used and were then shown the TEIF Method. The experimental design was explained in chapter 8.

Due to time limitations the scenario that was used only involved hearing impaired people and the experiment only involved evaluating requirements and technology solutions and so only helped answer sub research questions 3.1 and 3.2 regarding people with hearing impairment. A questionnaire was therefore used to help answer sub research questions 3.3 and 3.4 by asking participants whether they thought the TEIF Method would also help with gathering requirements and designing solutions and also to answer sub research questions 3.1, 3.2, 3.3, and 3.4 regarding the use of the TEIF Method for people with disabilities other than hearing impairment.

How the results of the experiment and questionnaire helped answer each of the sub research questions will be discussed in the following sections.

10.3.1 Sub research question 3.1

Sub research question 3.1, evaluating requirements for technology solutions, was explored both through analysis of whether the TEIF Method allowed significantly more correct requirements to be selected than the Other Methods using an independent samples t-test between the two methods and through a questionnaire question. More participants in the TEIF Method group selected each correct requirement than the Other Methods group (section 9-3). The incorrect requirement selected by the greatest number of participants in the TEIF Method group was requirement 6. Six of the incorrect requirements were selected by none of the TEIF Method group. The incorrect requirement selected by the greatest number of participants in the Other Methods group was requirement 22. Three of the incorrect requirements (9, 18, and 19, and reproduced below) were selected by none of the Other Methods group.

Requirement 9. help blind visitors at the museum.

Requirement 18. help hearing impaired visitor's friends email them to discuss the shadow puppet museum.

Requirement 19. improve Wi-Fi facilities for hearing impaired visitors.

One explanation for these three requirements not being selected by any of the Other Methods group might be because the word 'blind' did not appear in the transcript and the following extract of the transcript made it clear that requirements 18 and 19 were not one of the correct ten requirements.

'Suchat: There is good Wi-Fi at the museum so she emailed her friend who had visited the museum and he emailed back some details about the show that she had not understood when I talked.'

The rationale behind the selection of the 29 requirements for the evaluating requirement task consisting of the ten best requirements and the other 19 requirements was presented in section 8.7 and the lists of the requirements were provided in section 8.13. The ten best requirements were specifically mentioned in the interview transcript whereas the other 19 requirements while possibly helping disabled people were not specifically mentioned in the interview transcript.

Sub research question 3.1 also explored whether the TEIF Method helped evaluate requirements for technology solutions to problems involving interaction with hearing impaired people better than the Other Methods for the ten best requirements. As shown in section 9.3, the mean number of correct requirements was significantly higher for participants using the TEIF Method than the Other Methods.

Both the results of the evaluate requirement task of the experiment (section 9.3) and the questionnaire question 8 (the TEIF Method helped evaluate requirements: section 9.5.1) were in agreement with this finding. A one-sample test value = 3 was used to analyse the answer to questions 8 which has a mean rating of 4.5 and $p< 0.001$ showing participants in the TEIF Method group found the TEIF Method very helpful in evaluating requirements.

There was no significant difference between the mean ratings of the eight English native speakers and 28 non-native English speakers analysed by an independent samples t test (section 9.3). This suggested that the TEIF Method is suitable for all English speakers and the results from both native and non-native English speakers could be combined. Therefore no further analysis was carried out regarding any other possible differing results between native and non-native English speakers for this research.

10.3.2 Sub research question 3.2

Sub research question 3.2, evaluating technology solutions, was explored using both the following three different experimental approaches and questionnaire question 9. Question 9 results are relevant to, and are discussed in the second experimental approach B.

Approach A**:** Investigated whether the TEIF Method helped developers select the best technology solution(s) from solutions A, B and C more often than the Other Methods. The paired t test and the chi-square test were used for this investigation.

The results showed that the TEIF Method did not help developers select the exclusive best design solution(s) significantly more often than the Other Methods but it did help them select a solution significantly more often than the Other Methods that was not worse than a solution rated best by the experts. Applying the further criteria that no solution rated lowest by the participant should be rated highest by the experts resulted in no significant difference between the methods (section 9.4.2).

Participants were not explicitly asked to select the best solution(s) but were asked to rate the three solutions on a scale from 0-10. This required each participant to make 30 ratings. The researcher observed that participants found this a difficult task as they had to read and analyse each solution for each of the ten requirements. The solutions were presented in different orders on participants' task sheets to balance the experimental design. While it was possible for participants to rate the first requirement for all of the three solutions before moving on to the next requirement, no participant chose to use this approach, probably because it would have taken longer and involved more re-reading of solutions. However, using this approach might have helped ensure that participants' ratings better reflected the best solution. For example if they rated all ten requirements for solution A first and gave a rating of 10 for requirement 1 and then rated all ten requirements for solution B next and gave a rating of 5 for requirement 1 and then rated all ten requirements for solution C next, they would not be able to rate C higher than A for requirement 1 without returning to solution A and changing the rating. They would also probably have forgotten the details of solution A by the time they got to solution C. Therefore testing whether the participants rated the same solution highest as the solution the experts rated highest and also requiring the participants to rate the same solutions equally high as the experts was probably too strict a test of whether the TEIF Methods helped them select the best solution.

***Approach B*:** Investigated whether the TEIF Method helped developers rate technology solutions closer to the experts' ratings than the Other Methods (section 9.4.3.2).

For this investigation a three way repeated measures analysis of variance with two within subjects factors (*solution* and *requirement*) and one between subjects factor (*method*) was carried out on the discrepancy between the participants ratings and the experts' ratings for the TEIF Method and the Other Methods across ten requirements and three solutions.

As shown in Table 9-48, the third-order interaction effect *requirement*solution*method* was not significant. This indicates that the three factors were not mutually dependent.

However, the second order interaction effect of *solution*method* was significant, and this indicates that the mean discrepancy of *solution* depends on *method* and the mean discrepancy of *method* depends on *solution* and these discrepancies are over all requirements. The results showed that the TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A but not for solutions B and C, and this applied similarly to each requirement (Figure 9-20 and Table 9-53). The results also showed that the discrepancy ratings for solutions B and C were not significantly different for both the TEIF Method and the Other Methods, and that solution A was not significantly different from B or C for the Other Methods. These findings apply similarly to each requirement.

The reason why the TEIF Method was shown by the experiment to help developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A but not for solutions B or C might be because solutions B and C had more expert ratings between scale point 3 and 7 (i.e. in the middle of the scale) than solution A. As shown in Table 9-20, B had 6 of the 10 ratings between 3 and 7, C had 7 of the 10 ratings between scales 3 and 7, while A had 1 rating between 3 and 7. As the technology suggestions table only showed ticks and crosses for technologies these gave only a binary indication and so this was more help to the reader for very good or very bad solutions that would be given very high or very low ratings rather than solutions that would be in the middle of a 10 point rating scale. Therefore solutions that were very good solutions were given very high ratings of 8-10 by the experts (A had 9 ratings between 8 and 10 whereas B and C had only two ratings each between 8 and 10) whereas solutions that were identified by the experts as not as good (i.e. B and C) were given more ratings in the range of 3 to 7. There are three scale points between 8 and 10, whereas there are five scale points between 3 and 7. Therefore if participants agreed with the experts that a solution was very good, they were more likely to rate closer to the experts (e.g. giving a rating of 8 when the experts give a rating of 10 is only a difference of two rating points) than when the participants agreed with the experts a solution was not very good (e.g. giving a rating of 3 when the experts give a rating of 7 is a difference of four scale points). This explanation is supported by the fact that many participants commented that the technology suggestions table would have been more helpful if technologies had been rated on, for example, a four point scale (e.g. high, medium, low, not at all) for the level of meeting requirements rather than the binary yes / no which did not help them differentiate between many of the requirements and solutions as most of the table cells had ticks and only a few had crosses. Tooltips on an online version of the table provided some further explanations about how the technologies met each requirement issue but they were rarely looked at by participants because of time pressure of the experiment.

Further, it would have been possible to design solutions B and C to use more technologies than clearly did not meet the requirement issues but this might have made it more obvious to those not using the TEIF Method which solution was the best. The technology descriptions, in the technology suggestion table, were also made available to the participants using the Other Methods to remove any advantage of providing descriptive information about the technologies only to the TEIF Method group that in theory in real life, the Other Methods group would have been able to search for online. The fact that most of the table had ticks and the tooltips were rarely looked at by the TEIF participants meant that the potential advantage offered by the technology suggestion table was not fully realised.

The second order interaction effect of *method*requirement* was not significant (Table 9-32). This indicates the mean discrepancy of *method* does not depend on *requirement* and the mean discrepancy of *requirement* does not depend on *method.* This result suggests that any differences between methods are similar for each requirement over all the solutions. It seems that the method did not help any particular requirements to be rated closer to the experts more than it helped with any other requirements.

The main effect of *method* was not significant (Table 9-35). This suggests that the TEIF Method was neither better nor worse than the Other Methods in allowing participants to rate solutions closer to the expert ratings, with the exception that the TEIF Method gave a closer rating for solution A as noted earlier in the discussion of the second order interaction effect of *solution*method*. A possible explaination for this was also presented in the same section.

The second order interaction effect of *requirement*solution* was significant. This indicates the mean discrepancy of *requirement* depends on *solution* and the mean discrepancy of *solution* depends on *requirement* and these dependencies are over all methods. This result shows that, for each method similarly, there were discrepancies between solutions for requirements 1, 4, 8, 21, and 25 but not for requirements 11, 14, 17, 24, and 28.

If differences in expert ratings had been a reason for the discrepancies then these might occur only for requirements with large differences in ratings between solutions. This would explain the absence of discrepancies for requirements 11 and 28 for which the expert ratings for solutions A, B, and C were 7 and 6, 7 and 10, and 10 and 10 respectively (Table 9-19) but would not explain the absence of discrepancies for requirements 14, 17 or 24. It therefore seems that the dependency of *requirement* on *solution* requires a different explanation.

The simple main effects of requirement at each level of solution showed that there was a significant difference between requirement 8 and requirements 11, 14 and 24 for solution A (Table 9-58) and the following discussion suggests possible reasons why this result might have occurred.

Requirement 8 was significantly closer to the expert ratings than requirements 11, 14, and 24 for solution A. Requirement 8 for solution A had the closest participant rating to the expert rating for any requirement and for any solution (with a mean of 0.778 and a standard error of 0.187, see Table 9-54) The description of the technology in solution A that satisfies requirement 8 therefore appears to be the easiest for participants to understand. The solution states *‘Suchat indicates that the tour is about to start by pressing the start button on his mobile phone. Chuty’s phone vibrates at the same time to notify her of this’* and requirement 8 states *‘The technology solution should help notify hearing impaired visitors when the tour starts’.* Solution C provides similar technology but the description uses the word ‘alert’ instead of ‘notify’ and ‘begin’ instead of ‘start’ and does not explicitly state that Chuty’s phone actually vibrates although it is set to vibrate i.e. *‘Chuty sets her phone to vibrate and Suchat lets Chuty know when the tour begins by sending an SMS to alert her’.* The mean discrepancy between the participants and expert rating for requirement 8 and solution C was 1.86 with a standard error of 0.49. There was no mention of notification in solution B so experts rated solution B for requirement 8 as 0 but participants rated this much higher with a mean discrepancy of 1.56 and standard error of 0.372. Solution B never mentions the start of the tour but mentions that *‘After the tour, Chuty can use her smartphone to scan further information about the exhibits’* so perhaps this confused some people who might have thought notification was not necessary. Requirements 11, 14, and 24 had the greatest discrepancies for solution A of 2.19, 2.64, and 2.25 respectively and the solution did not explicitly use the same keywords as the requirements making it harder for participants to just spot keywords. For example requirement 11 states ‘*not miss information when the owner points to exhibits*’ but the solution does not use the words ‘*miss information’* and uses the words *‘to help Chuty understand Suchat’s answers when she looks at exhibits, she can use the further information …’.* Requirement 14 includes the words *‘hearing aids and lip-reading’* but the solution does not use these words, they only appear in the scenario. Requirement 24 includes the words ‘spontaneous speech’ but the solution only mentions that *‘Chuty asks some questions’ and ‘Suchat answers supported by … typing the answers…’.*

The simple main effects of requirement at each level of solution showed that there was a significant difference between requirements 21 and 25 for solution B (Table 9-59) and the following discussion suggests possible reasons why this result might have occurred.

Requirement 25 for solution B had the second lowest discrepancy for solution B with a mean of 1.67 and standard error of 0.264 (The lowest was requirement 8 with a mean of 1.56 and a much larger standard error 0.49.) for solution B and requirement 21 had the second highest mean discrepancy of 3.28 with a standard error of .238 (the highest was requirement 24 with a mean of 3.5 and a much larger standard error .575). Requirement 25 used the words *'keep costs low by working with existing Wi-Fi and visitors' smartphones'* while solution B stated four times that *'Chuty can use her smartphone'* making it easy for a participant to identify that solution B satisfies requirement 25. Requirement 21 used the keywords *'pre-prepared speech'* but solution B did not use these same keywords but instead uses the words *'pre-prepared sign language video with captions'* which might have confused some participants.

The simple main effects of requirement at each level of solution showed that there was no significant difference between any pairs of requirements for solution C.

Summarising the experimental findings using approach B, the results showed that the TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A, but not for solutions B and C, and this applied similarly to each requirement. *Question 9:* While the experimental result shows that the TEIF Method helps with solution A, the questionnaire results for question 9 (section 9.5.2) showed that the participants thought that the TEIF Method had helped them evaluate the solutions (mean rating = 4.28). On the rating scale between 1 and 5, a rating of around 4 suggests a strong opinion of the value of the TEIF Method in helping evaluate technology solutions and so this result provides some support for the experimental findings that the TEIF Method helped developers rate solution A significantly closer to the experts' ratings than the Other Methods.

Approach C: Investigated whether the TEIF Method helped rate differences (measure amount and direction) between technology solutions closer to experts' difference scores than the Other Methods (section 9.4.3.3). This investigation was concerned with '*differential*', the degree to which a particular solution was rated as better compared to another solution in the same way as an expert rated them.

For this investigation a three way repeated measures multivariate analysis of variance with two within subject factors (*requirement* and *differential*) and one between subject factor (*method*) was carried out. The two measures were (a) amount and (b) direction. Both measures were calculated for the TEIF Method and the Other Methods for each of ten requirements and each of three pairs of differentials A-B, A-C, and B-C.

The third order interaction effect of *requirement*differential*method* was significant (Table 9-63). This indicates that the three factors were mutually dependent.

This result suggests that the factor effects between solutions depend on particular requirements, on particular differentials, and on whether the method was the TEIF Method or the Other Methods. The three factors were mutually dependent in their effects on both the measures of amount and direction.

The second order simple interaction effects of *method*requirement* at each level of *differential* were analysed. A multivariate two-way analysis of variance with one within subject factor (*requirement*) and one between subject factor (*method*) was carried out for each differential A-B, A-C, and B-C. The two measures were (a) direction (b) amount.

10.3.2.1 Differential A-B

The second-order simple interaction effect of *requirement*method* for differential A-B was significant for the multivariate test (Table 9-64). The second-order simple interaction effect of *requirement*method* was significant for both measures amount and direction as shown by the univariate tests (Table 9-67), which indicates that the simple simple main effect of *requirement* on measures amount and direction depend on *method,* and the simple simple main effects of *method* depend on *requirement*.

The multivariate test of simple simple main effect of *method* at each level of *requirement* (Table 9-69) and the univariate tests (Table 9-70) showed that the TEIF Method helped differentiation between solutions to be closer to experts' differentiation than the Other Methods for differential A-B for requirement 8 on measures amount and direction but not for other requirements.

The expert differential A-B for requirement 8 was 10 which was larger than the expert differential A-B for any other requirements. This may account for the significant results involving requirement 8 (Figure 9-26 and Figure 9-27) and for the lack of significance for the other requirements. As the TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution, this method might help in also rating the differential A-B closer than the Other Methods but the lack of significance for the other nine requirements suggests that in general, there is no practically significant differential effect between the TEIF Method or the Other Methods.

The multivariate test of simple simple main effect of *requirement* at each level of *method* for differential A-B showed that there was a significant simple simple main effect of *requirement* for both the TEIF Method and the Other Methods (Table 9-71).

There were significant differences on measure amount for differential A-B for the TEIF Method between 16 pairs and 29 pairs were not significant (Table 9-72) of requirements for the 45 pairs of differences.

There were significant differences on measure amount for differential A-B between 26 pairs of requirements for the Other Methods. The remaining 19 pairs were not significantly different (Table 9-73).

The fewer significant differences between pairs of requirements for the TEIF Method on measure amount (16 pairs) (Table 9-74)compared to the Other Methods (26 pairs) (Table 9-75) suggests that the TEIF Method helped rate pairs more consistently similar to the experts compared to the Other Methods.

There were significant differences on measure direction for the TEIF Method between 11 pairs of requirements, while, there were no significant differences between 34 pairs of requirements (Table 9-74). There were significant differences on measure direction for the Other Methods between 16 pairs of requirements, while there were no significant differences between 29 pairs of requirements (Table 9-75). The fewer significant differences between pairs of requirements for the TEIF Method on measure direction (11 pairs) compared to the Other Methods (16 pairs) again suggests that the TEIF Method helps rate pairs more consistently similar to the experts compared to the Other Methods.

10.3.2.2 Differential A-C

The second-order simple interaction effect of *requirement*method* for differential A-C was significant for the multivariate test. The second-order simple interaction effect of *requirement***method* was significant on measure direction but not for measure amount for the univariate test (Table 9-79).

which indicates that the simple simple main effect of *requirement* depends on *method,* and the simple simple main effects of method depend on *requirement*. The simple simple main effect of *method* for requirements 1 and 8, were significant on measure direction (Table 9-85).

Requirement 1 was selected by the greatest number of participants in the TEIF group in the requirement task and so perhaps participants understood this requirement the best. As the TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solution A, this might help in also rating the differential A-C closer than the Other Methods, but the lack of significant findings for eight of the requirements and the results suggested that in general, there is no differential effect between the TEIF Method or the Other Methods.

The simple simple main effects of *requirement* showed significant differences on measure direction for the TEIF Method between 17 pairs of requirements, while there were no significant differences between 28 pairs (Table 9-86). There were significant differences on measure direction for the Other Methods between 21 pairs of requirements, while there were no significant differences between 24 pairs (Table 9-87). The fewer significant differences between pairs of requirements for the TEIF Method (17 pairs) compared to the Other Methods (21 pairs) suggested that the TEIF Method helped rate pairs more consistently similar to the experts compared to the Other Methods on measure direction.

The second-order simple interaction effect of *requirement***method* was not significant on measure amount for the univariate test, which indicates that the simple simple main effect of *requirement* does not depend on *method*, and the simple simple main effects of method does not depend on *requirement*. The simple main effects on measure amount were considered further because there was not a significant second order interaction effect. The simple main effect of *method* was not significant on measure amount (Table 9-80), while, the simple main effect of *requirement* was significant (Table 9-79).

The simple simple main effects of *requirement* showed significant differences on measure amount for overall method between 32 pairs of requirements, while there were no significant differences between 13 pairs (Table 9-84). This shows that the majority of pairs were rated differently by participants and the experts.

10.3.2.3 Differential B-C

The second-order simple interaction effect of *requirement*method* for differential B-C was significant for the multivariate test (Table 9-88) and also significant for both measures amount and direction for the univariate test (Table 9-91), which indicates that the simple simple main effects of *requirement* on measures amount and direction depend on *method*, and the simple simple main effects of *method* depend on *requirement*.

The multivariate test (Table 9-93) and the univariate tests (Table 9-94) of simple simple main effects of *method* for each *requirement* on measures amount and direction showed that there were significant simple simple main effects of *method* on both measures amount and direction for requirements 8 and 28, but not on the other requirements. Looking at the marginal mean values (Table 9-92) it can be seen that the TEIF Method helped differentiation between solutions B and C to be closer to experts' differentiation than the Other Methods on both measures amount and direction for requirements 8 and 28.

The expert differential B-C for requirement 8 was 10 which was larger than the expert differential B-C for any other requirement. The expert differential B-C for requirement 28 was 0 and was the only expert differential of 0 for B-C for any requirement where both solution B and C were rated 10. Requirement 28 was selected by the lowest number of participants in the Other Methods group in evaluating requirement task. This might help explain why the TEIF Method helped for these requirements.

There were significant simple simple main effects of *requirement* at each level of *method* using multivariate tests (Table 9-92). There were significant differences between 20 pairs of requirements on measure amount for the TEIF Method, and no significant differences between 25 pairs (Table 9-96). There were significant differences between 19 pairs of requirements on measure amount for the Other Methods and no significant differences between 26 pairs (Table 9-97)

There were significant differences between 18 pairs of requirements on measure direction for the TEIF Method and no significant differences between 27 pairs (Table 9-98). Finally, there were significant differences between 16 pairs of requirements on measure direction for the Other Methods, and no significant difference between 31 pairs (Table 9-99). These results are discussed in the following section.

10.3.3 Discussion of differential pair comparison results

The chi-square analysis showed that the TEIF Method was only significantly different from the Other Methods for the number of significantly different requirement pairs only for differential A-B on measure direction (Table 9-100). This suggests that the TEIF Method helped rate pairs more consistently similar to the experts compared to the Other Methods for this differential.

There was no significant difference in the number of different requirement pairs between differentials A-B and B-C for the TEIF Method and the Other Methods on measure amount (Table 9-100). While the results were derived from a rating scale 0 to 10, where participants indicated whether the solution met a requirement well or not, the guidance given to participants in the technology suggestion table was simply binary – tick or cross. This was a relatively insensitive guide to meeting requirements and it may be expected that a more sensitive guide would allow the TEIF Method to show superiority.

10.3.4 Discussion of association between significance of TEIF and Other Methods differential pair differences

Table 9-101 showed the number of significant differences between the two elements of a pair for all 45 possible pairs. The TEIF Method and the Other Methods showed significant association for differentials A-B and B-C on measure amount, and differential A-C on measure direction, but did not show such significant association for differential A-B or B-C on measure direction. Table 9-101 shows the similar result to Table 9-100, where participants using either the TEIF Method or the Other Methods shows similar ability in rating whether a requirement is better met in one solution than in another.

As already discussed in section 10.4.2, regarding rating the best solution for a requirement, a more nuanced guide to applicable technology suggestions would allow a clearer advantage, especially when these relative differences are small. It might be expected therefore that a more nuanced guide would help participants rate solution differentials closer to the expert differentials, this is more likely to show for extreme differentials (e.g. 10 or 0 when both solutions are rated 10 or 0) rather than small differentials of 0, 1, or 2 when both solutions are rated 5, 6, or 7.

10.3.5 Discussion of differential pair comparisons for each requirement

The analysis showed that the TEIF Method was not significantly different than the Other Methods for the number of significantly differential pairs (A-B and A-C, A-B and B-C, and A-C and B-C) for measures amount and direction for each requirement.

The Fisher Exact test results in Table 9-158 did not show a strong association between the pair differences and pair differences and method. As stated in section

10.3.3 the binary guidance from the ticks and crosses in the technology suggestions table was a relatively insensitive guide and perhaps more sensitive nuanced guidance would allow the TEIF Method to show superiority.

10.3.6 Discussion of Methods differential requirement pairs closer to expert

The TEIF Method was significantly different than the Other Methods for the number of requirement pairs significantly closer to experts for measures amount and direction for differential A-B (Table 9-185).

The differential A-B was rated by the experts as the largest of the three differentials and so its effect size would show the TEIF Method superiority. More sensitive nuanced technology suggestions table guidance might allow the TEIF Method to also show superiority for the other two differentials (A-C and B-C) that had smaller effect sizes than A-B.

The chi square test results (Table 9-186) shows a strong association between the pair differences and pair differences and method for differential A-B, such that the same pair tends to be significantly different for both methods or not significantly different for both methods. Once again, a more sensitive nuanced technology suggestions table guidance might allow the TEIF Method to show superiority.

10.3.7 Sub research question 3.3

To help answer sub research question 3.3 (gathering requirements), participants were asked to express their opinions through a questionnaire whether the TEIF Method would help with gathering requirements when designing technology solutions to interactions for hearing impaired people (question 10), and if information was provided for other disabled people (question 13).

The results in section 9.5.4 showed the participants thought that the TEIF Method would also help with gathering requirements for technology solutions to interaction problems involving hearing impaired people (mean rating = 4.53), and for other disabled people (mean rating = 4.47). On the rating scale between 1 and 5, with 3 as the neutral point, a rating of around 4.5 suggests a very strong opinion of the value of the TEIF Method in gathering requirements for hearing impairments as well as other disabilities. It would be valuable and useful to establish in the future the opinion from participants with regard to details of how the TEIF Method would help with different ways in gathering requirements e.g. document inspection, interview, interview transcribe analysis, and questionnaire.

10.3.8 Sub research question 3.4

To help answer sub research questions 3.4 (designing technology solutions) participants were asked to express their opinions through a questionnaire regarding whether the TEIF Method would help for designing technology solutions.

The results in section 9.5.4 showed that the participants thought that the TEIF Method would help designing technology solutions to interaction problems involving hearing impaired people (question 11, mean rating = 4.39), and if information was provided for other disabled people (question 12, mean rating = 4.56). On the rating scale between 1 and 5, with 3 as the neutral point, a rating of around 4.4 to 4.5 suggests a very strong opinion of the value of the TEIF Method in designing technology suggestions for hearing impairments as well as other disabilities. It would be valuable and useful to establish in detail in the future the opinion from participants how the TEIF Method would help with designing solutions.

10.4 Research question 4

Research question 4: In what ways does the TEIF Method help developers?

To help answer this research question the sub research questions were explored through questionnaire responses and also any difficulties the participants had with the TEIF Method steps were analysed as discussed in the following sections.

10.4.1 Sub research question 4.1

Sub research question 4.1: Does the TEIF Method help to improve awareness of interaction issues involving hearing impaired people?

A one-sample t-test was used to analyse the results of question number 5 (section 9.5.3). Participants thought that the TEIF Method helped improve a developer’s awareness of interaction issues involving hearing impaired people (mean rating = 4.44). On the rating scale between 1 and 5, a rating of between 4 and 5 suggests a strong opinion of the value of the TEIF Method to help a developer’s awareness of interaction issues involving hearing impaired people. It would be valuable and useful to obtain the opinion from users in the future regarding the development of the requirement question and answers in order to improve awareness of interaction issues involving other disabilities.

10.4.2 Sub research question 4.2

Sub research question 4.2: Does the TEIF Method help to improve understanding of how environment context affects interaction when hearing impaired people are involved?

A one-sample t-test was used to analyse the results of question number 6 (section 9.5.3). Participants thought that the TEIF Method helped to improve understanding of how environment context affects interaction when hearing impaired people are involved (mean rating = 4.44). On the rating scale between 1 and 5, a rating of around 4 suggests a strong opinion of the value of the TEIF Method help a developer's improve understanding of how environment context affects interaction when hearing impaired people are involved.

The result from the multiple choice questions (section 9.2.2) showed 100% understood the impact of background noise, 72% understood the importance of visual access to speaker face, 67% understood the effect on distances on the level of sound, but only 18% understood the importance of hard surface and reverberation. Although, the scenario mentioned that the shadow puppet theatre was made of wood perhaps the participants may not have thought that the museum was also made from wood. Future work may be needed to explain more clearly in the TEIF Method about the impact of hard surfaces and reverberation.

10.4.3 Sub research question 4.3

Sub research question 4.3: Does the technology suggestions table in the TEIF Method help identify technology solutions to interaction problems involving hearing impaired people?

A one-sample t-test was used to analyse the results of question number 7 (section 9.5.3). Participants thought that the technology suggestions table in the TEIF Method helped with identifying technology solutions to interaction problems involving hearing impaired people (mean rating = 4.44). On the rating scale between 1 and 5, a rating of around 4 suggests a strong opinion of the value of the TEIF Method helping identify technology solutions to interaction problems involving hearing impaired people. Future work that would be valuable and useful is to establish through experiment or case study how the TEIF Method would be helpful for designing technology solutions.

10.4.4 Sub research question 4.4

Sub research question 4.4: Is using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the Method?

A one-sample t-test was used to analyse the results of question number 12 (section 9.5.4). Participants thought that using the whole TEIF Method would be more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the technology suggestions table part of the method (mean rating = 4.56). On the rating scale between 1 and 5, a rating of around 4.5 suggests a very strong opinion of the value of using the whole TEIF Method for designing technology solutions compared to just using the technology suggestions table part of the TEIF Method. The opinion from users that would be valuable and useful to establish through future experiment or case study is how the whole TEIF Method would be helpful for designing technology solutions.

10.4.5 Summary of research question 4

It is very clear from the results of the questionnire that the participants thought the TEIF Method helped them to improve their awareness of interaction issues involving hearing impaired people and also helped improve their understanding of how environment context affects interaction. Participants thought the TEIF Method was helpful for identifying technology solutions to interaction problems involving hearing impaired people and that they would find using the whole TEIF Method more helpful than just using the technology suggestions table part of the TEIF Method. Possible future work was briefly discussed and is further discussed in chapter 11.

10.5 Issues Using the TEIF Method

The interaction types were understood by almost all the participants (section 9.2.1) which shows that this step was easy to follow. The best ten requirements for a technology solution that solves the disability related problems identified from the interview transcript were selected correctly by at least 67% of participants (section 9.2.3) and therefore this step was easy to follow for over two thirds of the participants. When identifying possible technologies (section 9.2.4) at least 72% of the participants provided correct answers for four requirements, at least 61% provided correct answers for another four requirements and at least 50% provided correct answers for the remaining two requirements which suggests that this step was the hardest to follow, particularly for requirements 17 (help visitors understand the shadow puppet show in the dark) and 21 (work with pre-prepared speech from the owner to the visitor).

Approximately 67% of the TEIF Method group and 94% of the Other Methods group found some steps in the TEIF Method were difficult to carry out (section 9.2.5). It has already been discussed in section 10.4.2 that participants found difficulties in rating solutions on the 0-10 scale when only a binary tick / cross classification of technologies was provided. It would also appear that a reason why the Other Methods group found the TEIF Method more difficult than the TEIF Method group was the fact that the Other Methods group only spent a much shorter short time reading the TEIF Method and did not actually use the TEIF Method. As discussed in the following section, the time limitation due to the experimental ethical requirements meant that some of the TEIF Method explanations had to be shortened which caused some difficulties for some participants in understanding some parts of the TEIF Method.

10.6 Limitations of the Present Study

Limitations to this experiment are described as follows:

1) *Time Limitation in Experiment*

Many details of how to use the TEIF Method were removed from the experimental tasks as explained in section 8.12 due to the restricted time available that was required to gain ethical approval from Southampton University and also to not discourage participation in the experiment. Some details from scenario, diagrams, explanation of the technology suggestions table were removed to shorten them. This may have affected the understanding of participants in learning to use the new method in such a very short time. The experiment still required a lot of reading, understanding and thinking so the participants may have become tired which may have affected the results.

2) Method steps and resources

In the experiment, a mixed method using both an online and offline paper prototype was used. Participants read through the offline paper material provided and did the written task on paper. The only online part offered for the participants was the technology suggestion table which as well as a paper version, a web version contained explanations in tool tips so participants could read the explanation of ticks and crosses when they needed to. Using paper could take a longer time to read and find a particular word compared to an online system using a search facility. Participants may not have understood the difference between the steps in the TEIF Method and the steps and tasks that were necessary for recording information and results for the experiment. In a real world situation, participants would not need to read a scenario from the system or record experimental results as they would be gathering requirements from real interviews for example and then use the TEIF Method online to help them analyse requirements and solutions. One reason, paper was used for the experiment was that it made it easier for the researcher to control the experimental tasks.

3) Technology Suggestion Table

The technology suggestions table has ticks and crosses to help developers analyse which technology is useful for which requirements in the scenario. The experiment discovered that the participants found it difficult to differentiate between solutions because many technologies had ticks but this gave no information regarding how well each technology helped meet the requirements in the scenario. It might be more useful if in the future the table provided levels of how well each technology met each requirement in the scenario to help differentiate between solutions.

4) Rating Scale

For the experiment participants were not explicitly asked to select the best solution(s) but were asked to make ratings for each of three solutions and ten requirements. In a real situation using the TEIF Method a developer could just compare technologies directly to select the best one, which would be a much easier task for them.

Chapter 11 Conclusion and Future Work

The motivation for this thesis was the lack of a framework or method to help developers with the gathering or evaluation of requirements and the design or evaluation of technology solutions to accessible interactions between people, technology, and objects. This chapter concludes the thesis by summarising the contributions to research and identifying directions for future work.

While the Technology Enhanced Interaction Framework (TEIF) has all the necessary components and sub components to be a general framework, the TEIF Method is focused on accessible interactions because other methods do not focus on this. The content of the TEIF Method used in the research focuses on accessible interactions for people with hearing impairment because of time limitations of the research. The TEIF Method content could be extended to any or multiple disabilities as future work.

The results from the experiments could be regarded as providing stronger evidence for the related conclusions than the results from the questionnaires.

The novel experimental design and analysis to compare software development methods can also be seen as an additional contribution.

11.1 Contributions

11.1.1 Technology Enhanced Interaction Framework

A TEIF for enhancing interactions with people, technology, and objects through the use of technology was developed and successfully validated by developer experts, accessibility experts, and an HCI professor (chapters 6 and 7) as having all the necessary components and sub components to be a general framework.

11.1.2 TEIF Method

The TEIF Method was developed and successfully validated similarly (chapters 6 and 7). An evaluation by technology developers through experiment and questionnaire showed that the TEIF Method has considerable potential for supporting developers gathering and evaluating requirements, and designing and evaluating accessible solutions.

11.1.2.1 Experimental results

Developers were able to use the TEIF Method to evaluate requirements for technology solutions to problems involving interaction with hearing impaired people better than the Other Methods (section 9.3).

The TEIF Method helped developers select a best solution significantly more often than the Other Methods (section 9.4.1) although it did not help developers select the exclusive best design solution(s) significantly more often.

The TEIF Method helped developers rate solutions significantly closer to the experts' ratings than the Other Methods for solutions whose requirements were well-met by technology (section 9.4.3).

The TEIF Method helped differentiation between solutions to be closer to experts' differentiation than the Other Methods for some solutions and requirements (section 9.4.4).

11.1.2.2 Questionnaire results

Developers' answers to questions provided additional evidence for the value of the TEIF and TEIF Method helping with the experimental tasks and also provided evidence of the TEIF Method having the potential to also help people with disabilities other than hearing impairment and to also help with gathering requirements and designing solutions.

Participants thought that the TEIF Method had helped them to:

- evaluate requirements for technology solutions to interaction problems involving hearing impaired people (section 9.5.1)
- evaluate the technology solutions to interaction problems involving hearing impaired people (section 9.5.2)

- improve their understanding of how environment context affects interaction when hearing impaired people are involved (section 9.5.3)
- improve their awareness of interaction issues involving hearing impaired people (section 9.5.4)

Participants also thought that:

- the technology suggestions table in the TEIF Method was helpful for identifying technology solutions to interaction problems involving hearing impaired people and if further appropriate information was provided, would be also helpful for other disabled people (section 9.5.3).
- the TEIF Method would also help with gathering requirements for technology solutions to interaction problems involving hearing impaired people and if further appropriate information was provided, also for other disabled people (section 9.5.4).
- the TEIF Method would also help with designing technology solutions to interaction problems involving hearing impaired people and if further appropriate information was provided, also for other disabled people (section 9.5.4).
- the whole TEIF Method would be more helpful for designing technology solutions to interaction problems than just using the technology suggestions table part of the method (section 9.5.4).

11.2 Future Work

11.2.1 Technology Suggestions Table Refinement

The HCI Professor and some participants suggested that it would be helpful if the technology suggestions table rated how well a technology met the requirements rather than just showing a tick or cross. Refinement into a more nuanced multi-level classification would involve the extensive involvement of both accessibility experts and users. An example of how this classification might work is shown in

Table 11-1 Technology suggestions table refinement

Technology	Requirement 1	Requirement 2	Requirement 3	Requirement 4	Requirement 5
A	High	Medium	N/A	High	Medium
B	Very low	High	Medium	Low	Very low
C	High	Very low	Very high	High	Medium
D	Low	low	low	N/A	Very high

N/A : Not apply

11.2.2 Index for Case Based Solutions

The HCI Professor's suggestion that the TEIF and TEIF Method could be used as an index for case based solutions (section 7.1.1) would involve building up a repository of solutions online that could be searched by requirement to provide ideas for developers on how to create accessible technology enhanced interactions for new scenarios. How well a previous solution met particular requirements would provide an indication of the applicability of the previous solution to the new scenario as shown in Table 11-2. This would be facilitated by proving the whole of the TEIF Method available online using an expert system to help guide the user.

Table 11-2 Index for case based solutions

Previous Scenario Solutions	1a.improve communication	2a.same time/ same place	3a.presenter-audience	6b. speaker speaks Thai	9a. hearing impaired	11a. people – people	11b. people - objects	12a.online technology	14a.pre-prepared speech	16a. indoor	17a. noise	17e.inadequate lighting	18a. low cost solution
3	High	Med	Low	High	High	Med	Low	High	Very high	Med	Med	N/A	low
4	Med	Low	High	Med	N/A	High	Med	N/A	med	N/A	low	N/A	High
2	Very high	High	Med	N/A	Very high	High	N/A	N/A	Very low	N/A	High	N/A	Very low
1	Med	High	High	Very high	Med	Very low	Low	N/A	N/A	Med	N/A	High	Med

N/A : Not apply

11.2.3 Gathering Requirements

It would be valuable and useful to establish in the future the opinion from users with regard to details of how the TEIF Method would help with different ways in gathering requirements e.g. interview, questionnaire, document inspection, and interview transcription analysis (section 10.3.7). The pilot studies (section 8.6) showed that developers found interviewing difficult and so they could use the requirement questions to help them with interviews and questionnaire questions.

11.2.4 Multiple Disabilities

It would be valuable and useful to obtain the opinion from users in the future regarding the development of the requirement questions and answers in order to improve awareness of interaction issues involving disabilities other than hearing impairment, including multiple disabilities (section 10.4.1). As discussed in chapter 8, while developing the experimental method some consideration was given to this and an extract of an example scenario involving multiple disabilities is provided below and an extended list of actions, reactions and issues is shown in Table 11-3 and Table 11-4.

'*Chuty is a hearing impaired person who visits an in situ shadow puppet museum in Nakhon Si Thammarat which is run by Suchat Trapsin. Chuty visits the museum with her best friends Anna and Aoo. Anna is a blind person and Aoo has a physical impairment. The museum has made available a mobile web site which visitors can use to enhance their visit. There is a specific function called live functionality which assists Chuty to communicate with the owners. Moreover, the museum also provides the specific function for people who are blind and physically impaired as well so they all can enjoy the culture by using their own mobile devices in accessing to information.*

At the entrance to the museum, Chuty sees a poster explaining that hearing impaired visitors should enable the live assistance functionality on the mobile web site before the tour starts. The function allows Suchat to notify her when the tour begins and change the topics. Anna finds that she can access information by listening to the audio description on her mobile devices. Aoo is a disabled wheelchair visitor so she cannot get access to all parts of the museum because Suchat's house is a Thai traditional house in which visitors have to climb up a ladder. However, Suchat provides the option for Aoo to use a mobile phone to look at a recording of the exhibits and Suchat also uses Skype to show and explain the culture to her.'

Table 11-3 An extended list of actions, reactions and issues

Actions	Reactions	Intentionality	Possible issues / problems / expressions & disabilities affecting actions
speak / talk		tell, ask, answer, explain	A1. non-native speaker A2. hearing impairments affect speech A3. background noise affects self-monitoring the speech A4. if your speech pathway is used for other purpose or 'blocked' (e.g. mouth covered) A5. mobility or neurological problems
	listen, hear	understand	R1. non-native listener R2. hearing impairments affect understanding / listening R3. environmental conditions (background noise, distance, reverberation (echo)) affects understanding / listening R4. if your hearing pathway is used for other purpose or blocked
	lip read	understand	R5. non-native lip-reader R6. hearing impairments can affect lip-reading (language skills and knowledge) if your eyes are used for other purposes R7. environmental conditions affects lip-reading (background lighting (e.g. too bright or too dark), distance, fog) R8. if your eyes are used for other purposes or pathway between speaker's mouth / face and lip reader's eyes 'blocked' (e.g. speaker's mouth covered up) R9. visual impairment can affect lip-reading
write		communicate	A6. non-native writer A7. hearing impairments can affect writing (language skills and knowledge) A8. environmental conditions affects writing (background lighting (e.g. too bright or too dark), distance, fog) A9. if your eyes are used for other purposes or pathway between written text and reader's eyes 'blocked' (e.g. object in the path) A10. visual impairment can affect writing A11. specific learning disability (e.g. dyslexia) can affect writing
	read	understand	R10. non-native reader R11. hearing impairments can affect reading (language skills and knowledge) R12. environmental conditions affects reading (background lighting (e.g. too bright or too dark), distance, fog) R13. if your eyes are used for other purposes or pathway between written text and reader's eyes 'blocked' (e.g. object in the path) R14. visual impairment can affect reading R15. specific learning disability (e.g. dyslexia) can affect reading
sign language expression		communicate	A12. non-native signer A13. mobility problems A14. if your signing pathway is used for other purpose or 'blocked' (e.g. driving)
	sign language reception	understand	R16. non-native signer R17. visual impairment can affect sign language reception R18. if your eyes are used for other purposes or pathway between signer and receiver's eyes 'blocked' (e.g. object in the path)

Table 11-4 An extended list of actions, reactions and issues (continued)

Actions	**Reactions**	**Intentionality**	**Possible issues / problems / expressions & disabilities affecting actions**
touch / press / move / hold		control	A15. mobility problems affect movement A16. Sensory / nerve problems affect feeling / touch A17. visual impairment can affect finding / navigating / recognising A18. not allowed to touch (e.g. museum statue) A19. moves too fast to touch (e.g. fish)
navigate		find something or somewhere	A20. visual impairment can affect finding / navigating / recognising
walk, climb,		move whole body	A21. visual impairment can affect finding / navigating / recognizing A22. mobility problems affect movement

11.2.5 Clarify Environmental Interaction Issues

Future work may be needed to explain more clearly in the TEIF Method about the impact of hard surfaces and reverberation (section 9.2.3).

11.2.6 Designing Technology Solutions

It would be valuable and useful to establish through future experiment or case study how the whole TEIF Method would be helpful for designing technology solutions (section 9.6).

11.2.7 Designing Healthcare Technology Solutions

The TEIF has the potential to make a contribution to healthcare technologies, a growing area of interest involving technology interactions with elderly and disabled people. For example, one of the four main strategic priorities of the Engineering and Physical Sciences Research Council theme ‘Healthcare Technologies’ is technologies for a healthy life-course including tools for self-management of health and technologies aimed at retaining and restoring personal function and retaining mobility and independence (EPSRC, 2014)

Also the President of the European Commission, Barroso (2013) stated ‘We also need to grasp the opportunities offered by digital technology E-health solutions, such as tele-consultations and tele-monitoring’.

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Appendix A. Technology Suggestion Tables

Table 0-1 Technology Suggestion Table 1

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
1. Mobile web site	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network. For more information about basic guideline mobile web practice:http://www.w3.org/TR/mobile-bp/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
2. Pre-prepared caption/subtitle	Captions are text versions of the spoken word. Captions allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. More information about captions see: http://webaim.org/techniques/captions/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
3. Frequently asked questions (FAQ)	FAQ are listed questions and answers, all supposed to be commonly asked in some context, and pertaining to a particular topic. It is very useful for the presenter who communicates with hearing impaired people because they can send the pre-prepared answers to the audience in case the questions that they ask match the FAQ. For more information about FAQ see: http://en.wikipedia.org/wiki/FAQ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
4. Quick Response Code (QR-code)	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special scanner to scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information. For more information about QR codes see: http://www.whatisaqrcode.co.uk/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
5. Instant messaging	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Instant_messaging	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	15
6. Short Message Service (SMS)	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Short_Message_Service	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	15

Table 0-2 Technology Suggestion Table 2

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
7. Vibrating alert	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone. For more information about vibrating alert see: **http://en.wikipedia.org/wiki/Vibrating_alert**	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	15
8. Barcode	Barcodes originally require a special reader to access them but later scanners and interpretive software became available on smartphone devices. There needs to be line of sight between the barcode and the reader. For more information about barcodes see: **http://www.britannica.com/EBchecked/topic/52455/bar-code**	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	15
9. Augmented Reality (AR)	AR is a virtual technology which enhances users' interests by imposing virtual objects on the real environment. Content can be viewed in 2D or 3D, and the object can be shown in different perspectives. The AR application which includes a display screen and a camera, is normally viewed using a browser. Augmented reality applications can enhance a user's experience when traveling by providing real time informational displays regarding a location and its features, including comments made by previous visitors of the site. AR applications allow tourists to experience simulations of historical events, places and objects by rendering them into their current view of a landscape. AR applications can also present location information by audio, announcing features of interest at a particular site as they become visible to the user. AR systems can interpret foreign text on signs and menus and, in a user's augmented view, re-display the text in the user's language. Spoken words of a foreign language can be translated and displayed in a user's view as printed subtitles For more information about Augmented Reality see:**http://en.wikipedia.org/wiki/Augmented_reality**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	15
10. Radio frequency identification (RFID)	RFID is a radio technology which can be read by an RFID receiver automatically with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can't determine which item the user is browsing. The RFID tags are clearly to show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content. For more information about RFID see:**http://cdn.intechopen.com/pdfs/31056/InTech-Using_rfid_nfc_and_qr_code_in_mobile_phones_to_link_the_physical_and_the_digital_world.pdf**	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	14
11. Induction Loop	Induction Loop systems utilize electromagnetic energy to transmit the signal. These systems can cover a small area with a loop placed under a rug or may be permanently installed within the walls or ceiling of larger areas. For individuals to access this type of technology, they must have a Telecoil (t-coil) within their hearing aids. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about induction loop see: **http://soundinduction.co.uk/media/PDFs/Signet_induction_loop_system_guide.pdf**	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13

Table 0-3 Technology Suggestion Table 3

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
12. Hearing Aid	A hearing aid is designed to provide for an individual's preferences, degree and configuration of hearing loss. For more information about hearing aids see: **http://www.actiononhearingloss.org.uk/your-hearing/need-hearing-aids.aspx**	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13
13. FM Systems	FM or Frequency Modulation systems, the sound is transmitted on a specific frequency or channel similar to a radio. FM systems can be used for whole rooms or by individuals. Large areas can be set up with single or multiple speakers depending on the size of the room. These systems can be permanently installed in a given location or there are also several versions that are portable. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about FM see:**http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx**	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13
14. Cochlear implant	A cochlear implant is a surgically-implanted device that converts sound energy into electrical stimuli that can be processed by the auditory nerve. For more information about cochlear implant see:**http://www.actiononhearingloss.org.uk/your-hearing/about-deafness-and-hearing-loss/cochlear-implants.aspx**	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✓	✗	12
15. Pen and paper	When other methods are not available writing may be an option for communicating with hearing impaired people.	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✗	12
16. Flashing light	A flashing light alert gets attention of hearing impaired people normally only used for room lights as need to get attention whether person is looking. Normally used for room lighting only off-line. High cost wireless systems are becoming available.	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓	✓	12
17. Speech recognition	The captioning is performed by an operator, using an electronic stenotype keyboard or more often, speech recognition revoicing by human operating using speech recognition software to transcribe into text. No training required for users. Speech recognition can help clarify missing words but sometimes make errors. If there is noise or some other sound in the room, the number of errors will increase. Speak recognition works best if the microphone is close to the user (e.g. in a phone or if the user is wearing a microphone). More distance microphones will tend to increase the number of errors. For more information about live captions see guideline 1.2.4 Captions (Live) – W3C:**http://www.w3.org/TR/UNDERSTANDING-WCAG20/media-equiv-real-time-captions.html**	✓	✓	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	12
18. Internet Protocol Relay	The deaf and hard of hearing person uses their computer to connect with an IP relay service. The operator places the call, identifies themselves and the relay service, and facilitates the exchange of information through text and voicing. More accurate than speech recognition but slower. For more information see:**http://en.wikipedia.org/wiki/Telecommunications_device_for_the_deaf** Captioned telephones display real-time captions of the current conversation. The captions are typically displayed on a screen embedded into the telephone base. A web version is available. For more information about captioned telephone see:**http://www.nad.org/issues/telephone-and-relay-services/relay-**	✓	✓	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✗	✓	11

Table 0-4 Technology Suggestion Table 4

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
19. Infrared Systems	These systems utilize light waves to transmit sound from the transmitter to a special light sensitive receiver which can be mobile. There must be a clear line of connection between the transmitter and receiver so that the light signal is not interrupted. These systems can be sensitive to external light sources or interfering objects. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about Infrared see: **http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx**	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	11
20. Voice Carry Over (VCO)	VCO relay is an option for people who can speak clearly, but have hearing loss significant enough to prevent them from hearing and understanding conversations over the telephone. Using VCO relay and a specially designed telephone with a text display, a VCO user can speak directly to the other person on the call. A communication assistant (CA) types what is spoken by the other person for the VCO user to read. For more information about Voice Carry Over see: **http://mn.gov/commerce/images/Voice-Carry-Over-Brochure.pdf**	✓	✗	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✗	✓	10
21. Computer with camera/ smartphone	Many individuals utilise the combination of a web camera and computer Internet service to be able to visually connect with others. Deaf or hard of hearing callers can communicate through sign language via a video phone e.g. Skype via smart phones or computer with webcam. It also would allow disabled people unable to climb stairs to interact with objects and communicate with people who might be upstairs.	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	0
22. Video Relay Service	Video relay service can be accessed to allow the sign language user to call other hearing people with the assistance of an operator. They then proceed to voice interpret the signed message from the caller. They are also able to convert the voice message into sign language for the deaf or hard of hearing person. For more information about Video Relay Service see: **http://en.wikipedia.org/wiki/Video_relay_service**	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	0

Appendix B. Explanation for the ticks and crosses

Table 0-5 Explanation for Mobile Web Technology

Mobile Website	**Explanations**	**Description**
1a improve communication	displays captions	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network. For more information about basic guideline mobile web practice: http://www.w3.org/TR/mobile-bp/
2a. same time / same place	People control and read captions.	
3a. presenter –audience	Presenter controls captions.	
6b. speaker speaks Thai	can display in Thai	
7b. audience speak Thai	can display in Thai	
9a.Audience have hearing impairments	can read captions	
11a. people to people	control and read captions	
11b. people to objects	display information from QRcodes	
12a. online technology	works online	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	displays captions	
16a. indoors	works indoors	
17a. noise	displays captions	
17e. inadequate lighting	can read in the dark	
18a. low cost solution	low cost and uses audience devices	
19a. work on smartphone	works on smartphones	

Table 0-6 Explanation for Pre-prepared captions

Pre-prepared captions	**Explanations**	**Description**
1a improve communication	displays captions	Captions are text versions of the spoken word. Captions allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. More information about captions see: http://webaim.org/techniques/captions/
2a. same time / same place	controls and reads captions	
3a. presenter –audience	Presenter controls captions.	
6b. speaker speaks Thai	can display in Thai	
7b. audience speak Thai	can display in Thai	
9a. Audience have hearing impairments	can read captions	
11a. people to people	control and read captions	
11b. people to objects	display information from QR-codes	
12a. online technology	works online	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	displays captions	
16a. indoors	works indoors	
17a. noise	displays captions	
17e. inadequate lighting	can read on backlit screens	
18a. low cost solution	relatively cheap	
19a. work on smartphone	can display on smartphones	

Table 0-7 Explanation for Instant Messaging

Instant Messaging	**Explanations**	**Description**
1a improve communication	displays text	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Instant_messaging
2a. same time / same place	works in real time	
3a. presenter –audience	sends and receives messages	
6b. speaker speaks Thai	can type in Thai	
7b. audience speak Thai	can type and read in Thai	
9a. Audience have hearing impairments	can type and read text	
11a. people to people	type and read text	
11b. people to objects	Objects can't type or read text	
12a. online technology	works online	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	also works with unplanned speech	
16a. indoors	works indoors	
17a. noise	vibrates to notify and display text	
17e. inadequate lighting	can read in the dark on backlit devices	
18a. low cost solution	can display on audience devices	
19a. work on smartphone	works on smartphones	

Table 0-8 Explanation for Short Message Service (SMS)

Short Message Service (SMS)	**Explanations**	**Description**
1a improve communication	displays text	SMS is a text messaging service component of phone, web, or mobile communication systems, using standardized communications protocols that allow the exchange of short text messages between fixed line or mobile phone devices is used as a synonym for all types of short text messaging. For more information see: http://en.wikipedia.org/wiki/Short_Message_Service 15
2a. same time / same place	works in real time	
3a. presenter –audience	send and receive messages	
6b. speaker speaks Thai	can type in Thai	
7b. audience speak Thai	can type and read in Thai	
9a. Audience have hearing impairments	notifies by vibration and read text	
11a. people to people	type and read text	
11b. people to objects	Objects can't type or read text	
12a. online technology	works online	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	also works with unplanned speech	
16a. indoors	works indoors	
17a. noise	notifies by vibration and displays text	
17e. inadequate lighting	can read in the dark on backlit devices	
18a. low cost solution	SMS are cheap	
19a. work on smartphone	works on smartphones	

Table 0-9 Explanation for Induction Loop

Induction Loop	Explanations	Description
1a improve communication	amplifies sound	Induction Loop systems utilize electromagnetic energy to transmit the signal. These systems can cover a small area with a loop placed under a rug or may be permanently installed within the walls or ceiling of larger areas. For individuals to access this type of technology, they must have a Telecoil (t-coil) within their hearing aids. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about induction loop see: http://soundinduction.co.uk/media/PDFs/Signet_induction_loop_system_guide.pdf
2a. same time / same place	amplifies sound	
3a. presenter –audience	Audience use to amplify sound from presenter.	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	amplifies sound	
11a. people to people	amplifies sound	
11b. people to objects	not relevant	
12a. online technology	not using Internet	
13a. mobile devices	uses person's own hearing aid	
14a. presenter planned what to say	amplifies sound weather planned or not	
16a. indoors	works indoors	
17a. noise	amplifies speech more than noise	
17e. inadequate lighting	works in the dark	
18a. low cost solution	cheaper than Infrared or FM system	
19a. work on smartphone	used hearing aid	

Table 0-10 Explanation for Hearing Aid

Hearing Aid	Explanations	Description
1a. improve communication	amplifies sound	A hearing aid is designed to provide for an individual's preferences, degree and configuration of hearing loss. For more information about hearing aids see: http://www.actiononhearingloss.org.uk/your-hearing/need-hearing-aids.aspx
2a. same time / same place	amplifies sound	
3a. presenter –audience	Audience use to amplify sound from a presenter.	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	amplifies sound	
11a. people to people	amplifies sound	
11b. people to objects	not relevant	
12a. online technology	not using Internet	
13a. mobile devices	Hearing aid is a mobile device.	
14a. presenter planned what to say	amplifies sound weather planned or not	
16a. indoors	works indoors	
17a. noise	amplifies sound	
17e. inadequate lighting	works in the dark	
18a. low cost solution	uses audience devices	
19a. work on smartphone	needs hearing aid	

Table 0-11 Explanation for Speech Recognition

Speech Recognition	**Explanations**	**Description**
1a. improve communication	displays captions	The captioning is performed by an operator, using an electronic stenotype keyboard or more often, speech recognition revoicing by human operating using speech recognition software to transcribe into text. No training required for users. Speech recognition can help clarify missing words but sometimes make errors. If there is noise or some other sound in the room, the number of errors will increase. Speak recognition works best if the microphone is close to the user (e.g. in a phone or if the user is wearing a microphone). More distance microphones will tend to increase the number of errors. For more information about live captions see guideline 1.2.4 Captions (Live) – http://www.w3.org/TR/UNDERSTANDING-WCAG20/media-equiv-real-time-captions.html
2a. same time / same place	works in real time	
3a. presenter –audience	Audience read captions as a presenter speaks	
6b. speaker speaks Thai	current Thai systems inaccurate	
7b. audience speak Thai	current Thai systems inaccurate	
9a. Audience have hearing impairments	can read captions but inaccurate	
11a. people to people	control and read captions but inaccurate	
11b. people to objects	Objects don't speak	
12a. online technology	work online but more accurate on desktop devices	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	also work with spontaneous speech	
16a. indoors	works indoors	
17a. noise	doesn't work well in noise	
17e. inadequate lighting	works in the dark	
18a. low cost solution	apps on smartphones	
19a. work on smartphone	works on smartphones	

Table 0-12 Explanation for Vibrating alert

Vibrating alert	**Explanations**	**Description**
1a. improve communication	notifies or gets attention	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone. For more information about vibrating alert see: http://en.wikipedia.org/wiki/Vibrating_alert
2a. same time / same place	notifies or gets attention	
3a. presenter –audience	Presenter notifies captions of change of captions.	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	notifies change in captions	
11a. people to people	control and notify change in captions	
11b. people to objects	Object doesn't notify	
12a. online technology	works online	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	notifies change in captions	
16a. indoors	works indoors	
17a. noise	can feel vibration	
17e. inadequate lighting	works in the dark	
18a. low cost solution	uses audience devices	
19a. work on smartphone	works on smartphones	

Table 0-13 Explanation for Radio frequency identification (RFID)

Radio frequency identification (RFID)	**Explanations**	**Description**
1a. improve communication	displays information	RFID is a radio technology which can be read by an RFID receiver automatically with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can't determine which item the user is browsing. The RFID tags are clearly to show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content. For more information about RFID see: http://cdn.intechopen.com/pdfs/31056/InTechUsing_rfid_nfc_and_qr_code_in_mobile_phones_to_link_the_physical_and_the_digital_world.pdf
2a. same time / same place	links to and reads information	
3a. presenter –audience	Presenter tells audience to use RFID reader	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	displays text	
11a. people to people	Presenter tells audience to use RFID reader	
11b. people to objects	scans and reads further information	
12a. online technology	can work online but not common	
13a. mobile devices	can use mobile reader	
14a. presenter planned what to say	pre-prepared information	
16a. indoors	works indoors	
17a. noise	works in noise	
17e. inadequate lighting	can read in the dark on backlit devices	
18a. low cost solution	require RFID reader	
19a. work on smartphone	require RFID reader	

Table 0-14 Explanation for Barcode

Barcode	**Explanations**	**Description**
1a. improve communication	can display information	Barcodes originally require a special reader to access them but later scanners and interpretive software became available on smartphone devices. There needs to be line of sight between the barcode and the reader. For more information about barcodes see: http://www.britannica.com/EBchecked/topic/52455/bar-code
2a. same time / same place	links to and reads information	
3a. presenter –audience	Presenter tells audience to scan and send information	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	can scan and read information	
11a. people to people	scan and read information	
11b. people to objects	scan barcodes and read information	
12a. online technology	can link to information on the Internet but not store URL only an ID number	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	send the link to website which display pre-prepared captions	
16a. indoors	works indoors	
17a. noise	works in noise	
17e. inadequate lighting	works in the dark but needs backlit display	
18a. low cost solution	can use smartphones as a barcodes reader	
19a. work on smartphone	Work on smartphones	

Table 0-15 Explanation for Quick Response Code (QR-code)

Quick Response Code (QR-code)	**Explanations**	**Description**
1a. improve communication	can display information	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special scanner to scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information. For more information about QR codes see: http://www.whatisaqrcode.co.uk/
2a. same time / same place	links to and reads information	
3a. presenter –audience	Presenter tells audience to scan and readinformation	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in Thai language	
9a. Audience have hearing impairments	scans QR-codes and reads information	
11a. people to people	Presenter tells audience to scan and read captions	
11b. people to objects	scan and read further information	
12a. online technology	normally require Internet	
13a. mobile devices	works on mobile devices	
14a. presenter planned what to say	pre-prepared information	
16a. indoors	works indoors	
17a. noise	works in noise	
17e. inadequate lighting	can read in the dark on backlit devices	
18a. low cost solution	uses audience devices	
19a. work on smartphone	works on smartphones	

Table 0-16 Explanation for FM Systems

FM Systems	**Explanations**	**Description**
1a. improve communication	amplifies sound	FM or Frequency Modulation systems, the sound is transmitted on a specific frequency or channel similar to a radio. FM systems can be used for whole rooms or by individuals. Large areas can be set up with single or multiple speakers depending on the size of the room. These systems can be permanently installed in a given location or there are also several versions that are portable. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about FM see: http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx
2a. same time / same place	amplifies sound	
3a. presenter –audience	Presenter amplify sound to audience	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	Amplifies sound	
11a. people to people	Amplifies sound	
11b. people to objects	not relevant	
12a. online technology	not using Internet	
13a. mobile devices	needs special technology	
14a. presenter planned what to say	amplifies sound weather planned or not	
16a. indoors	works indoors	
17a. noise	amplifies speech more than noise	
17e. inadequate lighting	works in the dark	
18a. low cost solution	requires FM Systems	
19a. work on smartphone	requires FM Systems	

Table 0-17 Explanation for Infrared Systems

Infrared Systems	**Explanations**	**Description**
1a. improve communication	amplifies sound	These systems utilize light waves to transmit sound from the transmitter to a special light sensitive receiver which can be mobile. There must be a clear line of connection between the transmitter and receiver so that the light signal is not interrupted. These systems can be sensitive to external light sources or interfering objects. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about Infrared see: http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx
2a. same time / same place	amplifies sound	
3a. presenter –audience	Presenter amplifies sound to audience	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	amplifies sound	
11a. people to people	amplifies sound	
11b. people to objects	not relevant	
12a. online technology	not using Internet	
13a. mobile devices	needs special technology	
14a. presenter planned what to say	amplify sound weather planned or not	
16a. indoors	works indoors but the signal cannot pass through walls	
17a. noise	amplifies sound	
17e. inadequate lighting	works in the dark	
18a. low cost solution	expensive	
19a. work on smartphone	needs special technology	

Table 0-18 Explanation for Flashing light

Flashing light	**Explanations**	**Description**
1a. improve communication	notifies or gets attention	A flashing light alert gets attention of hearing impaired people normally only used for room lights as need to get attention whether person is looking. Normally used for room lighting only off-line. High cost wireless systems are becoming available.
2a. same time / same place	Notifies or gets attention	
3a. presenter –audience	Presenter notifies or gets attention from audience	
6b. speaker speaks Thai	works in any language	
7b. audience speak Thai	works in any language	
9a. Audience have hearing impairments	notifies or gets attention	
11a. people to people	notifies or gets attention	
11b. people to objects	Objects don't notify.	
12a. online technology	normally uses for room lighting	
13a. mobile devices	normally uses for room lighting	
14a. presenter planned what to say	not relevant	
16a. indoors	works indoors if not too bright sunshine	
17a. noise	works in noise	
17e. inadequate lighting	works well in the dark	
18a. low cost solution	low cost technology	
19a. work on smartphone	works on smartphone	

Appendix C. Printed Online Questionnaire for Developer Experts Validation and Review

Participant Information Sheet (Developer Experts)

Study Title: Evaluation of the Technology Enhanced Interaction Framework and tool process
Researcher: Kewalin Angkananon
Ethics number: 4865
Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to signify consent on isurvey.

What is the research about?
The purpose of this study is to evaluate the Technology Enhanced Interaction Framework and associated tool which can help people design technology enhanced interactions particularly in complex situations involving disabled people. This evaluation is to be achieved by asking participants questions about the materials presented.

Why have I been chosen?
You have been approached to participate in this study because you are a technology developer (the term developer will be used to mean designer / developer) who has relevant knowledge.

What will happen to me if I take part?
You will be asked to look at the Technology Interaction Framework and answer some questions about it. You will be asked to read and evaluate a scenario and answer questions about requirements and then comment on the feedback provided. You will be asked whether you understand the suggestions offered by the tool and would find them useful. You will then be asked to check whether you understand the example solution and associated diagrams. You will be asked if you can follow the explanation of how the solution was derived. Finally, you will be asked to comment on the framework.

Are there any benefits in my taking part?
By taking part, you have the opportunity to assist the development of a new method to help design technology in complex situations involving disabled people.

Are there any risks involved?
There is no risk involved in taking part in this study. It is important to note that you are welcome to pause for a rest, or fully withdraw from the study, at any time.

Will my participation be confidential?
Yes. Your personal details will not be included on any written materials which you are asked to provide.

What happens if I change my mind?
You have the right to withdraw at any time without your legal rights being affected.

What happens if something goes wrong?
If you have a concern or complaint, please contact the ECS School Office on school@ecs.soton.ac.uk or school@ecs.soton.ac.uk02380 592909.

Where can I get more information?
Feel free to get in touch with Kewalin Angkananon: ka3e10@ecs.soton.ac.uk

Evaluation of The Technology Enhanced Interaction Framework: Developer Experts

You can go back to previous pages and questions but if you are going away from the computer for a few hours we suggest you select "save and quit" and return to complete your survey later by using the username and password isurvey displays (copy these down before selecting the log in link) or by following the original link sent to you in the email.

Section 1. Name

Question 1.1
Please provide your name:

Section 2. The Technology Enhanced Interaction Framework

Please read the Technology Enhanced Interaction Framework and then answer the following questions. The numbers after the sub-components refer to the requirements relevant to the technology solution for the scenario you will be given in the next section. Some sub-components do not have numbers because they are not relevant to the particular solution for the scenario presented.

Table 0-19 Technology Enhanced Interaction Framework

Main Component of Technology Enhanced Interaction Framework		
Main Component	**Sub-component**	**Example**
People	Role (3, 4, 11)	A person has a role when communicating with others (e.g. presenter, audience, peer).Roles normally come in pairs such as speaker and audience (e.g. teacher and student or owner and visitor) and peer to peer (e.g. student to student or visitor to visitor).
	Ability / disability (5, 6, 7, 8, 9, 10)	People have abilities and disabilities which can affect their use of technology or understanding of language and which can lead to communication or interaction breakdown (e.g. physical, sensory, language, culture, communication, Information Technology (IT)).
Objects	Dimension	Objects have 2 dimensions (2D) or 3 dimensions (3D), and a 3D object may have a 2D representation.
	Property	Objects have colour, shape and size.
	Content (15)	Objects have content which is human readable (text, pictures, audio, video) and machine readable (QR code, AR tag, barcode, RFID tag, NFC).
Technology	Electronic (12, 13, 19)	Electronic technology has stored information, is online (e.g. internet, phone network) or offline (e.g. not connected to the internet or phone network), and is mobile (e.g. smartphone) or non-mobile (e.g. desktop computer).
	Non-electronic	Non-electronic technology is used to store information in objects (e.g. writing with a pen on paper) and is mobile (e.g. pen) or non-mobile (e.g. full-size desktop typewriter).
	User Interface	People interact with technology through its user interface (e.g. touch screen, keyboard).
	Application or service (14)	Electronic technology is an application (e.g. dictionary) or a service (e.g. weather forecast).
	Cost	Technology has cost (e.g. of hardware, software, maintenance).
Interactions and communication	People-People (P-P) (11)	People communicate verbally (speak, listen, ask, answer) and non-verbally (lip-read, smile, touch, sign, gesture, nod). When communicating, people may refer (speak or point) to particular objects or technology – this is known as deixis.
	People-Objects (P-O) (11)	People interact with objects for two main purposes: controlling (e.g. touch, hold or move), and retrieving information (e.g. look, listen, read, in order to get information or construct personal understanding and knowledge).
	People-Technology (P-T) (11)	People control technology (e.g. hold, move, use, type, scan, make image, press, swipe) and transmit and store information (e.g. send, save, store, search, retrieve).
	People-Technology-People (P-T-P) (11)	People use technology (e.g. send sms, mms, email, chat, instant message) to transmit information to assist communication with other people.
	People-Technology-Objects (P-T-O) (11)	People use technology (e.g. point, move, hold, scan QR codes, scan AR tag, use camera, use compass) to transmit, store, and retrieve information (send, save, store, search, retrieve) to, in, and from objects.
Time/Place	Time (2)	Same and different time and place yield four categories: same time and same place (ST/SP), different time and same place (DT/SP), different time and different place (DT/DP), same time but different place (ST/DT).
	Place (2)	
Context	Location (16)	Location affects the use of technology (e.g. indoors, outdoors). For example GPS does not work well indoors.
	Weather condition (17)	Weather condition may affect the use of technology (e.g. rainy, cloudy, sunny, windy, hot, cold, dry, wet). For example, the mobile phone screen doesn't work well in sunshine.
	Signal type and quality	Signal type can affect the quality of electronic technology (e.g. broadband, GPS, 3G, 4G).
	Background Noise (17)	Background noise can affect the communication particularly for hearing impaired people (e.g. background music, crowded situation).
	Lighting (17)	Light can affect the interaction (e.g. Inadequate light, too bright).
Interaction layer	Culture (6, 7)	Cultural layer includes countries, traditional, language and gesture (e.g. "hello" is a normal greeting used in the culture).
	Intentionality (1)	Intention layer involves understanding, purpose and benefit (e.g. the intent is a greeting).
	Knowledge	Knowledge layer involves facts, concepts, procedures, and principles (e.g. how to spell the word "hello").
	Action	Action layer involves actions and behaviours (e.g. pressing the correct key and not hitting neighbouring keys).
	Expression	Expression layer describes how actions are carried out (e.g. whether action is correct, accurate, prompt).
	Physical	Physical layer is the lowest layer at which people interact with the physical world (e.g. the button is depressed and so sends the electronic code for the letter to the application).

Question 2.1

Are the instructions clear?

- a. Yes
- b. No

Question 2.2

How can they be improved?

Question 2.3

Are the examples and explanations clear?

- a. Yes
- b. No

Question 2.4

How can they be improved?

Question 2.5

Do you agree with the main components and sub-components of the framework?

- a. Yes, I agree
- b. No, I do not agree.

Question 2.6

How can they be improved?

TEIF Method

Section 3. Evaluate the Scenario, Questions, and Answers

Please read and analyse the following scenario which should provide all the information required for you to be able to answer the following questions which are based on the Technology Enhanced Interaction Framework. After you answer each question, what we think is the correct answer and an explanation will be presented to you (There will be a slight delay while the system processes your answers). You will be asked to suggest improvements to the questions, answers and explanations. The answers to the questions will help determine the requirements of the technology solution for the scenario. The requirement numbers were shown next to the sub-components in the table in the previous section and are also used in the Technology Suggestions tables in the following sections.

Suchat Trapsin allocated some parts of his house to become the Museum of Folk Art and Shadow Puppets, in Thailand. There are exhibits of shadow puppets inside the museum, but there is no information provided in text format. This is because Suchat normally explains the history and tradition in Thai by talking to visitors. He presents the same information in the same order every time.

On Friday afternoon, Chuty (who has been hearing impaired since birth) and her parents (who have some hearing loss due to their age), who are local people, visit the museum. Suchat starts the talk by explaining about the exhibits. During the talk, Chuty and her parents find that it is very difficult to hear Suchat clearly. Chuty asks Suchat some questions about the exhibits. Suchat answers the questions, but Chuty misses some of the words. While Chuty and her parents are watching the shadow puppet show, they also cannot hear the conversation clearly because of the background music which is part of the show. It is also fairly dark which makes lip-reading very difficult for them.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him. There is good Wi-Fi at the museum so he would like to use Chuty's and her parents' smartphones to keep his costs low.

Question 3.1

Are the instructions clear?

- a. Yes
- b. No

Question 3.2

How can they be improved?

Question 3.3

What is the main purpose of the technology solution? (*Requirement 1)*

- a. improve communication and interaction
- b. make the service more interesting and exciting
- c. improve the service efficiency in terms of time and ease of use
- d. improve the storage and retrieval of information
- e. make the service more realistic and authentic
- f. improve users' experiences in using the service

Question 3.3b

We agree.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him.

Question 3.3c

We think the answer is "a. improve communication".

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him.

Question 3.4

How can this question and multiple choices offered be improved?

Question 3.5

How can this answer and explanation be improved?

Question 3.6

Where and when does the scenario take place? (*Requirement 2)*

- a. same time / same place
- b. same time / different place
- c. different time / same place
- d. different time / different place

Question 3.6b

We agree.

Suchat, Chuty, and her parents are in the same place (The Museum of Folk Art and Shadow Puppets, Thailand) and at the same time (Friday afternoon).

Question 3.6c

We think the answer is "a. same time / same place".

Suchat, Chuty, and her parents are in the same place (The Museum of Folk Art and Shadow Puppets, Thailand) and at the same time (Friday afternoon).

Question 3.7

How can this question and multiple choices offered be improved?

Question 3.8

How can this answer and explanation be improved?

Question 3.9

What main role do people have in the scenario? (*Requirement 3)*

a. presenter - audience (the presenter gives information to the "audience" which could be only one person or many people and so controls the interaction. The audience can ask the presenter questions)

b. peer - peer (any person can give information or ask questions to any other person and therefore no one person controls interaction)

c. no communication between people only interaction with technology or objects

Question 3.9b

We agree.

The "presenter" (Suchat) talks to the "audience" (Chuty and her parents) and the audience ask the presenter questions.

Question 3.9c

We think the answer is "a. presenter - audience".

The "presenter" (Suchat) talks to the "audience" (Chuty and her parents) and the audience ask the presenter questions.

Question 3.10

How can this question and multiple choices offered be improved?

Question 3.11

How can this answer and explanation be improved?

Question 3.12

How many presenters and audience members are there? (*Requirement 4)*

a. one presenter – one audience member

b. one presenter – many audience members

c. many presenters – one audience member

d. many presenters – many audience members

Question 3.12b

We agree.

Suchat is a person who gives the information (one presenter) to Chuty and her parents (many audience members).

Question 3.12c

We think the answer is "**b. one presenter – many audience members".**

Suchat is a person who gives the information (one presenter) to Chuty and her parents (many audience members).

Question 3.13

How can this question and multiple choices offered be improved?

Question 3.14

How can this answer and explanation be improved?

Question 3.15

Does the presenter have a disability? (*Requirement 5)*

a. Yes

b. No

Question 3.15b

We agree.

Suchat doesn’t have any disability.

Question 3.15c

We think the answer is "b. No".

Suchat doesn’t have any disability.

Question 3.16

How can this question and multiple choices offered be improved?

Question 3.17

How can this answer and explanation be improved?

Question 3.18

What language does the presenter use? (*Requirement 6)*

- a. English
- b. Thai
- c. other language
- d. I don’t know

Question 3.18b

We agree.

Suchat talks to Chuty and her parents in Thai.

Question 3.18c

We think the answer is b. Thai.

Suchat talks to Chuty and her parents in Thai.

Question 3.19

How can this question and multiple choices offered be improved?

Question 3.20

How can this answer and explanation be improved?

Question 3.21

What language does the audience use? (*Requirement 7)*

- a. English
- b. Thai
- c. other language
- d. I don't know

Question 3.21b

We agree.

Chuty and her parents are local people who live in Thailand.

Question 3.21c

We think the answer is "b. Thai".

Chuty and her parents are local people who live in Thailand.

Question 3.22

How can this question and multiple choices offered be improved?

Question 3.23

How can this answer and explanation be improved?

Question 3.24

Does the audience have a disability? (*Requirement 8)*

- a. Yes
- b. No

Question 3.24b

We agree.

Chuty and her parents have a disability.

Question 3.24c

We think the answer is "a. Yes".

Chuty and her parents have disabilities as otherwise.

Question 3.25

How can this question and multiple choices offered be improved?

Question 3.26

How can this answer and explanation be improved?

Question 3.27

What kind of disability do the audience have? (*Requirement 9)*

- a. hearing impaired
- b. visually impaired
- c. physically impaired
- d. none

Question 3.27b

We agree.

Chuty has had hearing impairment at birth and her parents have hearing loss due to their age.

Question 3.27c

We think the answer is "a. hearing impaired".

Chuty has had hearing impairment at birth and her parents have hearing loss due to their age.

Question 3.28

How can this question and multiple choices offered be improved?

Question 3.29

How can this answer and explanation be improved?

Question 3.30

What level of hearing loss does the audience have? (*Requirement 10)*

- a. mild or moderate hearing loss
- b. severe or profound hearing loss
- c. I don't know

Question 3.30b

We agree.

There is no detailed information about the level of hearing loss of audience members in the scenario

Question 3.30c

We think the answer is "c. I don't know".

There is no detailed information about the level of hearing loss of audience member in the scenario.

Question 3.31

How can this question and multiple choices offered be improved?

Question 3.32

How can this answer and explanation be improved?

Question 3.33

What two interaction types occur in the scenario? (*Requirement 11)*

- a. people to people
- b. people to objects
- c. people to technology

- d. people to technology to people
- e. people to technology to objects

Question 3.33b

We agree.

Suchat communicates with Chuty and her parents (people - people).
This is one of the two interaction types which occur in the scenario.

Question 3.33c

We agree.

Chuty and her parents watch the shadow puppet show (people - objects).
This is one of the two interaction types which occur in the scenario.

Question 3.33d

We think the answers are "a. people - people and b. people - objects".

Suchat communicates with Chuty and her parents (people - people).
Chuty and her parents watch the shadow puppet show (people - objects).

Question 3.34

How can this question and multiple choices offered be improved?

Question 3.35

How can this answer and explanation be improved?

Question 3.36

What type of technology would be appropriate for the solution to the scenario? (*Requirement 12)*

- a. online technology (Internet)
- b. off-line technology
- c. I do not know

Question 3.36b

We agree.

There is good Wi-Fi at the museum and Suchat would like to use Chuty's and her parents' smartphones.

Question 3.36c

We think the answer is "**a. online".**

There is good Wi-Fi at the museum and Suchat would like to use Chuty's and her parents' smartphones.

Question 3.37

How can this question and multiple choices offered be improved?

Question 3.38

How can this answer and explanation be improved?

Question 3.39

What type of technology devices would be appropriate for the solution to the scenario? (*Requirement 13)*

- a. mobile devices
- b. non-mobile devices
- c. I do not know

Question 3.39b

We agree.

Suchat would like to use Chuty's and her parents' smartphones.

Question 3.39c

We think the answer is "a. mobile devices".

Suchat would like to use Chuty's and her parents' smartphones.

Question 3.40

How can this question and multiple choices offered be improved?

Question 3.41

How can this answer and explanation be improved?

Question 3.42

Has the presenter planned what he wants to say? (*Requirement 14)*

- a. Yes
- b. No
- c. I do not know

Question 3.42b

We agree.

Suchat has already prepared what to talk to the visitors about (pre-prepared speech).

Question 3.42c

We think the answer is **"a. Yes".**

Suchat has already prepared what to talk to the visitors about (pre-prepared speech).

Question 3.43

How can this question and multiple choices offered be improved?

Question 3.44

How can this answer and explanation be improved?

Question 3.45

Are audios or videos shown in the scenario? (*Requirement 15)*

- a. audio
- b. video
- c. neither

Question 3.45b

We agree.

There is no audio or video information to be shown in the scenario. The music is just a background sound.

Question 3.45c

We think the answer is "c. neither".

There is no audio or video information to be shown in the scenario. The music is just a background sound.

Question 3.46

How can this question and multiple choices offered be improved?

Question 3.47

How can this answer and explanation be improved?

Question 3.48

Where does the situation take place? (*Requirement 16)*

- a. indoors
- b. outdoors
- c. I do not know

Question 3.48b

We agree.

Inside the museum **(**the Museum of Folk Art and Shadow Puppets**).**

Question 3.48c

We think the answer is "a. indoors".

Inside the museum **(**the Museum of Folk Art and Shadow Puppets**).**

Question 3.49

How can this question and multiple choices offered be improved?

Question 3.50

How can this answer and explanation be improved?

Question 3.51

What are the two main environmental considerations identified that impact the scenario? (*Requirement 17)*

a. noise (Background noise affects everyone's ability to hear and understand what is said. Noise has even greater impact on deaf and hard of hearing people because it tends to mask or cover over speech.)

b. room acoustics (Surface (walls windows tile) and objects within every room interact to produce reverberation in response to sound.)

c. distance (How far is the audience standing from the presenter? . The further a student is from the presenter or sound source the softer the sound they receive.)

d. visual access (How well can the audience see everything that is happening in different locations?)

e. lighting (Inadequate lighting or large banks of windows can be challenging for deaf or hard of hearing audience because they cannot see the speakers face well or an interpreter may be located in shadows)

Question 3.51b

We agree.

Chuty and her parents cannot hear the conversation clearly because of the music background ,which is part of the show.

This is one of the two environmental considerations that impact the scenario.

Question 3.51c

We agree.

It is fairly dark which makes lip-reading very difficult.

This is one of the two environmental considerations that impact the scenario.

Question 3.51d

We think the answers are "a. noise and e. inadequate lighting".

Chuty and her parents cannot hear the conversation clearly because of the music background ,which is part of the show, and it is also fairly dark which makes lip-reading very difficult.

Question 3.52

How can this question and multiple choices offered be improved?

Question 3.53

How can this answer and explanation be improved?

Question 3.54

Does the customer require a low cost solution? (*Requirement 18)*

- a. Yes
- b. No

Question 3.54b

We agree.

Suchat would like to use Chuty's and her parents' smartphones to keep his costs low.

Question 3.54c

We think the answer is "a. Yes".

Suchat would like to use Chuty’s and her parents’ smartphones to keep his costs low.

Question 3.55

How can this question and multiple choices offered be improved?

Question 3.56

How can this answer and explanation be improved?

Question 3.57

Should the technology solution work on a smart phone? (*Requirement 19)*

- a.Yes
- b. No

Question 3.57b

We agree.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him using their smartphones.

Question 3.57c

We think the answer is "a. Yes".

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him using their smartphones.

Question 3.58

How can this question and multiple choices offered be improved?

Question 3.59

How can this answer and explanation be improved?

Question 3.60

How can the scenario be improved to make it easier to answer the questions?

Question 3.61

Was it helpful to have the requirement numbers next to the sub-components in the Technology

Enhanced Interaction Framework table shown in the previous section?

- a. Yes
- b. No

Question 3.62

Is there a better way to show the relationship between the Technology Enhanced Interaction Framework and the requirement questions?

Question 3.63

Are there any questions, requirements, components or sub-components missing that would be relevant to the scenario?

Section 4. The Technology Suggestions: Table 1

Please read the technology suggestions and descriptions in Table 1. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Table 1 The Technology Suggestions

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
1. Mobile web site	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network. For more information about basic guideline mobile web practice:http://www.w3.org/TR/mobile-bp/	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	16
2. Pre-prepared caption/subtitle	Captions are text versions of the spoken word. Captions allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. More information about captions see: http://webaim.org/techniques/captions/	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	16
3. Frequently asked questions (FAQ)	FAQ are listed questions and answers, all supposed to be commonly asked in some context, and pertaining to a particular topic. It is very useful for the presenter who communicates with hearing impaired people because they can send the pre-prepared answers to the audience in case the questions that they ask match the FAQ. For more information about FAQ see: http://en.wikipedia.org/wiki/FAQ	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	16
4. Quick Response Code (QR-code)	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special scanner to scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information. For more information about QR codes see: http://www.whatisaqrcode.co.uk/	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	16
5. Instant messaging	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Instant_messaging	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔	✔	15
6. Short Message Service (SMS)	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org /wiki/Short_Message_Service	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔	✔	15

Question 4.1

Are the descriptions of the technologies in Table 1 clear?

- a. Yes
- b. No

Question 4.2

How can they be improved?

Question 4.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 1?

- a. Yes, I agree
- b. No, I do not agree

Question 4.4

Please explain

Section 5. The Technology Suggestions: Table 2

Please read the technology suggestions and descriptions in Table 2. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Table 2 The Technology Suggestions (continued)

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
7. Vibrating alert	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone. For more information about vibrating alert see: http://en.wikipedia.org/wiki/Vibrating_alert	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	15
8. Barcode	Barcodes originally require a special reader to access them but later scanners and interpretive software became available on smartphone devices. There needs to be line of sight between the barcode and the reader. For more information about barcodes see: http://www.britannica.com/EBchecked/topic/52455/bar-code	✓	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	15
9. Radio frequency identification (RFID)	RFID is a radio technology which can be read by an RFID receiver automatically with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can't determine which item the user is browsing. The RFID tags are clearly to show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content. For more information about RFID see:http://cdn.intechopen.com/pdfs/31056/InTech-Using_rfid_nfc_and_qr_code_in_mobile_phones_to_link_the_physical_and_the_digital_world.pdf	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	14
10. Induction Loop	Induction Loop systems utilize electromagnetic energy to transmit the signal. These systems can cover a small area with a loop placed under a rug or may be permanently installed within the walls or ceiling of larger areas. For individuals to access this type of technology, they must have a Telecoil (t-coil) within their hearing aids. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about induction loop see: http://soundinduction.co.uk/media/PDFs/Signet_induction_loop_system_guide.pdf	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13
11. Hearing Aid	A hearing aid is designed to provide for an individual's preferences, degree and configuration of hearing loss. For more information about hearing aids see: http://www.actiononhearingloss.org.uk/your-hearing/need-hearing-aids.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13
12. FM Systems	FM or Frequency Modulation systems, the sound is transmitted on a specific frequency or channel similar to a radio. FM systems can be used for whole rooms or by individuals. Large areas can be set up with single or multiple speakers depending on the size of the room. These systems can be permanently installed in a given location or there are also several versions that are portable. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about FM see:http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13

Question 5.1

Are the descriptions of the technologies in Table 2 clear?

- a. Yes
- b. No

Question 5.2

How can they be improved?

Question 5.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 2?

- a. Yes, I agree
- b. No, I do not agree

Question 5.4

Please explain

Section 6. The Technology Suggestions: Table 3

Please read the technology suggestions and descriptions in Table 3. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Table 3 The Technology Suggestions (continued)

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
13. Flashing light	A flashing light alert gets attention of hearing impaired people normally only used for room lights as need to get attention whether person is looking. Normally used for room lighting only off-line. High cost wireless systems are becoming available.	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓	✓	12
14. Speech recognition	The captioning is performed by an operator, using an electronic stenotype keyboard or more often, speech recognition revoicing by human operating using speech recognition software to transcribe into text. No training required for users. Speech recognition can help clarify missing words but sometimes make errors. If there is noise or some other sound in the room, the number of errors will increase. Speak recognition works best if the microphone is close to the user (e.g. in a phone or if the user is wearing a microphone). More distance microphones will tend to increase the number of errors. For more information about live captions see guideline 1.2.4 Captions (Live) –W3C:http://www.w3.org/TR/UNDERSTANDING-WCAG20/media-equiv-real-time-captions.html	✓	✓	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	12
15. Infrared Systems	These systems utilize light waves to transmit sound from the transmitter to a special light sensitive receiver which can be mobile. There must be a clear line of connection between the transmitter and receiver so that the light signal is not interrupted. These systems can be sensitive to external light sources or interfering objects. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about Infrared see:: http://www.nidcd.nih.gov/health /hearing/Pages/Assistive-Devices.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	11

Question 6.1

Are the descriptions of the technologies in Table 3 clear?

○ a. Yes

○ b. No

Question 6.2

How can they be improved?

Question 6.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?

○ a. Yes, I agree

○ b. No, I do not agree

Question 6.4

How can they be improved?

Section 7. Scenario Technology Solution

Please read the scenario technology solution suggested and then answer the questions.

The technology developer has made available a mobile web site with which Chuty and her parents can use their smart phones to enhance the visit. There is specific function called live functionality which assists Chuty and her parents to communicate with Suchat. At the entrance to the museum, Chuty sees a poster explaining that hearing impaired visitors should enable the live assistance functionality on the mobile web site before the tour starts. Therefore, she and her parents go to mobile website and enable the function. The function allows Suchat to notify Chuty and her parents when the tour begins and to change the topics.

Suchat indicates that the tour is about to start by pressing the ‘start’ button on his mobile phone. Chuty and her parents’ phones vibrate at the same time to notify them of this, and as Suchat starts speaking the pre-prepared summary captions for the first topic, appear on their smartphones. As the captions are presented on the mobile website, the words are highlighted in a sentence, allowing them to follow the conversation. Suchat can also notify Chuty and her parents that the topic is changing by sending a message to the server and the captions change automatically on the mobile website.

Sometimes Chuty can’t catch all of the conversation but she can pick out keywords through lip reading and hearing. Moreover, she can search for text by using automatic speech recognition of keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour. She can scroll up and down to find the conversation.

When Suchat shows the shadow puppet, he uses his mobile phone to select and indicate the captions of the show that he is currently performing. Chuty and her parents then can enjoy the show by watching the shadow puppet and they also can read the captions when they need to on their smartphones.

During the tour, Chuty asks some questions by typing instant messages on her smartphone which Suchat answers supported by selecting pre-prepared caption answers to frequently asked questions or by typing the answers on his smartphone. When Chuty asks questions about the exhibits, to help Chuty understands Suchat’s answers she can use the further information displayed on her smartphone browser through the links from the QR codes on the exhibits.

Chuty and her parents find that the mobile web site is very helpful for them in understanding the conversation during the visit. They hope that other local museums would use a similar mobile web site in order to assist hearing impaired visitors during their visit to Thai in situ authentic cultural museums.

Question 7.1

Is the scenario solution clearly described?

- a. Yes
- b. No

Question 7.2

How can the scenario solution description be improved?

Question 7.3

Does the solution meet the scenario requirements?

- a. Yes
- b. No

Question 7.4

How can the solution be improved?

Section 8. The Mobile Web Interactions

Please look at the Mobile Web Interactions Diagram and then answer the question.

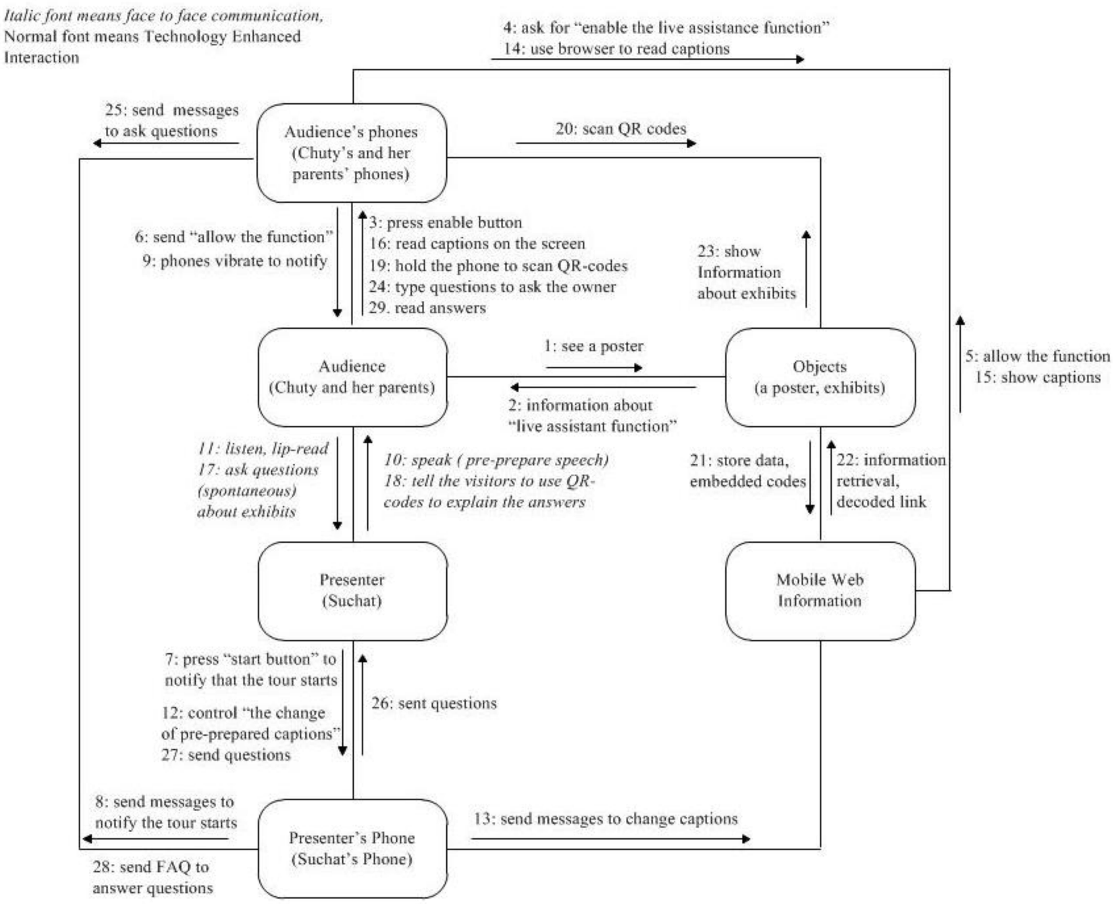
Question 8.1

Does the Mobile Web Interactions diagram help understand the scenario solution?

- a. Yes
- b. No

Question 8.2

How can it be improved?



Section 9. The Use Case Diagram

Please look at the Use Case Diagram and then answer the question.

Question 9.1

Does the Use Case Diagram help understand the scenario solution?

- a. Yes
- b. No

Question 9.2

How can it be improved?

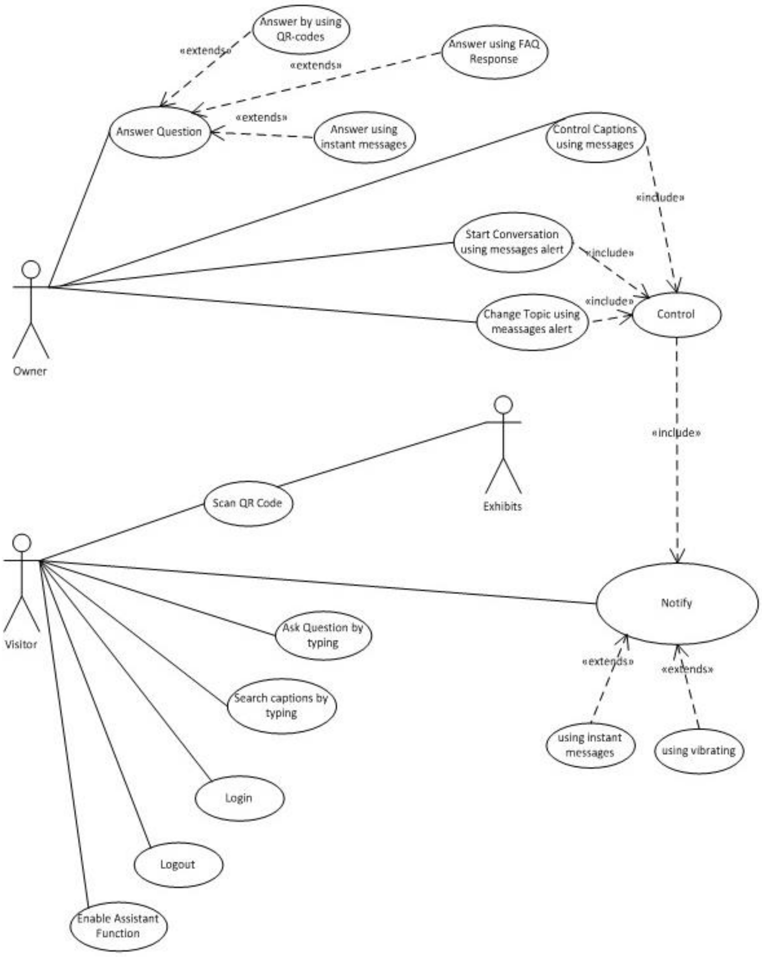


Figure 2 The Use Case Diagram

Section 10. Chosen Solution and Explanations

Please answer the question after you have read the following explanation of how the framework helped decide on the solution that was derived from the suggestions.

The Technology Enhanced Interaction Framework can help developers to design technology solutions to meet Suchat's requirements by helping them think about the possible factors which might be involved in the interactions. The tool, which is based on the framework, helps a developer who is not an accessibility expert to understand the problems and solutions faced by disabled people so that the developer can ensure that their designs are suitable for all users.

The possible technology solutions proposed in the suggestions table are selected by gathering Suchat's requirements using the questions which are based on the main and sub-components of the framework. From the scenario, Chuty and her parents have a hearing loss, which lead to the communication breakdown, when they communicate with Suchat. From the requirements, Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him which is shown by the answer to the requirement 1 question. So, the technologies which are shown in the suggestion table are all about improving the communication.

In this scenario, which identified people - people communication problems, the tool helps design the solution by showing the technologies which can improve the communication between Suchat and Chuty and her parents. Suchat's role in the communication is important because he can control technology to send an instant message to Chuty and her parents' phones to make them vibrate to let them know when the conversation starts. The technology solution selected to enable this is the instant messaging which was chosen over sms, the other possible technology solution suggested, because it is free of cost using wireless and smartphones. This solution is better than simply turning lights in the room on and off as this would not be noticeable in sunlight.

FM, Infrared and Induction loops are possible solutions but are expensive technologies that only work with suitable hearing aids and with people who have substantial remaining hearing ability.

Captions however can be of value to everybody, even people with no useful hearing and were therefore selected as the solution of choice. Thai speech recognition is not very accurate for spontaneous speech and therefore as Suchat already knows what he plans to say the best solution is pre-prepared summary captions.

As he presents his talk Suchat controls the changing pre-prepared captions on the mobile website using his smartphone. He has an application on his phone that can send a message to the webserver to display the next caption on the webpage that Chuty and her parents are looking at. This solution was chosen over using a pre-prepared captioned video as that would not have supported live face to face communication and interaction between Suchat and his visitors.

If Chuty and her parents ask spontaneous questions about some of the exhibits in the museum then Suchat will not have been able to anticipate and pre-prepare the order the captions need to be presented in. Considering the types of interactions is therefore important in designing technology solutions, because, in this scenario which has objects involved (i.e. exhibits in the museum) technology can help the people-object interactions when information about the object is only provided verbally by Suchat through introducing people-technology-object interactions using machine readable QR codes in order to provide this information. QR codes were selected rather than other possible approaches listed in the suggestions table (e.g. barcodes, RFID tags, Infrared system, Augmented Reality) because they are simple, cheap, quick and work with smartphones using free software that provides a link to information on a mobile website.

Suchat said that there is good wireless at the museum so the developers know that he would like to use online technology indoors which is reflected in the answers to requirement 12 and 16 questions. He also would like to use Chuty's and her parents' smartphones to keep his costs low, which is shown in the answers to requirement 18 and 19 questions. The 'ticks' in the suggestion tables, show the technologies that meet Suchat's requirements in the scenario. The highest scoring technologies are the Mobile Website, Pre-prepared Caption/Subtitle, Frequently Asked Questions (FAQ) and Quick Response Code (QR-code) (16 ticks) which cover all of the problems and requirements. Therefore, these was chosen as the best choice in designing technology for this scenario. However, the final decision of the designed technology would also depend on Suchat's opinion of which factors are the most important ones which might result in choosing other technology suggestions for improving the communication and interactions.

Question 10.1
Is the explanation of how the solution was derived from the suggestions easy to understand?

- ○ a. Yes
- ○ b. No

Question 10.2
How can the explanation be improved?

Question 10.3
Do you agree that the framework with its associated questions and suggestions can help designers design technology to enhance interactions particularly in complex situations involving disabled people?

- ◉ a. Yes, I agree
- ○ b. No, I do not agree

Question 10.4
How can the framework with associated questions and suggestions be improved?

Question 10.5
Are there any comments you would like to make about the framework

Appendix D. Printed Online Questionnaire for Accessibility Experts Validation and Review

Participant Information Sheet (Accessibility Experts)

Study Title: Evaluation of the Technology Enhanced Interaction Framework and tool process
Researcher: Kewalin Angkananon
Ethics number: 4865
Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?
The purpose of this study is to evaluate the Technology Enhanced Interaction Framework and associated tool which can help people design technology enhanced interactions particularly in complex situations involving disabled people. This evaluation is to be achieved by asking participants questions about the materials presented.

Why have I been chosen?
You have been approached to participate in this study because you are an accessibility expert who has relevant knowledge.

What will happen to me if I take part?
You will be asked to read and evaluate a scenario and answer questions about requirements and then comment on the feedback provided. You will be asked whether you understand the suggestions offered by the tool and whether they are correct. You will be asked to check whether the example solution meets the scenario's requirements. You will be asked if you can follow the explanation of how the solution was derived.

Are there any benefits in my taking part?
By taking part, you have the opportunity to assist the development of a new method to help design technology in complex situations involving disabled people. You may also view the study as an opportunity to find out about alternative design techniques, and to meet other participants. Light refreshments will be provided during the study.

Are there any risks involved?
There is no risk involved in taking part in this study. It is important to note that you are welcome to pause for a rest, or fully withdraw from the study, at any time.
Will my participation be confidential?
Yes. Your personal details will not be included on any written materials which you are asked to provide. Any audio recordings will be edited to maintain anonymity. For example, if a person's name is mentioned; the stored data will remove this detail.

What happens if I change my mind?
You have the right to withdraw at any time without your legal rights being affected.

What happens if something goes wrong?
If you have a concern or complaint, please contact the ECS School Office on school@ecs.soton.ac.uk or school@ecs.soton.ac.uk02380 592909.

Where can I get more information?
Feel free to get in touch with Kewalin Angkananon: ka3e10@ecs.soton.ac.uk

Evaluation of The Technology Enhanced Interaction Framework: Accessibility Experts

You can go back to previous pages and questions but if you are going away from the computer for a few hours we suggest you select "save and quit" and return to complete your survey later by using the username and password isurvey displays (copy these down before selecting the log in link) or by following the original link sent to you in the email.

Section 1. Name

Question 1.1

Please provide your name:

TEIF Method

Section 2. Evaluate the Scenario, Questions, and Answers

Instructions: Please read and analyse the following scenario which should provide all the information required for you to be able to answer the following questions which are based on the Technology Enhanced Interaction Framework. After you answer each question, what we think is the correct answer and an explanation will be presented to you (There will be a slight delay while the system processes your answers). You will be asked to suggest improvements to the questions, answers and explanations. The answers to the questions will help determine the requirements of the technology solution for the scenario. The requirement numbers shown next to the questions are also used in the Technology Suggestions tables in the following sections.

Suchat Trapsin allocated some parts of his house to become the Museum of Folk Art and Shadow Puppets, in Thailand. There are exhibits of shadow puppets inside the museum, but there is no information provided in text format. This is because Suchat normally explains the history and tradition in Thai by talking to visitors. He presents the same information in the same order every time.

On Friday afternoon, Chuty (who has been hearing impaired since birth) and her parents (who have some hearing loss due to their age), who are local people, visit the museum. Suchat starts the talk by explaining about the exhibits. During the talk, Chuty and her parents find that it is very difficult to hear Suchat clearly. Chuty asks Suchat some questions about the exhibits. Suchat answers the questions, but Chuty misses some of the words. While Chuty and her parents are watching the shadow puppet show, they also cannot hear the conversation clearly because of the background music which is part of the show. It is also fairly dark which makes lip-reading very difficult for them.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him. There is good Wi-Fi at the museum so he would like to use Chuty’s and her parents’ smartphones to keep his costs low.

Question 2.1

Are the instructions clear?

- a. Yes
- b. No

Question 2.2

How can they be improved?

Question 2.3

What is the main purpose of the technology solution? (*Requirement 1)*

- a. improve communication and interaction
- b. make the service more interesting and exciting
- c. improve the service efficiency in terms of time and ease of use
- d. improve the storage and retrieval of information

○ e. make the service more realistic and authentic

○ f. improve users' experiences in using the service

Question 2.3b

We agree.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him.

Question 2.3c

We think the answer is "a. improve communication".

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him.

Question 2.4

How can this question and multiple choices offered be improved?

Question 2.5

How can this answer and explanation be improved?

Question 2.6

Where and when does the scenario take place? (*Requirement 2)*

○ a. same time / same place

○ b. same time / different place

○ c. different time / same place

○ d. different time / different place

Question 2.6b

We agree.

Suchat, Chuty, and her parents are in the same place (The Museum of Folk Art and Shadow Puppets, Thailand) and at the same time (Friday afternoon).

Question 2.6c

We think the answer is "a. same time / same place".

Suchat, Chuty, and her parents are in the same place (The Museum of Folk Art and Shadow Puppets, Thailand) and at the same time (Friday afternoon).

Question 2.7

How can this question and multiple choices offered be improved?

Question 2.8

How can this answer and explanation be improved?

Question 2.9

What main role do people have in the scenario? (*Requirement 3)*

○ a. presenter - audience (the presenter gives information to the "audience" which could be only one person or many people and so controls the interaction. The audience can ask the presenter questions)

○ b. peer - peer (any person can give information or ask questions to any other person and therefore no one person controls interaction)

○ c. no communication between people only interaction with technology or objects

Question 2.9b

We agree.

The "presenter" (Suchat) talks to the "audience" (Chuty and her parents) and the audience ask the presenter questions.

Question 2.9c

We think the answer is "a. presenter - audience".

The "presenter" (Suchat) talks to the "audience" (Chuty and her parents) and the audience ask the presenter questions.

Question 2.10

How can this question and multiple choices offered be improved?

Question 2.11

How can this answer and explanation be improved?

Question 2.12

How many presenters and audience members are there? (*Requirement 4)*

- a. one presenter – one audience member
- b. one presenter – many audience members
- c. many presenters – one audience member
- d. many presenters – many audience members

Question 2.12b

We agree.

Suchat is a person who gives the information (one presenter) to Chuty and her parents (many audience members).

Question 2.12c

We think the answer is "b. one presenter – many audience members".

Suchat is a person who gives the information (one presenter) to Chuty and her parents (many audience members).

Question 2.13

How can this question and multiple choices offered be improved?

Question 2.14

How can this answer and explanation be improved?

Question 2.15

Does the presenter have a disability? (*Requirement 5)*

- a. Yes
- b. No

Question 2.15b

We agree.

Suchat doesn't have any disability.

Question 2.15c

We think the answer is "b. No".

Suchat doesn't have any disability.

Question 2.16

How can this question and multiple choices offered be improved?

Question 2.17

How can this answer and explanation be improved?

Question 2.18

What language does the presenter use? (*Requirement 6)*

- a. English
- b. Thai
- c. other language
- d. I don't know

Question 2.18b

We agree.

Suchat talks to Chuty and her parents in Thai.

Question 2.18c

We think the answer is b. Thai.

Suchat talks to Chuty and her parents in Thai.

Question 2.19

How can this question and multiple choices offered be improved?

Question 2.20

How can this answer and explanation be improved?

Question 2.21

What language does the audience use? (*Requirement 7)*

- a. English
- b. Thai
- c. other language
- d. I don't know

Question 2.21b

We agree.

Chuty and her parents are local people who live in Thailand.

Question 2.21c

We think the answer is "b. Thai".

Chuty and her parents are local people who live in Thailand.

Question 2.22

How can this question and multiple choices offered be improved?

Question 2.23

How can this answer and explanation be improved?

Question 2.24

Does the audience have a disability? (*Requirement 8)*

- a. Yes
- b. No

Question 2.24b

We agree.

Chuty and her parents have a disability.

Question 2.24c

We think the answer is "a. Yes".

Chuty and her parents have disabilities as otherwise.

Question 2.25

How can this question and multiple choices offered be improved?

Question 2.26

How can this answer and explanation be improved?

Question 2.27

What kind of disability do the audience have? (*Requirement 9)*

- a. hearing impaired
- b. visually impaired
- c. physically impaired
- d. none

Question 2.27b

We agree.
Chuty has had hearing impairment at birth and her parents have hearing loss due to their age.

Question 2.27c
We think the answer is "a. hearing impaired".
Chuty has had hearing impairment at birth and her parents have hearing loss due to their age.

Question 2.28
How can this question and multiple choices offered be improved?

Question 2.29
How can this answer and explanation be improved?

Question 2.30
What level of hearing loss does the audience have? (*Requirement 10)*

- a. mild or moderate hearing loss
- b. severe or profound hearing loss
- c. I don't know

Question 2.30b
We agree.
There is no detailed information about the level of hearing loss of audience members in the scenario

Question 2.30c
We think the answer is "c. I don’t know".
There is no detailed information about the level of hearing loss of audience member in the scenario

Question 2.31
How can this question and multiple choices offered be improved?

Question 2.32
How can this answer and explanation be improved?

Question 2.33
What two interaction types occur in the scenario? (*Requirement 11)*

- a. people to people
- b. people to objects
- c. people to technology
- d. people to technology to people
- e. people to technology to objects

Question 2.33b
We agree.
Suchat communicates with Chuty and her parents (people - people).
This is one of the two interaction types which occur in the scenario.

Question 2.33c
We agree.
Chuty and her parents watch the shadow puppet show (people - objects).
This is one of the two interaction types which occur in the scenario.

Question 2.33d
We think the answers are "a. people - people and b. people - objects".
Suchat communicates with Chuty and her parents (people - people).
Chuty and her parents watch the shadow puppet show (people - objects).
Question 2.34
How can this question and multiple choices offered be improved?

Question 2.35

How can this answer and explanation be improved?

Question 2.36

What type of technology would be appropriate for the solution to the scenario? (*Requirement 12)*

- a. online technology (Internet)
- b. off-line technology
- c. I do not know

Question 2.36b

We agree.

There is good Wi-Fi at the museum and Suchat would like to use Chuty's and her parents' smartphones.

Question 2.36c

We think the answer is "a. online".

There is good Wi-Fi at the museum and Suchat would like to use Chuty's and her parents' smartphones.

Question 2.37

How can this question and multiple choices offered be improved?

Question 2.38

How can this answer and explanation be improved?

Question 2.39

What type of technology devices would be appropriate for the solution to the scenario? (*Requirement 13)*

- a. mobile devices
- b. non-mobile devices
- c. I do not know

Question 2.39b

We agree.

Suchat would like to use Chuty's and her parents' smartphones.

Question 2.39c

We think the answer is "a. mobile devices".

Suchat would like to use Chuty's and her parents' smartphones.

Question 2.40

How can this question and multiple choices offered be improved?

Question 2.41

How can this answer and explanation be improved?

Question 2.42

Has the presenter planned what he wants to say? (*Requirement 14)*

- a. Yes
- b. No
- c. I do not know

Question 2.42b

We agree.

Suchat has already prepared what to talk to the visitors about (pre-prepared speech).

Question 2.42c

We think the answer is **"a. Yes".**

Suchat has already prepared what to talk to the visitors about (pre-prepared speech).

Question 2.43

How can this question and multiple choices offered be improved?

Question 2.44

How can this answer and explanation be improved?

Question 2.45

Are audios or videos shown in the scenario? (*Requirement 15)*

- a. audio
- b. video
- c. neither

Question 2.45b

We agree.

There is no audio or video information to be shown in the scenario. The music is just a background sound.

Question 2.45c

We think the answer is "c. neither".

There is no audio or video information to be shown in the scenario. The music is just a background sound.

Question 2.46

How can this question and multiple choices offered be improved?

Question 2.47

How can this answer and explanation be improved?

Question 2.48

Where does the situation take place? (*Requirement 16)*

- a. indoors
- b. outdoors
- c. I do not know

Question 2.48b

We agree.

Inside the museum **(**the Museum of Folk Art and Shadow Puppets**).**

Question 2.48c

We think the answer is "a. indoors".

Inside the museum **(**the Museum of Folk Art and Shadow Puppets**).**

Question 2.49

How can this question and multiple choices offered be improved?

Question 2.50

How can this answer and explanation be improved?

Question 2.51

What are the two main environmental considerations identified that impact the scenario? (*Requirement 17)*

- a. noise (Background noise affects everyone’s ability to hear and understand what is said. Noise has even greater impact on deaf and hard of hearing people because it tends to mask or cover over speech.)
- b. room acoustics (Surface (walls windows tile) and objects within every room interact to produce reverberation in response to sound.)
- c. distance (How far is the audience standing from the presenter? . The further a student is from the presenter or sound source the softer the sound they receive.)
- d. visual access (How well can the audience see everything that is happening in different locations?)

- e. lighting (Inadequate lighting or large banks of windows can be challenging for deaf or hard of hearing audience because they cannot see the speakers face well or an interpreter may be located in shadows)

Question 2.51b

We agree.

Chuty and her parents cannot hear the conversation clearly because of the music background ,which is part of the show.

This is one of the two environmental considerations that impact the scenario.

Question 2.51c

We agree.

It is fairly dark which makes lip-reading very difficult.

This is one of the two environmental considerations that impact the scenario.

Question 2.51d

We think the answers are "a. noise and e. inadequate lighting".

Chuty and her parents cannot hear the conversation clearly because of the music background ,which is part of the show, and it is also fairly dark which makes lip-reading very difficult.

Question 2.52

How can this question and multiple choices offered be improved?

Question 2.53

How can this answer and explanation be improved?

Question 2.54

Does the customer require a low cost solution? (*Requirement 18)*

- a. Yes
- b. No

Question 2.54b

We agree.

Suchat would like to use Chuty's and her parents' smartphones to keep his costs low.

Question 2.54c

We think the answer is "a. Yes".

Suchat would like to use Chuty's and her parents' smartphones to keep his costs low.

Question 2.55

How can this question and multiple choices offered be improved?

Question 2.56

How can this answer and explanation be improved?

Question 2.57

Should the technology solution work on a smart phone? (*Requirement 19)*

- a. Yes
- b. No

Question 2.57b

We agree.

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him using their smartphones.

Question 2.57c

We think the answer is "a. Yes".

Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him using their smartphones.

Question 2.58

How can this question and multiple choices offered be improved?

Question 2.59

How can this answer and explanation be improved?

Question 2.60

How can the scenario be improved to make it easier to answer the questions?

Section 3. The Technology Suggestions: Table 1

Please read the technology suggestions and descriptions in Table 1. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
1. Mobile web site	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network. For more information about basic guideline mobile web practice:http://www.w3.org/TR/mobile-bp/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
2. Pre-prepared caption/subtitle	Captions are text versions of the spoken word. Captions allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. More information about captions see: http://webaim.org/techniques/captions/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
3. Frequently asked questions (FAQ)	FAQ are listed questions and answers, all supposed to be commonly asked in some context, and pertaining to a particular topic. It is very useful for the presenter who communicates with hearing impaired people because they can send the pre-prepared answers to the audience in case the questions that they ask match the FAQ. For more information about FAQ see: http://en.wikipedia.org/wiki/FAQ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
4. Quick Response Code (QR-code)	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special scanner to scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information. For more information about QR codes see: http://www.whatisaqrcode.co.uk/	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
5. Instant messaging	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org/wiki/Instant_messaging	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	15
6. Short Message Service (SMS)	This is a simple, easy and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions. For more information about IM see: http://en.wikipedia.org /wiki/Short_Message_Service	✓	✓	✓	✓	✓	✓	✓	✗	✓	✓	✓	✓	✓	✓	✓	✓	15

Question 3.1

Are the descriptions of the technologies in Table 1 clear?

- a. Yes
- b. No

Question 3.2

How can they be improved?

Question 3.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 1?

- a. Yes, I agree
- b. No, I do not agree

Question 3.4

Please explain

Section 4. The Technology Suggestions: Table 2

Please read the technology suggestions and descriptions in Table 2. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Table 2 The Technology Suggestions (continued)

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
7. Vibrating alert	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone. For more information about vibrating alert see: http://en.wikipedia.org/wiki/Vibrating_alert	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔	✔	15
8. Barcode	Barcodes originally require a special reader to access them but later scanners and interpretive software became available on smartphone devices. There needs to be line of sight between the barcode and the reader. For more information about barcodes see: http://www.britannica.com/EBchecked/topic/52455/bar-code	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔	✔	✔	✔	✔	✔	✔	15
9. Augmented Reality (AR)	AR is a virtual technology which enhances users' interests by imposing virtual objects on the real environment. Content can be viewed in 2D or 3D, and the object can be shown in different perspectives. The AR application which includes a display screen and a camera, is normally viewed using a browser. Augmented reality applications can enhance a user's experience when traveling by providing real time informational displays regarding a location and its features, including comments made by previous visitors of the site. AR applications allow tourists to experience simulations of historical events, places and objects by rendering them into their current view of a landscape. AR applications can also present location information by audio, announcing features of interest at a particular site as they become visible to the user. AR systems can interpret foreign text on signs and menus and, in a user's augmented view, re-display the text in the user's language. Spoken words of a foreign language can be translated and displayed in a user's view as printed subtitles For more information about Augmented Reality see:http://en.wikipedia.org/wiki/Augmented_reality	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✔	15
10. Radio frequency identification (RFID)	RFID is a radio technology which can be read by an RFID receiver automatically with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can't determine which item the user is browsing. The RFID tags are clearly to show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content. For more information about RFID see:http://cdn.intechopen.com/pdfs/31056/InTech-Using_rfid_nfc_and_qr_code_in_mobile_phones_to_link_the_physical_and_the_digital_world.pdf	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✔	✘	✘	14
11. Induction Loop	Induction Loop systems utilize electromagnetic energy to transmit the signal. These systems can cover a small area with a loop placed under a rug or may be permanently installed within the walls or ceiling of larger areas. For individuals to access this type of technology, they must have a Telecoil (t-coil) within their hearing aids. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about induction loop see: http://soundinduction.co.uk/media/PDFs/Signet_induction_loop_system_guide.pdf	✔	✔	✔	✔	✔	✔	✔	✘	✘	✔	✔	✔	✔	✔	✔	✘	13

Question 4.1

Are the descriptions of the technologies in Table 2 clear?

○ a. Yes

○ b. No

Question 4.2

How can they be improved?

Question 4.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 2?

○ a. Yes, I agree

○ b. No, I do not agree

Question 4.4

Please explain

Section 5. The Technology Suggestions: Table 3

Please read the technology suggestions and descriptions in Table 3. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Table 3 The Technology Suggestions (continued)

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
12. Hearing Aid	A hearing aid is designed to provide for an individual's preferences, degree and configuration of hearing loss. For more information about hearing aids see: http://www.actiononhearingloss.org.uk/your-hearing/need-hearing-aids.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13
13. FM Systems	FM or Frequency Modulation systems, the sound is transmitted on a specific frequency or channel similar to a radio. FM systems can be used for whole rooms or by individuals. Large areas can be set up with single or multiple speakers depending on the size of the room. These systems can be permanently installed in a given location or there are also several versions that are portable. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about FM see:http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✓	✓	✓	✗	13
14. Cochlear implant	A cochlear implant is a surgically-implanted device that converts sound energy into electrical stimuli that can be processed by the auditory nerve. For more information about cochlear implant see:http://www.actiononhearingloss.org.uk/your-hearing/about-deafness-and-hearing-loss/cochlear-implants.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✓	✗	12
15. Pen and paper	When other methods are not available writing may be an option for communicating with hearing impaired people.	✓	✓	✓	✓	✓	✓	✓	✓	✗	✗	✓	✓	✓	✗	✓	✗	12
16. Flashing light	A flashing light alert gets attention of hearing impaired people normally only used for room lights as need to get attention whether person is looking. Normally used for room lighting only off-line. High cost wireless systems are becoming available.	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✗	✓	✓	✓	✓	✓	12
17. Speech recognition	The captioning is performed by an operator, using an electronic stenotype keyboard or more often, speech recognition revoicing by human operating using speech recognition software to transcribe into text. No training required for users. Speech recognition can help clarify missing words but sometimes make errors. If there is noise or some other sound in the room, the number of errors will increase. Speak recognition works best if the microphone is close to the user (e.g. in a phone or if the user is wearing a microphone). More distance microphones will tend to increase the number of errors. For more information about live captions see guideline 1.2.4 Captions (Live) –W3C:http://www.w3.org/TR/UNDERSTANDING-WCAG20/media-equiv-real-time-captions.html	✓	✓	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✓	✓	12
18. Internet Protocol Relay	The deaf and hard of hearing person uses their computer to connect with an IP relay service. The operator places the call, identifies themselves and the relay service, and facilitates the exchange of information through text and voicing. More accurate than speech recognition but slower. For more information see:http://en.wikipedia.org/wiki/Telecommunications_device_for_the_deaf Captioned telephones display real-time captions of the current conversation. The captions are typically displayed on a screen embedded into the telephone base. A web version is available. For more information about captioned telephone see:http://www.nad.org/issues/telephone-and-relay-services/relay-services/captioned-telephone-service-cts	✓	✓	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✗	✓	11

Question 5.1

Are the descriptions of the technologies in Table 3 clear?

- a. Yes
- b. No

Question 5.2

How can they be improved?

Question 5.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?

- a. Yes, I agree
- b. No, I do not agree

Section 6. The Technology Suggestions: Table 4

Please read the technology suggestions and descriptions in Table 4. Note that the rightmost column (Total score) shows the number of scenario requirements (as identified by the answers to the requirement questions) which have been met by each technology. Tool-tips are provided to explain why each technology meets (or does not meet) each requirement. Please hover the pointer over the tick or cross symbols to read the explanation. Then, please answer the questions that follow.

Table 4 The Technology Suggestions (continued)

Technology suggestions	Descriptions	1a. improve communication	2a. same time / same place	3a. presenter-audience	6b. speaker speaks Thai	7b. audience speak Thai	9a. hearing impaired	11a. people - people	11b. people - objects	12a. online technology	13a. mobile devices	14a. pre-prepared speech	16a. indoors	17a. noise	17e. inadequate lighting	18a. low cost solution	19a. work with smart phones	Total score
19. Infrared Systems	These systems utilize light waves to transmit sound from the transmitter to a special light sensitive receiver which can be mobile. There must be a clear line of connection between the transmitter and receiver so that the light signal is not interrupted. These systems can be sensitive to external light sources or interfering objects. The speaker uses a microphone and so the system amplifies the speech more than the background noise. For more information about Infrared see: http://www.nidcd.nih.gov/health/hearing/Pages/Assistive-Devices.aspx	✓	✓	✓	✓	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓	✗	✗	11
20. Voice Carry Over (VCO)	VCO relay is an option for people who can speak clearly, but have hearing loss significant enough to prevent them from hearing and understanding conversations over the telephone. Using VCO relay and a specially designed telephone with a text display, a VCO user can speak directly to the other person on the call. A communication assistant (CA) types what is spoken by the other person for the VCO user to read. For more information about Voice Carry Over see: http://mn.gov /commerce/images/Voice-Carry-Over-Brochure.pdf	✓	✗	✓	✗	✗	✓	✓	✗	✓	✓	✓	✓	✗	✓	✗	✓	10
21. Computer with camera/ smartphone	Many individuals utilise the combination of a web camera and computer Internet service to be able to visually connect with others. Deaf or hard of hearing callers can communicate through sign language via a video phone e.g. Skype via smart phones or computer with webcam. It also would allow disabled people unable to climb stairs to interact with objects and communicate with people who might be upstairs.	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	0
22. Video Relay Service	Video relay service can be accessed to allow the sign language user to call other hearing people with the assistance of an operator. They then proceed to voice interpret the signed message from the caller. They are also able to convert the voice message into sign language for the deaf or hard of hearing person. For more information about Video Relay Service see: http://en.wikipedia.org /wiki/Video_relay_service	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	✗	0

Question 6.1

Are the descriptions of the technologies in Table 4 clear?

- a. Yes
- b. No

Question 6.2

How can they be improved?

Question 6.3

Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 4?

- a. Yes, I agree
- b. No, I do not agree

Question 6.4

How can they be improved?

Section 7. Scenario Technology Solution

Please read the scenario technology solution suggested and then answer the questions.

The technology developer has made available a mobile web site with which Chuty and her parents can use their smart phones to enhance the visit. There is specific function called live functionality which assists Chuty and her parents to communicate with Suchat. At the entrance to the museum, Chuty sees a poster explaining that hearing impaired visitors should enable the live assistance functionality on the mobile web site before the tour starts. Therefore, she and her parents go to mobile website and enable the function. The function allows Suchat to notify Chuty and her parents when the tour begins and to change the topics.

Suchat indicates that the tour is about to start by pressing the 'start' button on his mobile phone. Chuty and her parents' phones vibrate at the same time to notify them of this, and as Suchat starts speaking the pre-prepared summary captions for the first topic, appear on their smartphones. As the captions are presented on the mobile website, the words are highlighted in a sentence, allowing them to follow the conversation. Suchat can also notify Chuty and her parents that the topic is changing by sending a message to the server and the captions change automatically on the mobile website.

Sometimes Chuty can't catch all of the conversation but she can pick out keywords through lip reading and hearing. Moreover, she can search for text by using automatic speech recognition of keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour. She can scroll up and down to find the conversation.

When Suchat shows the shadow puppet, he uses his mobile phone to select and indicate the captions of the show that he is currently performing. Chuty and her parents then can enjoy the show by watching the shadow puppet and they also can read the captions when they need to on their smartphones.

During the tour, Chuty asks some questions by typing instant messages on her smartphone which Suchat answers supported by selecting pre-prepared caption answers to frequently asked questions or by typing the answers on his smartphone. When Chuty asks questions about the exhibits, to help Chuty understands Suchat's answers she can use the further information displayed on her smartphone browser through the links from the QR codes on the exhibits.

Chuty and her parents find that the mobile web site is very helpful for them in understanding the conversation during the visit. They hope that other local museums would use a similar mobile web site in order to assist hearing impaired visitors during their visit to Thai in situ authentic cultural museums.

Question 7.1

Is the scenario solution clearly described?

- a. Yes
- b. No

Question 7.2

How can the scenario solution description be improved?

Question 7.3

Does the solution meet the scenario requirements?

- a. Yes
- b. No

Question 7.4

How can the solution be improved?

Section 8. Chosen Solution and Explanations

***Please answer the question after you have read the following explanation of how the framework helped decide on the solution that was derived from the suggestions*.**

The Technology Enhanced Interaction Framework can help developers to design technology solutions to meet Suchat's requirements by helping them think about the possible factors which might be involved in the interactions. The tool, which is based on the framework, helps a developer who is not an accessibility expert to understand the problems and solutions faced by disabled people so that the developer can ensure that their designs are suitable for all users.

The possible technology solutions proposed in the suggestions table are selected by gathering Suchat's requirements using the questions which are based on the main and sub-components of the framework. From the scenario, Chuty and her parents have a hearing loss, which lead to the communication breakdown, when they communicate with Suchat. From the requirements, Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him which is shown by the answer to the requirement 1 question. So, the technologies which are shown in the suggestion table are all about improving the communication.

In this scenario, which identified people - people communication problems, the tool helps design the solution by showing the technologies which can improve the communication between Suchat and Chuty and her parents. Suchat's role in the communication is important because he can control technology to send an instant message to Chuty and her parents' phones to make them vibrate to let them know when the conversation starts. The technology solution selected to enable this is the instant messaging which was chosen over sms, the other possible technology solution suggested, because it is free of cost using wireless and smartphones. This solution is better than simply turning lights in the room on and off as this would not be noticeable in sunlight.

FM, Infrared and Induction loops are possible solutions but are expensive technologies that only work with suitable hearing aids and with people who have substantial remaining hearing ability. Captions however can be of value to everybody, even people with no useful hearing and were therefore selected as the solution of choice. Thai speech recognition is not very accurate for spontaneous speech and therefore as Suchat already knows what he plans to say the best solution is pre-prepared summary captions. As he presents his talk Suchat controls the changing pre-prepared captions on the mobile website using his smartphone. He has an application on his phone that can send a message to the webserver to display the next caption on the webpage that Chuty and her parents are looking at. This solution was chosen over using a pre-prepared captioned video as that would not have supported live face to face communication and interaction between Suchat and his visitors.

If Chuty and her parents ask spontaneous questions about some of the exhibits in the museum then Suchat will not have been able to anticipate and pre-prepare the order the captions need to be presented in. Considering the types of interactions is therefore important in designing technology solutions, because, in this scenario which has objects involved (i.e. exhibits in the museum) technology can help the people-object interactions when information about the object is only provided verbally by Suchat through introducing people-technology-object interactions using machine readable QR codes in order to provide this information. QR codes were selected rather than other possible approaches listed in the suggestions table (e.g. barcodes, RFID tags, Infrared system, Augmented Reality) because they are simple, cheap, quick and work with smartphones using free software that provides a link to information on a mobile website. Suchat said that there is good wireless at the museum so the developers know that he would like to use online technology indoors which is reflected in the answers to requirement 12 and 16 questions. He also would like to use Chuty's and her parents' smartphones to keep his costs low, which is shown in the answers to requirement 18 and 19 questions. The 'ticks' in the suggestion tables, show the technologies that meet Suchat's requirements in the scenario. The highest scoring technologies are the Mobile Website, Pre-prepared Caption/Subtitle, Frequently Asked Questions (FAQ) and Quick Response Code (QR-code) (16 ticks) which cover all of the problems and requirements. Therefore, these was chosen as the best choice in designing technology for this scenario. However, the final decision of the designed technology would also depend on Suchat's opinion of which factors are the most important ones which might result in choosing other technology suggestions for improving the communication and interactions.

Question 8.1

Is the explanation of how the solution was derived from the suggestions easy to understand?

○a. Yes

○b. No

Question 8.2

How can the explanation be improved?

Question 8.3

Do you agree that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people?

○ a. Yes, I agree

○ b. No, I do not agree

Question 8.4

How can the framework with associated questions and suggestions be improved?

Question 8.5

Are there any comments you would like to make about the framework?

Appendix E. Pilot Study Findings

There are three participants took part in the Pilot Study. Two participants completed the questionnaire which developed for Developer Experts and one participant completed the questionnaire for Accessibility Experts. The finding as follows:

Table 0-20 The findings from pilot study: Framewrok and Scenario

Section	**Question**	**Participant 1**	**Participant 2**	**Participant 3**
Framework	1. Are the examples and explanations clear?	Yes	Yes	Yes
	2. How can they be improved?	Yes	Yes	No
	3. Do you agree with the main components and sub-components of the framework?			1. Role example peer to peer change to "student to student or visitor to visitor" 2. change "answer the following question" to "questions" as there are 2 questions 3. change 'lead to communication breakdown' to 'lead to communication or interaction breakdown' 4. for p-t-p move the bracketed examples to after the word technology 5. for place and time change to ST/SP, DT/SP, DT/DP, ST/DP
	4. How can they be improved?			6. have the how can it be improved box showing for either yes or no answer even before the answer is selected so user can type in the box as they find things to improve ... I am noting things down in a separate document as I read the framework because there is nowhere to type as I haven't read the framework completely and so haven't answered the questions yet ... if I think they are generally clear then the improve box won't appear and I can't give you any advice 7. it is annoying that I can't copy and paste from the table as that means I have to retype
Scenario	22. How can the scenario be improved to make it easier to answer the questions?			1. Change "It is because Suchat" to "This is because Suchat" 2. Change "Please analyse the following scenario to answer the following questions." to "Please read and analyse the following scenario which should provide all the information required for you to be able to answer the following questions. After you answer each question, what we think is the correct answer and an explanation will be presented to you" you will be asked to suggest improvements to the questions, answers and explanations. The answers to the questions will help determine the requirements of the technology solution for the scenario. 3. display the text boxes all the time as selecting another answer resets them and loses the text just entered
	1: What is the main purpose of the technology solution?			1. change to only a single answer allowed as choosing another one resets the text box and loses the comments explain to the user that they can only choose one answer 2. change “What is the purpose of technology solution?" to "What is the main purpose of the technology solution?" 3. change c. " easy to use" to "ease of use" 4. d. change "improve the storage and retrieval information" to " improve the storage and retrieval of information"
	3: How can this question and multiple choices offered be improved?			change "What role do people have in the scenario?" to "What main role do people have in the scenario? and change to only one answer allowed
	8: Does the presenter have a disability?			change answer to Chuty and her parents have disabilities as otherwise
	9: What language does the presenter use?			Q9 is not needed as the answer is given in question 8.
	10: What language does the audience use?			change answer to There is no detailed information about the level of hearing loss of audience members in the scenario
	11: Does the audience have a disability?			1. change question to What two interaction types occur in the scenario? 2. change answers to "This is one of the two interaction types which occur in the scenario.

Table 0-21 The findings from pilot study: Technology Suggestions Tables 1 and 2

Section	Question	Participant 1	Participant 2	Participant 3
Technology Suggestions: Table 1	1. Are the explanations of the technologies in Table 1 clear?	No It's not immediately clear what this table is about. Also, where do the requirements come from? They are numbered but there is no indication of what the numbers mean.	Yes	No 1. not being able to copy and paste makes suggesting improvements difficult and not being to follow the hyperlinks mean no comments can be made about them 2. your explanation about mobile web site needs to include some more information that explains why it fits the requirements as it is not obvious why the ticks are there 3. mobile web site change to "basic guidelines on mobile web practice" 4. What does 'benefit for other' mean? After closed captions in technology suggestions column 5. Your explanation about pre-prepared caption/subtitle is about audio and video but you have it as a solution for this scenario where there is no audio or video. You therefore need to include something relevant to this scenario e.g. "pre-prepared captions can also be used in a face to face situation when the speaker is giving a pre-prepared presentation"
	2. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 1?	No I am not sure how captions aren't suitable for person-object interactions.	No 1. I'm not sure that captions/subtitles are an online technology. 2. Can you put the tables as actual tables? Instead of images? not good for accessibility 3. the first explanation "A Mobile Web" you can't have "A Mobile Web"	No It is not obvious why the ticks are there being able to select a tick and see a further explanation would be one way to do this.
Technology Suggestions: Table 2	1. Are the explanations of the technologies in Table 2 clear?	No I don't think this format table is very suitable to display this data. It is very hard to read since all the requirements are sideways. This is a website, you don't necessarily need to save space in this way, you should reformat it to be easier to read.	No 1. You put FQA instead of FAQ 2. your SMS explanation has some bad grammar	No 1. your explanation about the suggested technologies needs to include some more information that explains why it fits the requirements 2. not clear how IM, SMS, FAQ works in this scenario
	2. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 2?	Yes	No Inductions loops can be used in inadequate lighting as they are an audio technology.	being able to select a tick and see a further explanation would be one way to do this

Table 0-22 The findings from pilot study: Technology Suggestions Tables 3-5

Section	Question	Participant 1	Participant 2	Participant 3
Table 3	1. Are the explanations of the technologies in Table 3 clear?	Yes	Yes	No 1. hearing aid: change to provide for and remove 'and special features' 2. speech recognition: remove ‘while the program is on the air'
	2. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?	No I'm not sure how Vibrating Alert satisfies "Audience Speaks Thai"	No Hearing aids can be used in inadequate lighting.	
Table 4	1. Are the explanations of the technologies in Table 4 clear?	Yes	No Barcode explanation: second sentence needs a capital letter	No 1. RFID: remove references 2. Bluetooth: what is 'a trigger technology’? should be ' can be used as a trigger technology' should be "number of devices" remove reference 3. Barcodes: should be capital T in 'There' 4. What library?
	2. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 4?	Yes	Yes	
Table 5	1. Are the explanations of the technologies in Table 5 clear?		No explanation of FM Systems: first sentence has bad grammar maybe add "Using " to the front of it	No infra-red is light and so how can it be broadcast by a speaker
	2. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 5?			
	3. Are there any important technologies missing?	No	No	not sure would need more time to think
	4. Do you agree the technology suggestions total score is helpful?	No It is good to a certain degree, but not all of the requirements are equally important. Also, quite a few of the requirements were ticked in every single example, which is kind of redundant.	Yes	No your explanation about the suggested technologies needs to include some more information that explains why it fits the requirements as it is not obvious why the ticks are there being able to select a tick and see a further explanation would be one way to do this.

Table 0-23 The findings from pilot study: Technology Suggestions Tables 5 (continued) and Scenario Technology Solution

Section	Question	Participant 1	Participant 2	Participant 3
Table 5	5. Do you agree with the way of presenting the technology suggestions?	No The descriptions are fine, but the requirements bit need to be replaced. The sideways text is very hard to read, and the facts there are so many of them make it very intimidating to read. I'd remove the redundant options I mentioned above and perhaps change way the requirements are shown. Maybe a symbol for each requirement (e.g. a dollar symbol could represent "low cost") with a legend at the top to show what each symbol means.	Yes	- your explanation about the suggested technologies needs to include some more information that explains why it fits the requirements as it is not obvious why the ticks are there - being able to select a tick and see a further explanation would be one way to do this
	6. Do you agree that the provided links to further information are useful?	I'm sorry, I didn't click them. There was already an overload of information and I didn't want to confuse myself.	Yes	they don't work as it is in an image
	7. How can the technology suggestions be improved to make it easier to design the technology solutions to the scenario?	Not sure.	'Solutions' is spelt wrong.	make the explanations fit the questions better
Scenario Technology Solution	1. Is the scenario solution clearly described?	Yes	Yes	No 1. change to "The function allows Suchat to notify Chuty and her parents when the tour begins and when he changes the topic he is talking about" 2. change to "Chuty's and her parents' phones . 3. remove comma so changes to "first topic appear' 4. change to "presented on a mobile website" 5. change to "allowing them to follow the conversation" 6. change to "Suchat can also notify Chuty and her parents that the topic is changing by sending a message to the server and this causes the captions to change automatically on the mobile website. 7. why is she using speech recognition not typing? "Moreover, she can search for text by using automatic speech recognition of keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour." 8. change to "This helps her to scroll up and down to find the conversation " 9. change to "They hope that other local museums would use similar mobile web sites
	2. Does the solution meet the scenario requirements?	Yes	Yes	No why is she using speech recognition not typing? "Moreover, she can search for text by using automatic speech recognition of keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour."

Table 0-24 The findings from pilot study: Mobile Web Interactions, Usecase, Chosen Solution and Explanations

Section	Question	Participant 1	Participant 2	Participant 3
Mobile Web Interactions	Does the Mobile Web Interactions diagram help understand the scenario solution?	Yes	No 1. There is a lot of information to take in from this diagram. Perhaps a sequence diagram would be more appropriate? 2. two number 14s 3. it has no number 23	1. 10 change to 'italic font' 'normal font' 2. change 'pre-prepared' 3. why is this arrow pointing towards object? (21) 4. no '23' 5. change to 'send questions' there is no mention of speech recognition which was in the solution text (26) 6. have the box appear for either answer 7. Q!: no mention of FAQ in activity diagram, no mention of speech recognition, change to "vibration"
Use Case	Does the Use Case Diagram help understand the scenario solution?	No	Use Case	Does the Use Case Diagram help understand the scenario solution?
Chosen Solution and Explanations	1. Is the explanation of how the solution was derived from the suggestions easy to understand?	-	Yes	1. change "which leads to the communication breakdown" 2. change "instant message to Chuty's and her parents' phones" 3. instant messaging is normally about text communication not triggering a change 4. change "Captions however can be of value to everybody, even people with no useful hearing and were therefore selected as the solution of choice as the scenario did not describe the level of hearing loss' 5. Image recognition, typing a code number were not in the table change to 'developer knows' 6. change to 'Chuty's and her parents' smartphones'have the text box appear for either question
	2. Do you agree that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people?	Yes	Yes	needs more explanations of ticks
	3. Are there any comments you would like to make about the framework?	I think I've made quite a lot of comments already! :-P	it's difficult to correct the grammar without rewriting lots of parts	

Appendix F. Expert Validation and Review Findings

After analysing the data collected from the pilot study which is provided in Appendix E changes were made to the survey. There were two main ries of changes to the pilot study: content and the isurvey system as summarised in Table 0-25 (questionnaire for developer experts) and Table 0-26 (questionnaire for accessibility experts). Further details are given in Appendix J. The pilot study participants were asked whether the changes satisfied all the issues they had identified. The findings found that they were satisfied with all the changes made. The updated version after the pilot study surveys are available at: https://www.isurvey.soton.ac.uk/6291 (Developer experts) and https://www.isurvey.soton.ac.uk/6577 (Accessibility Experts). The printed versions are in Appendix H and I.

Pilot Findings

Table 0-25 Pilot Study Finding for developer expert questionnaire

Category of changes	**What was changed?**	**Result of changes**
Content		
rewrite the instructions	1. Scenario Section 2. Technology Suggestions Section	make it clearer
rewrite the descriptions	1. Technology Suggestions Section 2. Scenario Technology Solution Section 3. Chosen Solution and Explanations Section	make it clearer
add explanation of the technology suggestion tables	Technology Suggestions Section: Table 1, 2, 3, 4 and 5	help respondents understand why technologies have ticks or crosses in cells corresponding to requirements
improve content	1. Framework Section: role 2. Scenario Section: scenario, requirement questions (question number 1, 3, 9,10,11) multiple choices (answers of question number 1, 3,10,11) and the explanations of answers 3. Technology Suggestions: Table 1, 2, 3, 4 and 5 4. Scenario Technology Suggestions Section 5. Mobile Web Interactions Section 6. Chosen Solution and Explanations	make it clear and understandable without assuming knowledge use more picture to explain instead of lots of text
isurvey System		
change the image tables to html tables	1. Framework Section 2. Technology Suggestions Section: Table 1, 2, 3, 4 and 5	make the table accessible, now can copy the content in order to make change, can link to the websites were provided, can provide explanations in tooltip
remove the logic and always display comment box and question	1. Framework Section 2. Scenario Section 3. Technology Suggestions Section 4. Mobile Web Interactions Diagram Section 5. Use case Diagram Section 6. Scenario Technology Solution 7. Chosen Solution and Explanations	isurvey processing was slow therefore logic didn’t display question before user moved on to next question and processing icon at the top of page which was out of view unless scroll up

The participant who did the piloting questionnaire for accessibility expert suggested the changes as shown in Table 0-25

Table 0-26 Pilot Study Finding for accessibility expert questionnaire

Category of changes	What was changed?	Result of changes
Content		
spelling and grammar mistakes	1. Scenario Section 2. Technology Suggestions Section, Table 1, 2, 3 and 4 3. Scenario Technology Solution Section 4. Mobile Web Interactions Section 5. Chosen Solution and Explanations Section	make it correct and more understandable
isurvey System		
Choice, force entry to move on or just reminder	1. Framework Section 2. Scenario Section 3. Technology Suggestions Section 4. Mobile Web Interactions Diagram Section 5. Use case Diagram Section 6. Scenario Technology Solution 7. Chosen Solution and Explanations	remind the respondents to provide the answer but allow blank entry

The participants were satisfied with all the changes made. The updated version after the pilot study surveys are available at: https://www.isurvey.soton.ac.uk/6291 (Developer experts) and https://www.isurvey.soton.ac.uk/6577 (Accessibility Experts).

Expert Validation and Review Findings

Developer experts

Section 1: The Technology Enhanced Interaction Framework (TEIF)

Table 0-27 Developer experts validate and review TEIF

Questions	Expert 1	Expert 2	Expert 3
1. Are the instructions clear?	Yes	Yes	Yes
2. How can they be improved?		Consider explaining what they might be used for, in addition to the explanation of what they are. I see the examples, but not necessarily why you are capturing that information.	
3. Are the examples and explanations clear?	Yes	Yes	Yes
2a. How can they be improved?	'Object' is a very generic word (I may be influenced here as a CompSci who grew up with Object Oriented programming) is there a better word?		
4. Do you agree with the main and sub-components of the framework?	Yes	Yes	Yes
3a. How can they be improved?	Weather conditions seem like an oddly specific sub-component.		

As shown in Table 0-27, all the developer experts agreed that the instructions, examples and explanation of the framework are clear. Expert 2 suggested improving the instruction while Expert 1 suggested improving the examples and the explanation of the framework. All the experts agreed with the main and sub-components of the framework but expert 1 pointed out that a weather condition seems like an oddly specific sub-component.

Section 2: Evaluate the Scenario, Questions, and Answers

As shown in Table 0-28, all the developer experts agreed that the instructions of the section 2 are clear and expert 1 suggested a way to improve them.

Table 0-28 Developer experts validate and review the instruction of section 2

Questions	**Expert 1**	**Expert 2**	**Expert 3**
1. Are the instructions clear?	Yes	Yes	Yes
2. How can they be improved?	You could clarify what type of analysis is required from your participants.		

Table 0-29 Developer experts validate and review the requirement questions and multiple choices

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**
1. What is the main purpose of the technology solution?			
How can this question and multiple choices offered be improved?	I have a strong urge, having selected my answer to q3, to try other responses! Because I get this "we agree" response to my selection, I kinda want to say "well what if I had selected a different answer..."	I think that A and F are equally valid - the users have a bad experience in the example (they cannot hear), and therefore the proposal improves their experience.	-
How can this answer and explanation be improved?	More detail.	See above	-
2. Where and when does the scenario take place?			
How can this question and multiple choices offered be improved?	More detail.	-	-
How can this answer and explanation be improved?	More detail.	-	-
6. What language does the presenter use?			
How can this question and multiple choices offered be improved?	-	-	It would be better to enable people to choose more than one.
How can this answer and explanation be improved?	-	-	-
7. What language does the audience use?			
How can this question and multiple choices offered be improved?	-	-	It would be better to enable people to choose more than one.
How can this answer and explanation be improved?	-	-	-
8. Does the audience have a disability?			
How can this question and multiple choices offered be improved?	'Disability' can be an evocative word. People with disabilities sometimes say they are actively dis-abled by those around them who behave in ways to disable them. Be careful here!	-	-
How can this answer and explanation be improved?	See above	-	-
10. What level of hearing loss does the audience have?			
How can this question and multiple choices offered be improved?	-	-	
How can this answer and explanation be improved?	Quote the original scenario to explain why you say this!	-	(Expert 3 disagreed with the suggested answer c. I don't know and selected b. severe or profound hearing loss) The proposed framework/tool has to consider the worst level of hearing loss
11. What two interaction types occur in the scenario?			
How can this question and multiple choices offered be improved?	I think this is ok, but 'technology' is a bit of a subjective term. Puppets could be argued to be technology (likewise door handles, tables, etc.)		I think people to technology must be considered to. This regards how disable (hearing loss) people can easily use the technology.
How can this answer and explanation be improved?	Again, include quotes from the original text.		-
12. What type of technology would be appropriate for the solution to the scenario?			
How can this question and multiple choices offered be improved?	Both online and offline technology offer opportunities here! Give option d, either online or offline.	Note that printed programmes/transcripts would also be appropriate.	ONLY online? it will raise a problem when Wi-Fi is slow.
How can this answer and explanation be improved?	Quote the original.	It would be stronger to explain the benefits of online vs offline.	-

Table 0-30 Developer experts validate and review the requirement questions and multiple choices (Continued)

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**	**Requirement questions & multiple choices**
13. What type of technology devices would be appropriate for the solution to the scenario?				
How can this question and multiple choices offered be improved?	Offer the "both" option.	-		How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	Quote the original.	Mobile is appropriate because they can be used in the audience of the show, whereas fixed units would be more awkward.	-	How can this answer and explanation be improved?
14. Has the presenter planned what he wants to say?				
How can this question and multiple choices offered be improved?	But he might vary his original speech based on audience interaction! "Yes, mostly" maybe.	-		How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	Quote the original.	-	-	How can this answer and explanation be improved?
15. Are audios or videos shown in the scenario?				
How can this question and multiple choices offered be improved?	I'd use the word 'technology' above. Audio information is conveyed from Suchat!	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	Quote the original.	-	-	How can this answer and explanation be improved?
16. Where does the situation take place?				
How can this question and multiple choices offered be improved?	-	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	Quote the original scenario to explain why you say this!	-	-	How can this answer and explanation be improved?
17. What are the two main environmental considerations identified that impact the scenario?				
How can this question and multiple choices offered be improved?	-	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	-	The lip-reading aspect wasn't obvious to me at first, whereas room acoustics sounded more likely. I understand the explanation of the answer, though.	-	How can this answer and explanation be improved?
18. Does the customer require a low cost solution?				
How can this question and multiple choices offered be improved?	-	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	-	It doesn't explain why - the answer is probably just that this is not a high budget presentation.	-	How can this answer and explanation be improved?

As shown in Table 0-29 and Table 0-30, all the developer experts agreed that requirement questions and multiple choices number 3, 4, 5, 9 and 19 are fine while question 12 needs to be improved to make it clearer. Expert 1 and expert 2 suggested improving the multiple choice of question 1 because choice ‘a’ and ‘f’ seem equally valid. Expert 3 disagreed with the answer c (I don’t know) to question 10 and suggested that the answer should be b (severe or profound hearing loss) by giving reason The proposed framework/tool has to consider the worst level of hearing loss.

Table 0-31 Developer experts validate and review the questions related to section 2

Questions	Expert 1	Expert 2	Expert 3
60. How can the scenario be improved to make it easier to answer the questions?	Seems ok, but make it more accessible! I've scrolled way down; I'm miles from the scenario now so rereading it is hard.	No Suggestion, it was perfectly fine.	-
61. Was it helpful to have the requirement numbers next to the sub-components in the Technology Enhanced Interaction Framework table shown in the previous section?	No	No	Yes
62. Is there a better way to show the relationship between the Technology Enhanced Interaction Framework and the requirement questions?	Yeah, integrate the framework within the questions. Sentence one (requirements 1, 2). Sentence 2 (requirement 4). But only if you want to emphasise how it fits with them, not if you're doing a survey of laypeople.	-	-
63. Are there any questions, requirements, components or sub-components missing that would be relevant to the scenario?	No	No	No

As shown in Table 0-31, all the developer experts agreed that none of the main and sub-components is missing. Expert 1 suggested improving the way of presenting scenario because has to scrolled up and down which hard to re-read it. Expert 1 and expert 2 agreed that the requirement numbers next to the sub-components in the Technology Enhanced Interaction Framework table shown in the previous section wasn't helpful because they are far away to refer to those numbers.

Section 3: The Technology Suggestions

Table 0-32 Developer experts validate and review the Technology Suggestions

Questions	Expert 1	Expert 2	Expert 3
Technology suggestions: Table 1			
1. Are the descriptions of the technologies in Table 1 clear?	Yes	Yes	Yes
2. How can they be improved?	-	-	-
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 1?	Yes, I agree	Yes, I agree	Yes, I agree
4. Please explain	They look ok, except I don't understand the people-object column.	I agree, but since most of them are ticks, it feels like the framework hasn't differentiated much. If you want differentiation, you may wish to add more constructs.	-
Technology suggestions: Table 2			
1. Are the descriptions of the technologies in Table 2 clear?	Yes	Yes	Yes
2. How can they be improved?	-	-	-
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 2?	No, I do not agree	Yes, I agree	Yes, I agree
4. Please explain	Again, I don't understand the people-object column, but in what way doesn't a vibrating alert notify? Notification is its point!You could store a URL encoded in a barcode. Are induction loops cheaper than RFID readers?	Differentiation is better than the previous set.	-
Technology suggestions: Table 3			
1. Are the descriptions of the technologies in Table 3 clear?	Yes	Yes	Yes
2. How can they be improved?	-	-	-
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?	Yes, I agree	Yes, I agree	Yes, I agree
4. Please explain	-	-	-

As shown in Table 0-32, all the developer experts agreed that the descriptions of the technologies in Table 1 are clear and the ticks correctly identify the requirements met the technology suggested but the expert 1 mentioned that she doesn't understand the people-object column. Expert 2 suggested that since most of them are ticks, it feels like the framework hasn't differentiated much. If you want differentiation, you may wish to add more constructs.

All the developer experts agreed that the descriptions of the technologies in Table 2 are clear. Expert 1 disagreed that the ticks correctly identify the requirements met by the technology suggested in Table 2 and suggested using vibrating alert notify and store URL encoded in a barcode, and also considered the price between induction loops and RFID reader.

All the developer experts agreed that the descriptions of the technologies in Table 3 are clear and the ticks correctly identify the requirements met the technology suggested.

Section 4: Scenario Technology Solution

Table 0-33 Developer experts validate and review the Scenario Technology Solution

Questions	**Expert 1**	**Expert 2**	**Expert 3**
1. Is the scenario solution clearly described?	Yes	Yes	Yes
2. How can the scenario solution description be improved?	It's great!	-	-
3. Does the solution meet the scenario requirements?	Yes	Yes	Yes
4. How can the solution be improved?	It seems good.	It sounds like it would work as described.	-

As shown in Table 0-33, all the developer experts agreed that the Scenario Technology Solution is clearly described and meet the scenario requirements.

Section 5: The Mobile Web Interactions Diagram

Table 0-34 Developer experts validate and review the Use Case Diagram

Questions	**Expert 1**	**Expert 2**	**Expert 3**
1. Does the Mobile Web Interactions diagram help understand the scenario solution?	Yes	Yes	Yes
2. How can it be improved?	The numbers are meaningless without a key to remind your readers of what they mean.	Number 7 Jumps from Audience to Presenter. It would also be useful to clearly mark Number 1, as I had to hunt around for it. This view is actor-oriented, each block represents a person - it might be clearer if it were a state diagram instead - not sure.	Regarding the numbering of actions in the figure, I assume that all actions are sequential. Is it true that there are no parallel actions?

As shown in Table 0-34, all the developer experts agreed that the Mobile Web Interactions Diagram helps understanding the scenario solution and suggested the way to improve the diagram by explaining the numbers and mark the starting number of the actions clearer.

Section 7: Chosen Solution and Explanations

Table 0-35 Developer experts validate and review the Chosen Solution and Explanations

Questions	**Expert 1**	**Expert 2**	**Expert 3**
1. Is the explanation of how the solution was derived from the suggestions easy to understand?	Yes	Yes	Yes
2. How can it be improved?	It's fine.	-	-

As shown in Table 0-35, all the developer experts agreed that the explanations of Chosen Solution and Explanations was derived from the suggestions and easy to understand.

Validation and Reviewing the TEIF

Table 0-36 Developer experts validate and review the TEIF

Questions	Expert 1	Expert 2	Expert 3
1. Do you agree that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people?	Yes, I agree	Yes, I agree	Yes, I agree
2. How can the framework with associated questions and suggestions be improved?	Break it down into small steps for users. And put the easier steps first to ease them into it!	-	The associated questions and suggestions are useful as long as they come from people represented Suchat and Chuty.
3. Are there any comments you would like to make about the framework?	How was it developed?	I think the framework does help isolate specific issues - something the importance of specific issues are not clear to software engineers, and development time can increase as a result - this framework feels like it may improve in that area.	-

As shown in Table 0-36, all the developer experts agreed that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people. Expert 1 and expert 3 suggested the ways to improve the framework with associated questions and suggestions. Expert 1 stated that break the framework method down into small steps for users. And put the easier steps first to ease them into it. Expert 3 mentions that the associated questions and suggestions are useful as long as they come from people represented (Suchat and Chuty). Expert 2 provided the comment that he agreed that the framework does help isolate specific issues but something the importance of specific issues are not clear to software engineers, and development time can increase as a result. However, the expert 1 has doubt about "How was the framework developed?"

Accessibility Experts

Section 1: Evaluate the Scenario, Questions, and Answers

Table 0-37 Accessibility experts validate and review the instruction of section 1

Questions	Expert 1	Expert 2	Expert 3
1. Are the instructions clear?	No	No	Yes
2. How can they be improved?	I am unclear as to which set of instructions question 1 is referring! If question 1 is referring to the instructions beginning 'Please read and analyse...' then the following improvements could be made: explain what the Technology Enhanced Interaction Framework is; provide an example and/or diagram of the process; clarify what the requirement numbers are for (and explain using the present tense). If question 1 is referring to the scenario then it is unclear what the instructions are; there appear to be no direct instructions in the scenario.	It is unclear "what does instructions mean?" "Does it mean the instructions in the scenario?"	-

As shown in Table 0-37, expert 1 and 2 pointed out that the instructions of the section 1 are unclear but expert 1 stated that the instructions are clear. Both expert 1 and 2 suggested that should provide the meaning of instructions and clarify the requirement numbers if questions are referring to the scenario.

Table 0-38 Accessibility experts validate and review Requirement Questions, and Answers

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**
1. What is the main purpose of the technology solution?			
How can this question and multiple choices offered be improved?	By 'this question' I am assuming question 3? In which case the question and multiple answers are fine (choice (f) is perhaps a bit vague). However, it might be worth having a question about whether or not a technology solution is needed in the first place. BTW, the text boxes that I am using to input my answers are rather small and awkward to use!	Too long for a screen reader user. a) was my answer and it was clear but f) could have also been correct so there was a dilemma.	-
How can this answer and explanation be improved?	The answer is fine. The explanation is simply a repeat of what was given in the scenario and could perhaps be more clearly linked to option (a).	-	-
2. Where and when does the scenario take place?			
How can this question and multiple choices offered be improved?	I think this question is phrased rather confusingly. It could be broken down into two simpler questions - something like: 'Are the people in the scenario in the same place or in different places?' and 'Are the people in the scenario present at the same time or different times?'	Explain what you mean time and place that as not obvious that Suchat was opening his house when Chuty visit. They have to be in the same time and at the same place.	
How can this answer and explanation be improved?	The answer and explanation are fine.	-	
3. What main role do people have in the scenario?			
How can this question and multiple choices offered be improved?	Modify the question slightly to 'What main roles do the people have in the scenario?' Rephrase choice (a) slightly so that it reads '(the "presenter" controls the interaction by giving information to the "audience", which could be...). In choice (b) insert 'the' between 'controls' and 'interaction'. In choice (c) insert a comma after 'people' or put 'only interaction with technology or objects' in parentheses.	-	-
How can this answer and explanation be improved?	The answer and explanation are fine.	-	-
4. How many presenters and audience members are there?			
How can this question and multiple choices offered be improved?	As long as question 12 follows question 9 (about roles) the question and choices are fine. I guess you could add 'in the scenario' to the question.	-	-
How can this answer and explanation be improved?	The answer is fine. I think the explanation is a little awkward. How about 'Suchat is the presenter and his role in the scenario is to give information to Chuty and her parents who are members of the audience'?	-	-
5. Does the presenter have a disability?			
How can this question and multiple choices offered be improved?	The scenario does not mention that the presenter has a disability, but I am uncomfortable assuming that. Perhaps rephrase the question to 'Does the scenario suggest that the presenter has a disability?'	-	-
How can this answer and explanation be improved?	The answer is fine. The explanation could perhaps be 'The scenario does not suggest that Suchat has a disability'.	-	The scenario does not provide the answer to this so it would be better to state this in the scenario "Suchard, who has no disability"

Table 0-39 Accessibility experts validate and review Requirement Questions, and Answers (continued 1)

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**	**Requirement questions & multiple choices**
6. What language does the presenter use?				
How can this question and multiple choices offered be improved?	The question is fine provided that the question about roles (who is the presenter and who are the audience) has been answered first. The choices are fine.	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are fine.	-	The scenario does not provide the answer to this so it would be better to state this in the scenario	How can this answer and explanation be improved?
7. What language does the audience use?				
How can this question and multiple choices offered be improved?	I assumed that the audience used Thai, but it is not explicit in the scenario - perhaps the question should be 'Based on the information given in the scenario, what language do you assume the audience are using?'	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are ok. I quickly Googled 'Thailand' and 'languages' and it appears that several languages (and dialects) are spoken in Thailand in addition to the official language - it might be worth bearing this in mind!	-	The scenario does not provide the answer to this so it would be better to state this in the scenario	How can this answer and explanation be improved?
8. Does the audience have a disability?				
How can this question and multiple choices offered be improved?	If you use 'audience' as a singular noun it sounds odd to apply the attribute of 'disability' to the audience as a collective. I think it would be clearer to ask 'Do members of the audience have a disability?' The words 'disability' and 'disabled' can also be controversial. Many Deaf people do not view themselves as being 'disabled'. The choices are fine.	Do any member of the audience have unknown disability? They could be hidden disability.	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are fine provided that the question about roles precedes this question.	-	-	How can this answer and explanation be improved?
9. What kind of disability do the audiences have?				
How can this question and multiple choices offered be improved?	Here you use 'audience' as a plural noun ('do' versus 'does'), but I would still add 'members' to make it clear as in: 'What kind of disability do the audience members have?' or (slightly more general) 'What kind of disability do members of the audience have?' The choices are ok.	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer is fine. I'm not keen on 'at birth' and 'due to their age' in the explanation. I would prefer something like 'Chuty has had a hearing impairment since birth and her parents both have age-related hearing loss.'	-	-	How can this answer and explanation be improved?

Table 0-40 Accessibility experts validate and review Requirement Questions, and Answers (continued 2)

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**	**Requirement questions & multiple choices**
10. What level of hearing loss does the audience have?				
How can this question and multiple choices offered be improved?	I find this question confusing - it does not make sense to ask about the degree of hearing loss of the audience as a collective. Perhaps ask about the degree of hearing loss of individual audience members instead? I think the choices may be confusing for people who are unfamiliar with the classifications used for degrees of hearing loss. A respondant might answer '(c) I don't know' because they are unsure what the classifications mean rather than picking up on the fact that not enough information is provided in the scenario.	Change to "What level of hearing loss do members of the audience have?"	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are fine.	-	The scenario does not provide the answer to this so it would be better to leave this question out or state this in the scenario (e.g. No information is available about the level of hearing loss)	How can this answer and explanation be improved?
11. What two interaction types occur in the scenario?				
How can this question and multiple choices offered be improved?	The question asks what two interaction types occur in the scenario. I would argue that only one interaction type actually occurs (people to people). In the scenario Suchat would like a 'people to technology to people' interaction, but this hasn't actually occurred yet. The choices are fine.	-	-	How can this question and multiple choices offered be improved?
12. What type of technology would be appropriate for the solution to the scenario?				
How can this question and multiple choices offered be improved?	This question assumes that a technological solution would be an appropriate solution, but there may be other, simpler non-technological solutions to this problem! I am also not convinced by the argument that, because there is good Wi-Fi at the museum, the most appropriate technological solution would involve online technology. Perhaps the question should read 'Suchat would like a technological solution that uses the museum's Wi-Fi. What type of technology would be appropriate?'	It is unclear between online and offline technology. The online technology "have to be internet + smartphone" can't be on its own.	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are fine.	Maybe say " online technology using wifi "	there might be an offline app (e.g. speech recognition?) that would be appropriate so it would be better to state that an online solution is required	How can this answer and explanation be improved?

Table 0-41 Accessibility experts validate and review Requirement Questions, and Answers (continued 3)

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**	**Requirement questions & multiple choices**
13. What type of technology devices would be appropriate for the solution to the scenario?				
How can this question and multiple choices offered be improved?	Again this question assumes that a technological solution is required. I chose option '(a) mobile devices' only because I knew what the survey expected of me! Perhaps the question should be 'What type of technology devices does Suchat want to use?'	-	What type of technology devices would Suchat prefer for the solution to the scenario?	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are fine, although I can't help wondering how Suchat knows that Chuty and her parents have smartphones!	-	-	How can this answer and explanation be improved?
14. Has the presenter planned what he wants to say?				
How can this question and multiple choices offered be improved?	-	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	-	Suchat has already prepared his talk for the visitors (pre-prepared speech).	-	How can this answer and explanation be improved?
15. Are audios or videos shown in the scenario?				
How can this question and multiple choices offered be improved?	It is unclear what is meant by 'audios' in the question (audio can just mean an audible sound and so could include Suchat's speech) and 'audio' is not 'shown'. The question might be better phrased, 'Are audio recordings or videos used in the scenario?'	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	I disagree with the answer and explanation. The music is described as being 'part of the show'. Music is important for setting the scene and conveying emotion!	-		How can this answer and explanation be improved?

Table 0-42 Accessibility experts validate and review Requirement Questions, and Answers (continued 4)

Requirement questions & multiple choices	**Expert 1**	**Expert 2**	**Expert 3**	**Requirement questions & multiple choices**
17. What are the two main environmental considerations identified that impact the scenario?				
How can this question and multiple choices offered be improved?	The question is ok. Choice (a) implies that the music is unwanted 'noise', but I am not convinced that we can assume this from the scenario. If the music is part of the show it may be desirable (but just not at the same time as the speech)! I would also change 'students' to 'individuals' and 'mark' to 'mask'. The description of reverberation in choice (b) is unclear. Choice (c) assumes the audience is a student. Check the grammar in choice (e) - '...for deaf or hard of hearing [members of the] audience, because...' and 'speaker's face'. Choices (a) and (e) are also the only choices that mention deaf or hard of hearing audiences, making these choices obvious.	-	better to not include (b) as choice	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answers are fine. In the explanations change 'music background' to 'background music', remove the space between 'background' and the comma and add a space between the comma and 'which'. Include a comma after 'dark'.	-	-	How can this answer and explanation be improved?
18. Does the customer require a low cost solution?				
How can this question and multiple choices offered be improved?	The role of 'customer' has not been introduced until now. 'Customer' could also apply to people visiting Suchat's museum.	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer is fine. The explanation implies that smartphones will keep Suchat's costs low, but maybe there is a lower cost alternative?	It is the first time you have used the word customer - Is Suchat your customer? I assume so.	-	How can this answer and explanation be improved?
19. Should the technology solution work on a smart phone?				
How can this question and multiple choices offered be improved?	'Should the technology solution work on a smart phone?' is a bit unclear as a question - we don't know what the proposed solution is yet and it may not work on a smartphone. Perhaps the question should be 'Would Suchat like the technology solution to work on a smartphone?'	-	-	How can this question and multiple choices offered be improved?
How can this answer and explanation be improved?	The answer and explanation are fine.	-	-	How can this answer and explanation be improved?

As shown in Table 0-37 -042 all the experts agreed that only requirement question 16 is fine while other 18 requirement questions and multiple choices need to be improved. Expert 1 and expert 2 suggested improving the multiple choice of question 1 because choice ‘a’ and ‘f’ both can be the answer.

Table 0-43 Accessibility experts validate and review the questions related to section 2

Question	Expert 1	Expert 2	Expert 3
60. How can the scenario be improved to make it easier to answer the questions?	-	It is a long way to scroll up and down - all the time - that is if you need to re-read.	see answers above

As shown in Table 0-43, experts 2 suggested that the requirement questions and answers are a long way to scroll up and down all the time that need to re-read the scenario.

Section 2: The Technology Suggestions

Table 0-44 Accessibility experts validate and review the questions for section 2

Questions	**Expert 1**	**Expert 2**	**Expert 3**
Technology suggestions: Table 1			
1. Are the descriptions of the technologies in Table 1 clear?	No	Yes	Yes
2. How can they be improved?	Less text, larger font, avoid jargon and undefined acronyms (e.g. URL, IM) and show an image where possible. In the FAQ section change 'FQA' to 'FAQ'. The explanation of captioning 'Captions are text versions of the spoken word' is not particularly helpful. I would also avoid descriptions that are subjective (e.g. 'It is very useful...' and 'This is very simple, easy...'. The web links are useful.	Check SMS. SMS has same information as IM	-
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 1?	-	Yes, I agree	Yes, I agree
4. Please explain	I cannot answer question 3 - there are too many ticks and the explanations are not in a consistent format. It would take me too long to seriously consider them all!	The ticks match the technology suggestions.	-
Technology suggestions: Table 2			
1. Are the descriptions of the technologies in Table 2 clear?	No	Yes	Yes
2. How can they be improved?	Again, there is too much text - images would be helpful.	ok	-
Questions	**Expert 1**	**Expert 2**	**Expert 3**
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 2?	-	Yes, I agree	Yes, I agree
4. Please explain	Again, I can't answer question 3 - there are too many ticks to go through and the format of the explanations varies, which doesn't help.	ok	-
Technology suggestions: Table 3			
1. Are the descriptions of the technologies in Table 1 clear?	Yes	No	Yes
2. How can they be improved?	-	Improve the flashing light one. Explain it clearer.	no Q4 box provided following Q3 to say how tooltip could be improved 16 + 12a & 13a tooltip should say 'used' not 'uses
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?	Yes, I agree	Yes, I agree	Yes, I agree
4. Please explain	-	-	-

Table 0-45 Accessibility experts validate and review the questions for section 2 (continued 1)

Questions	Expert 1	Expert 2	Expert 3	Questions
Technology suggestions: Table 3				
1. Are the descriptions of the technologies in Table 1 clear?	Yes	No	Yes	1. Are the descriptions of the technologies in Table 1 clear?
2. How can they be improved?	-	Improve the flashing light one. Explain it clearer.	no Q4 box provided following Q3 to say how tooltip could be improved 16 + 12a & 13a tooltip should say 'used' not 'uses	2. How can they be improved?
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?	Yes, I agree	Yes, I agree	Yes, I agree	3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 3?
4. Please explain	-	-	-	4. Please explain
Technology suggestions: Table 4				
1. Are the descriptions of the technologies in Table 1 clear?	No	Yes	Yes	1. Are the descriptions of the technologies in Table 1 clear?
2. How can they be improved?	See my comments for Tables 1, 2 & 3.	Some quick English language changes.	-	2. How can they be improved?
3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 4?	-	Yes, I agree	Yes, I agree	3. Do you agree that the ticks correctly identify the requirements met by the technology suggested in Table 4?
4. Please explain	See my comments for the tick explanations in tables 1, 2 & 3.	ok	The scenario doesn't state they don't sign so need to state it	4. Please explain

As shown in Table 0-44 and table 0-45, expert 2 and 3 agreed that the descriptions of the technologies in Table 1 are clear and the ticks correctly identify the requirements met the technology suggested but the expert 2 pointed out that the there is a repeated information in SMS and IM. Expert 1 disagreed about the descriptions and the ticks and suggested that providing less text, larger font, avoid jargon and undefined acronyms and also spot the spelling mistakes and some grammar improvement.

Expert 2 and 3 agreed that the descriptions of the technologies in Table 2 are clear and the ticks correctly identify the requirements met the technology suggested. Expert 1 disagreed about the descriptions and commented that too many ticks to consider and lots of information.

Expert 1 and 3 agreed that the descriptions of the technologies in Table 3 are clear while expert 2 disagreed and suggested improving the description of the flashing lighting clearer. Expert 3 suggested providing the question asking “How tooltip could be improved?” and also suggested improving grammar. All experts agreed that the ticks correctly identify the requirements met by the technology suggested in Table 3.

Expert 2 and 3 agreed that the descriptions of the technologies in Table 4 are clear while expert 2 disagreed and suggested provide less text but more images. Expert 3 suggested providing the question asking “How tooltip could be improved?” and also suggested improving grammar. Expert 2 and 3 agreed that the ticks correctly identify the requirements met by the technology suggested in Table 3 while expert 1 didn’t provide the answer by giving reason that there is too much information.

Section 3: The Scenario Technology Solution

As shown in Table 0-46, expert 1 and 3 agreed that the Scenario Technology Solution is clearly described and meet the scenario requirements and expert 1 suggested some grammar improvement. Expert 2 stated that there is some problem in the Scenario Technology Solution and suggested that the way to improve the solution by adding “proving devices in case the visitors do not have their own devices”. Expert 3 also suggested explaining more about Thai speech recognition in the solution.

Table 0-46 Accessibility experts validate and review the Scenario Technology Solution

Questions	Expert 1	Expert 2	Expert 3
1. Is the scenario solution clearly described?	Yes	No	Yes
2. How can the scenario solution description be improved?	Add a comma after 'Suchat starts speaking' and remove the comma after 'first topic'.	some problems!	-
3. Does the solution meet the scenario requirements?	Yes	Yes	No
4. How can the solution be improved?	-	loaning out wifi connected tablets or phones if the visitors do not have their own devices	The technology suggestions stated that Thai speech recognition didn't work? even if it did wouldn't it be strange for Chuty to speak into her phone while Suchard is presenting?

Section 4: The Chosen Solution and Explanations

As shown in Table 0-47, all developer experts agreed that the explanations of Chosen Solution and Explanations was derived from the suggestions and easy to understand. Expert 3 suggested discussing the use of speech recognition by the users (Chuty and her parents).

Table 0-47 Accessibility experts validate and review the Chosen Solution and Explanations

Questions	Expert 1	Expert 2	Expert 3
1. Is the explanation of how the solution was derived from the suggestions easy to understand?	Yes	Yes	Yes
2. How can it be improved?	Sorry - I have run out of time. This survey has taken me too long!	ok	pressing a button on a website to send a message to a server is not instant messaging "The technology solution selected to enable this is the instant messaging which was chosen over sms, the other possible technology solution suggested, because it is free of cost using wireless and smartphones. " The use of speech recognition by chuty is not discussed

Experts validation and review TEIF

As shown in Table 0-48, all expert1 and 3 agreed that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people while expert 2 disagreed and provided the reason that it is hard to read the table on the small screen. Expert 2 also comment on the framework that it is a partial solution as there may be so many other variables such as dexterity of the older people using the mobile phones.

Table 0-48 Accessibility experts validate and review the TEIF

Questions	Expert 1	Expert 2	Expert 3
1. Do you agree that the framework with its associated questions and suggestions can help developers design technology to enhance interactions particularly in complex situations involving disabled people?	Yes, I agree	No, I do not agree	Yes, I agree
2. How can the framework with associated questions and suggestions be improved?	-	May be hard to read the tables on small screens	you haven't shown me the framework
3. Are there any comments you would like to make about the framework?	-	It is a partial solutions as there may be so many other variables such as dexterity of the older people using the mobile phones etc. But I love the idea and would like to link it to EmpTech!	-

Conclusion

An accessibility expert and two developer/developer experts were asked to undertake the pilot study. The three pilot study participants made suggestions and comments on content and the isurvey system. Changes were made following the suggestions and comments. The pilot study participants were satisfied with all the changes. Six experts were chosen to review and validate the Framework based on their expertise and experiences. Three experts were developer/developer experts, the other three were accessibility experts. Both groups of experts were asked to validate and review the framework in a slightly different way via an online survey (isurvey). The developer/developer experts focused on the framework and interaction and use case diagram, whereas the accessibility experts were asked to check the descriptions and explanations of the technology suggestions

Appendix G. Scenario Transcript

A. Report

Chuty, a hearing impaired businesswoman in her 30s, who lives in Thailand, would like to visit the Shadow Puppet Museum, as her local friends have suggested as a good place. Chuty has had a hearing impairment since birth but because of her intelligence and her family's support has managed to become successful.

When Chuty enters the museum, she meets Suchat Trapsin who allocated some parts of his house to become the Museum of Folk Art and Shadow Puppets. Suchat says that he wished he had a better parking facility for visitors. There are exhibits of shadow puppets inside the museum, but there is no information provided in text format because Suchat normally explains the history and tradition in Thai by talking to visitors. He presents the same information in the same order every time. Suchat starts the talk by explaining about the exhibits. During the talk, Chuty finds it very difficult to hear Suchat clearly. Chuty asks Suchat some questions about the exhibits. Suchat answers the questions while pointing at the exhibits, but Chuty misses some of the words and also cannot look at the exhibits while Suchat is talking as then she wouldn't be able to lip-read him. While Chuty is watching the shadow puppet show which is performed by Suchat, they cannot hear the conversation clearly because of the background music which is part of the show. It is also fairly dark which makes lip-reading very difficult for them. Suchat would like to have a technology solution that makes it easier for Chuty to understand him. There is good Wi-Fi at the museum so he would like to use Chuty's smartphone to keep his costs low.

There is a shop in the museum that sells souvenirs. Chuty thinks the prices are quite high but Suchat tells her this is because everything is hand made. Chuty suggests that Suchat should find a cheaper way to manufacture them. Since, Chuty has not eaten for many hours and are hungry but there is no food or drink available in the museum and near by. As Chuty has stayed at the museum so long, so she would like to go to the toilet. Unfortunately, there is only one toilet provided at the museum, which make it difficult for both Suchat's family and visitors. Chuty gets very wet from the heavy rain as she walks between the many separate small buildings that make up the museum. Chuty sends an email to her friend who had visited the museum previously. Her local hearing friend was able to explain some more details about the show that Chuty had not understood.

B. Interview

<u>Interview Transcript:</u> *Verbatim Transcript of Interview with Suchat Trapsin, the Thai owner of the Museum of folk art and Shadow Puppets who is the presenter of the shadow puppet show there and has lived in Thailand all his life and only speaks Thai.*

Interviewer: *"Can you tell me about your recent visitor"*

Suchat: *"Chuty is a very successful Thai businesswoman in her 30s who has lived in Thailand all her life and only speaks Thai. She became hearing impaired in her twenties and depends completely on her hearing aids and lip-reading. She speaks clearly and I had no problem understanding her".*

Interviewer: *"Why did Chuty visit the Shadow Puppet Museum?"*

Suchat: *"Her friend suggested the Shadow Puppet Museum was a good place to visit as she is very interested in Thai culture".*

Interviewer: *"Did she find the museum easily?"*

Suchat: *"No, because her GPS device lost its signal".*

Interviewer: *"Did she have any problems when she arrived at the museum?"*

Suchat: *"There is no proper car park, only a dirt drive with trees by the side. I would like to find a way to provide better parking facilities for visitors".*

Interviewer: *"What happened next?"*

Suchat: *"I was in the wooden shadow puppet theatre and picked up and rang a tiny metal bell to start the museum tour. All the visitors then came into the theatre except for Chuty and so I had to go and fetch her. I gave a tour by explaining about the museum in Thai. I know I talk very quietly".*

Interviewer: *"Did she find the exhibits interesting?"*

Suchat*: She asked me some questions about the shadow puppets exhibits and I answered by talking at the same time as pointing at the shadow puppets exhibit I was referring to. She touched the shadow puppets to feel the old original_leather. She got very wet from the heavy rain as she walked between the separate buildings.*

Interviewer: *"How about the Shadow Puppet show?"*

Suchat*: During my presenting of the shadow puppet show, there is loud background music. I also perform the show in the dark and after presenting my introduction to the show I go behind a screen to operate the puppets and talk for them. She felt quite tired as she had not eaten for many hours and so was hungry but there is no food or drink available in the museum. The prices of the puppets sold in the shop were rather high for her and it would be good if I could find a cheaper way to make them.*

Interviewer: *"So did she miss lots of information?"*

Suchat*: There is good Wi-Fi at the museum so she emailed her friend who had visited the museum and he emailed back some details about the show that she had not understood when I talked".*

Interviewer: *"Do you have any suggestions to help improve the museum?"*

Suchat: *"Oh yes. There is only one toilet for both my family and visitors which was very inconvenient for us."*

Interviewer: *"How much money could you afford to spend on any improvements to the museum?"*

Suchat*: "I have very little money to spend on any devices".*

Interviewer: *"Do you change your talk frequently?"*

Suchat*: "No, I have been running the museum in my home for 30 years and so now normally I present the same information in the same order every time when I gave my museum talk and shadow puppet show".*

Interviewer: *"Why is no written information provided for visitors?"*

Suchat*: "Shadow puppets are part of a verbal story telling culture".*

Interviewer "Is there anything else you would like to tell me?"

Suchat*: "I get very tired talking and standing all day as I am 70 years old but thankfully don't have any disability".*

Appendix H. User Evaluation Material - TEIF Method

Participant Sheet for TEIF Method Group

Study Title: User Evaluation of the Technology Enhanced Interaction Framework and Method

Researcher: Kewalin Angkananon

Ethics number: 8194

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

The purpose of this study is to evaluate the use of the Technology Enhanced Interaction Framework and associated method to help technology designers or developers who are not accessibility experts design technology solutions to interaction issues (i.e. problems) encountered by disabled people. This evaluation is to be achieved by asking participants questions about the materials presented. Some participants will use the Technology Enhanced Interaction Framework and others will use whatever method(s) they choose.

Why have I been chosen?

You have been approached to participate in this study because you are a technology designer or developer with a computing related qualification at degree level who is not also an accessibility expert.

What will happen to me if I take part?

From an interview transcript you will identify from the choices provided the best requirements and designs for a technology solution to the interaction issues encountered by the disabled person involved. You will also be asked to answer some questions about your experience. This study can be expected to take between one hour and one and a half hours.

Are there any benefits in my taking part?

By taking part, you have the opportunity to assist the development of a new method to help design technology for complex situations involving disabled people.

Are there any risks involved?

There is no risk involved in taking part in this study. It is important to note that you are welcome to pause for a rest, or fully withdraw from the study, at any time.

Will my participation be confidential?

Your data will be kept confidential. It will be held on a password protected computer, and used only for the purposes of this study. In addition, the data will be anonymised by separating identifying data. It will be linked to your consent form by an ID number. If you would like to access your data after your participation, change it, or withdraw it, please contact the investigator (ka3e10@ecs.soton.ac.uk).

What happens if I change my mind?

You have the right to withdraw at any time without your legal rights being affected.

What happens if something goes wrong?

If you have a concern or complaint, please contact the ECS School Office on school@ecs.soton.ac.uk or school@ecs.soton.ac.uk02380 592909.

Where can I get more information?

Feel free to get in touch with Kewalin Angkananon: ka3e10@ecs.soton.ac.uk

Glossary

The following glossary helps clarify the meaning of some terms used:

Term	**Meaning**
Disability	A physical or mental impairment that has a substantial and long-term negative effect on ability to do normal daily activities
Hearing impaired person	A person who has a permanent hearing loss or a decrease in hearing that has a substantial and long-term negative effect on their ability to hear.
Shadow Puppet	A model of a person or animal that is moved by pulling wires or strings and used in the dark with a light source to project a shadow from behind a screen
Spontaneous speech	Words spoken that have not been planned
Pre-prepared speech	Words spoken that have been planned
Lip-reading	Watching the way someone's lips move to help understand what they are saying
Sign language	A language that uses hands, face and other body movements instead of spoken words
Hearing aid	Battery-powered, electronic device consisting of a microphone, amplifier and receiver that makes sounds louder for people with a hearing loss.
Notification	The act of informing somebody about something
Background noise	Any sound that is not the sound that you are specifically listening for
Hard surface	A solid, firm, and rigid surface (e.g. Glass, Wood, Concrete)
An observer has visual access to somebody or something	There is nothing blocking the line of sight of the observer and there is adequate lighting.
presenter	A person who presents a tour or show
audience	Spectators or listeners at an event such as a show

TEIF STEP 1: Identify interaction types

The Technology Enhanced Interaction Framework (TEIF) has 5 interactions types described in Table 1

Task Purpose: Check whether you can identify these types

Instruction: Please read the 5 types of interaction in Table 1 and match each of them with one of the following 5 sentences by writing the corresponding letter A-E in the column marked 'Match'.

A. Suchat rang the tiny metal bell to let Chuty know when the tour started.

B. Chuty uses GPS to navigate to the museum.

C. Chuty uses her mobile phone to scan QR-codes on an object to get further information.

D. Suchat gave a museum tour by explaining about the museum in Thai and Chuty asked him some questions.

E. Chuty touches the puppets in order to feel the leather.

Table 0-49 Interaction Types

Interaction Type	Description	Match
People-People (P-P)	People have abilities (e.g. speak Thai) and disabilities (e.g. hearing impairment), which could lead to communication breakdown. A person has a role when communicating with others and roles normally come in pairs (e.g. presenter and audience). People communicate verbally (speak, listen, ask, answer) and non-verbally (lip-read, smile, touch, sign, gesture, nod). When communicating, people may refer (speak or point) to particular objects or technology – this is known as deixis. People can communicate spontaneously or using pre-prepared speech.	
People-Objects (P-O)	Objects are 'real' (e.g. exhibit at museum) and can be anything that is not a technology or a person involved in communication or interaction. Objects have dimensions, colour, shape and size and can have content, which can be human readable (e.g. text printed on exhibit at museum) or machine readable (e.g. QR code printed on exhibit at museum). People interact with objects for two main purposes: controlling (e.g. touch, hold or move), and retrieving information (e.g. look, listen, read, in order to get information or construct personal understanding and knowledge).	
People-Technology (P-T)	Technology is a tool that helps people achieve their purpose. Technology has a cost and can be online and mobile and electronic (e.g. smartphone) and non-electronic (e.g. metal bell). People control technology (e.g. hold, move, use, type, scan, make image, press, and swipe) and transmit, store or retrieve information (e.g. send, save, store, search, retrieve).	
People-Technology-People (P-T-P)	People use technology to transmit information to assist communication with other people. This can include sending sms, mms, email, chat, instant messages or notifying through sounds, vibration or light.	
People-Technology-Objects (P-T-O)	People use technology (e.g. point, move, hold, scan QR codes, scan AR tag, use camera, use compass) to transmit, store, and retrieve information (send, save, store, search, retrieve) to, in, and from objects.	

TEIF STEP 1 : Answer and explanations

ANSWERS

People-People (P-P) **D**
Explanation: Suchat (P) communicates with Chuty (P).
People-Objects (P-O) **E**
Explanation: Chuty (P) interacts with the puppets (O).
People-Technology (P-T) **B**
Explanation: Chuty (P) interacts with GPS (T).
People-Technology-People (P-T-P) **A**
Explanation:.Suchart (P) used the bell (T) to communicate with Chuty (P).
People-Technology-Objects (P-T-O) **C**
Explanation: Chuty (P) uses mobile phone (T) to interact with objects (O)

TEIF STEP 2: Analyse how interactions are affected by hearing impairment

Purpose: help you to analyse the interaction issues affected by hearing impairment

Instruction:

1) Please read the interview transcript and answer (✓) the following questions about it. The ○ symbol means you can choose only one answer. The ☐ symbol means you can choose more than one answer.

2) Please also where possible underline the words in the transcript that helped you with each answer and write the number of question and answer choice you select (e.g. 15a) above the underlined words on the interview transcript sheet (note that if the same words help with more than 1 answer you should write the numbers of all the relevant question answer choices).

Interview Transcript: *Verbatim Transcript of Interview with Suchat Trapsin, the Thai owner of the Museum of folk art and Shadow Puppets who presents the shadow puppet show there.*

Interviewer: "Can you tell me about your recent visitor"
Suchat: "*Chuty is a very successful Thai businesswoman in her 30s who has lived in Thailand all her life. She became hearing impaired in her twenties and depends completely on her hearing aids and lip-reading.*
Interviewer: "Why did Chuty visit the Shadow Puppet Museum?"
Suchat: "Her friend suggested the Shadow Puppet Museum was a good place to visit as she is very interested in Thai culture".
Interviewer: "Did she find the museum easily?"
Suchat: "No, because her GPS device lost its signal".
Interviewer: "Did she have any problems when she arrived at the museum?"
Suchat: "There is no proper car park, only a dirt drive with trees by the side. I would like to find a way to provide better parking facilities for visitors".
Interviewer: "What happened next?"
Suchat: "I was in the wooden shadow puppet theatre and picked up and rang a tiny metal bell to start the museum tour. All the visitors then came into the theatre except for except for Chuty and so I had to go and fetch her. I gave a tour by explaining about the museum in Thai. I know I talk very quietly".
Interviewer: "Did she find the exhibits interesting?"
Suchat: She asked me some questions about the shadow puppets exhibits and I answered by talking at the same time as pointing at the shadow puppets exhibit I was referring to. She touched the shadow puppets to feel the old original_leather. She got very wet from the heavy rain as she walked between the separate buildings.
Interviewer: "How about the Shadow Puppet show?"
Suchat: During my performance of the shadow puppet show, there is loud background music. I also perform the show in the dark and after presenting my introduction to the show I go behind a screen to operate the puppets and talk for them. She felt quite tired as she had not eaten for many hours and so was hungry but there is no food or drink available in the museum. The prices of the puppets sold in the shop were rather high for her and it would be good if I could find a cheaper way to make them.
Interviewer: "So did she miss lots of information?"
Suchat: There is good Wi-Fi at the museum so she emailed her friend who had visited the museum and he emailed back some details about the show that [12a]she had not understood when I talked".
Interviewer: "Do you have any suggestions to help improve the museum?"
Suchat: "Oh yes. There is only one toilet for both my family and visitors which was very inconvenient for us."
Interviewer "How much money could you afford to spend on any improvements to the museum?"
Suchat: "I have very little money to spend on any devices".
Interviewer "Do you change your talk frequently?"
Suchat: "No, I have been running the museum in my home for 30 years and so now normally I present the same information in the same order every time when I gave my museum talk and shadow puppet show".
Interviewer: "Why is no written information provided for visitors?"
Suchat: "Shadow puppets are part of a verbal story telling culture".
Interviewer "Is there anything else you would like to tell me?"
Suchat: "I get very tired talking and standing all day as I am 70 years old but don't have any disability".
Interviewer: "Thank you".

1) What main role did people have in the scenario?
- ○ a. presenter - audience (the presenter controls the interaction and gives information to the "audience" which could be only one person or many people. The audience can ask the presenter questions).
- ○ b. peer - peer (any person can give information or ask questions to any other person and therefore no one person controls interaction)
- ○ c. I don't know

2) Did the presenter have a disability?
- ○ a. Yes
- ○ b. No

3) Did any of the audience have a disability?
○ a. Yes
○ b. No

3) What kind of disability did any of the audience have?
○ a. hearing impaired
○ b. visually impaired
○ c. physically impaired
○ d. none

4) What language did the owner and the disabled visitor speak in their interactions?
○ a. English
○ b. Thai
○ c. Other (please identify)…………………………..
○ d. I don't know
5) Did the hearing impaired person use sign language?
○ a. Yes
○ b. No

6) Did the hearing impaired person wear hearing aids?
○ a. Yes
○ b. No

7) Did the hearing impaired person use lip-reading?
○ a. Yes
○ b. No

8) Is cost an issue for a solution?
○ a. Yes
○ b. No
○ c. I don’t know

9) Which environmental considerations may have impacted the interactions with the disabled person in the transcript?
☐ a. Background noise (may affect everyone’s ability to hear and understand what is said but has the greatest impact on hearing impaired people).
☐ b. Hard surfaces (e.g. walls, windows, tiles and objects) in a room produce reverberation of sound (may affect everyone’s ability to hear and understand what is said but has the greatest impact on hearing impaired people).
☐ c. The greater the distance that the audience is from the presenter or sound source, the quieter the sound they receive (which may affect everyone’s ability to hear and understand what is said but has the greatest impact on hearing impaired people).
☐ d. Visual access to the speaker’s face (Blocked line of sight or inadequate lighting or glare from sunlight may affect the understanding of hearing impaired audience who lip-read).

10) What ‘types’ of speech did the presenter use?
☐ a. prepared or rehearsed speech (i.e. know beforehand exactly what they are going to say)
☐ b. spontaneous speech (i.e. don’t know beforehand exactly what they are going to say)
☐ c. I don't know

11) How could the disability have affected actions and reactions in the People to People (P-P) interactions with the disabled person?

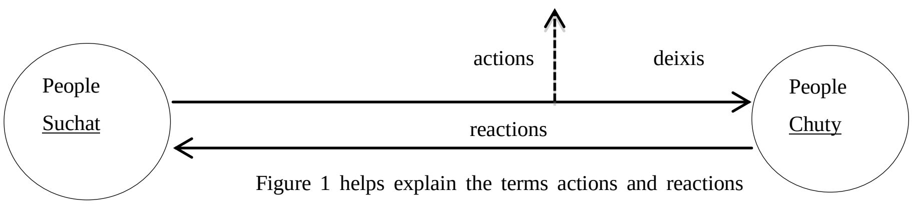


Figure 1 helps explain the terms actions and reactions

☐ a. hearing impairment reduced understanding (reaction) of speaking (action) especially with quiet speech and background noise

☐ b. hearing impairment reduced lip-reader's understanding (reaction) of speaking (action) when speaker pointed at the object because lip reader needed to look away from the speaker's lips/face.
☐ c. hearing impairment reduced lip-reader's understanding (reaction) of speaking (action) because pathway between speaker's mouth/face and lip-readers' eyes were blocked (e.g. speaker's mouth covered up) or inadequate lighting.
☐ d. I don't know

12) How did disability affect the actions and reactions in the People to Technology (P-T-P) interactions in the transcript?

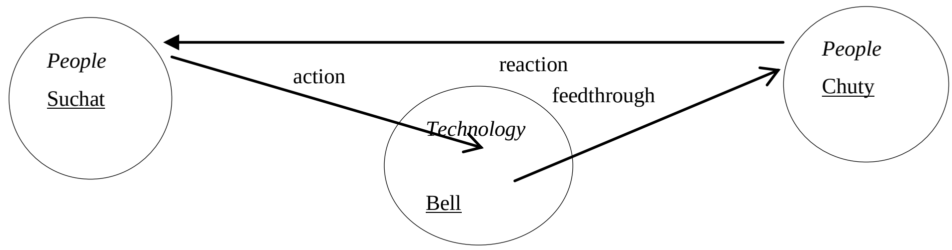


Figure 2 helps explain the terms "action", "reaction" and "feedthrough action"

☐ a. Hearing impairment made it difficult to hear (reaction) notification (action) through technology created sounds (feedthrough action)
☐ b. Dyslexia made it difficult to read (reaction) emails typed (action) and sent (feedthrough action)
☐ c. Physical disablity made it difficult to feel (reaction) notification (action) through technology created vibrations (feedthrough action)
☐ d. Visual disability made it difficult to see (reaction) notification (action) through technology created light signals (feedthrough action)

TEIF STEP 3: Identify questions-answers related to requirements

Instruction: Using table 2 sheets (Table 0-68 – 0-69) can help you with TASK 1 analysing the best 9 requirements for a technology solution that solves the disability related problems identified from the interview transcript. Put a tick (✓) in the appropriate table cell when the answer in that column is related to the requirement in that row otherwise leave the cell empty. *The ticks ✓ are answers but the answers are not shown to the participants in this step.

Table 0-50 Identify question answers related to requirements

	TEIF Step 2 issue answers with question & answer numbers									
Requirement Number	presenter audience (1a)	speak Thai (5b)	hearing aids and use lip-reading (8a)	low cost solution (9a)	background noise (10a)	prepared speech (11a)	spontaneous speech (11b)	Hearing impaired lip reader's understanding when point at an object. (12b)	Hearing impaired lip reader's understanding when inadequate lighting or eyes are blocked (12d)	difficult to hear notification (13a)
1. ☐ help hearing impaired visitors in the audience understand the owner present information.	✓									
2. ☐ help provide sign language for hearing impaired visitors.										
3. ☐ improve mobile phone signal for hearing impaired visitors.										
4. ☐ help hearing impaired visitors understand conversation in background music.					✓					
5. ☐ work with hearing impaired people who use sign language.										
6. ☐ enable hearing impaired visitors to ask the owner questions.							✓			
7. ☐ help wheelchair users in the museum.										
8. ☐ help notify hearing impaired visitors that the tour starts.										✓
9. ☐ help blind visitors to the museum.										
10. ☐ keep disabled visitors dry by not having to walk between buildings.										
11. ☐ help visitors to not miss information when the owner points to exhibits.								✓		
12. ☐ help find parking facilities for disabled visitors.										
13. ☐ improve GPS reception for hearing impaired visitors.										
14. ☐work with hearing impaired visitors who wear hearing aid and use lip-reading									✓	
15. ☐ help the owner make more profit.										
16. ☐ improve catering for disabled visitors.										
17. ☐ help visitors to understand the shadow puppet show in the dark.										
18. ☐ help hearing impaired visitor's friends email them to discuss the shadow puppet museum.										
19. ☐ improve Wi-Fi facilities for hearing impaired visitors.						✓				
20. ☐ reduce costs of shadow puppet souvenirs for disabled visitors.										
21. ☐ work with pre-prepared speech from the owner to the visitors.										
22. ☐ improve toilet facilities for disabled visitors.										
23. ☐ help find nearest toilet facilities for disabled visitors.										
24. ☐ work with spontaneous speech between the owner and the visitors.										
25. ☐ keep costs low by working with existing Wi-Fi and visitors' smartphones.				✓						
26. ☐ improve parking facilities for disabled visitors.										
27. ☐ help find nearest food outlet for disabled visitors.										
28. ☐ work in Thai language.		✓								
29. ☐ help hearing impaired visitors email friends to discuss the shadow puppet museum.										

TASK 1: Identify Requirements

A developer wishes to develop a technology solution to the disability related problems identified from the information provided in the interview transcript.

1) Based on the information in the transcript please select from the 29 possible requirements listed below the best 10 requirements that will help the developer identify what a technology solution should achieve. Put a tick in the box ☑ by each of the 10 requirements and write the number of each of these 10 requirements above the underlined words on the interview transcript sheet (note that if the same words help with more than 1 requirement you should write the numbers of each of the requirements).

2) Underline the words in the interview transcript that helped you identify these requirements.

The technology solution should:

1. ☐ help hearing impaired visitors in the audience understand the owner present information.
2. ☐ help provide sign language for hearing impaired visitors.
3. ☐ improve mobile phone signal for hearing impaired visitors.
4. ☐ help hearing impaired visitors understand conversation in background music.
5. ☐ work with hearing impaired people who use sign language.
6. ☐ enable hearing impaired visitors to ask the owner questions.
7. ☐ help wheelchair users in the museum.
8. ☐ help notify hearing impaired visitors that the tour starts.
9. ☐ help blind visitors to the museum.
10. ☐ keep disabled visitors dry by not having to walk between buildings.
11. ☐ help visitors to not miss information when the owner points to exhibits.
12. ☐ help find parking facilities for disabled visitors.
13. ☐ improve GPS reception for hearing impaired visitors.
14. ☐work with hearing impaired visitors who wear hearing aid and use lip-reading
15. ☐ help the owner make more profit.
16. ☐ improve catering for disabled visitors.
17. ☐ help visitors to understand the shadow puppet show in the dark.
18. ☐ help hearing impaired visitor's friends email them to discuss the shadow puppet museum.
19. ☐ improve Wi-Fi facilities for hearing impaired visitors.
20. ☐ reduce costs of shadow puppet souvenirs for disabled visitors.
21. ☐ work with pre-prepared speech from the owner to the visitors.
22. ☐ improve toilet facilities for disabled visitors.
23. ☐ help find nearest toilet facilities for disabled visitors.
24. ☐ work with spontaneous speech between the owner and the visitors.
25. ☐ keep costs low by working with existing Wi-Fi and visitors' smartphones.
26. ☐ improve parking facilities for disabled visitors.
27. ☐ help find nearest food outlet for disabled visitors.
28. ☐ work in Thai language.
29. ☐ help hearing impaired visitors email friends to discuss the shadow puppet museum.

Table 0-51 Technology Suggestion Table

Technology Suggestions	**Descriptions**	presenter audience (1a)	speak Thai (5b)	hearing aids and use lip-reading (8a)	low cost solution (9a	background noise (10a)	prepared speech (11a	spontaneous speech (11b)	Hearing impaired lip reader's understanding when point at an object. (12b)	Hearing impaired lip reader's understanding when inadequate lighting or eyes are blocked (12c)	difficult to hear notification (13a)	total
1.Mobile web site	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
2.Mobile Application (App)	A mobile application is a software application designed to run on smartphones, tablet computers and other mobile devices. They are usually downloaded to a target device through application distribution platforms, which are typically operated by the owner of the mobile operating system. Some applications do not require an Internet connection to work.	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	10
3.Pre-prepared caption/subtitle	Captions are text versions of the spoken word. Captions can also allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. Anyone can easily type their own captions.	✓	✓	✓	✓	✓	✓	×	✓	✓	×	8
4.Frequently asked questions (FAQ)	FAQ are listed questions and answers, all supposed to be commonly asked in some context, and pertaining to a particular topic.	✓	✓	✓	✓	✓	✓	×	✓	✓	×	8
5.Quick Response Code (QR-code)	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special printer or scanner to print or scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information.	✓	✓	✓	✓	✓	✓	×	✓	✓	×	8
6.Instant messaging	This is a simple and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions.	✓	✓	✓	✓	✓	×	×	×	✓	✓	7
7.Short Message Service (SMS)	SMS is a text messaging service component of phone, web, or mobile communication systems, using standardized communications protocols that allow the exchange of short text messages between fixed line or mobile phone devices.	✓	✓	✓	✓	✓	×	×	×	✓	✓	7
8.Vibrating alert	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone.	✓	✓	✓	✓	✓	×	×	×	✓	✓	7
9.Radio frequency identification (RFID)	RFID is radio technology, which can be read by a RFID receiver with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can't determine which item the user is browsing. The RFID tags show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content.	✓	✓	✓	×	✓	✓	×	✓	✓	×	7
10.Speech recognition	Speech recognition (SR) is the translation of spoken words into text. SR systems that do not use training are called "speaker independent speech recognition" and usually run on apps on mobile devices connected to servers while "speaker dependent" systems run on desktop or laptop computers and use "training" to fine tune the recognition of a person's speech, resulting in more accurate transcriptions. SR can make errors. SR works best if the microphone is close to the user. More distant microphones will increase the errors if there is noise or some other sound in the room. English SR systems are much more accurate than Thai SR systems. SR is much more accurate using dictated speech (e.g. 96% using English SR) than conversational speech (e.g. 70% using English SR).	✓	✓	✓	✓	×	×	✓	×	✓	×	6
11.Sign Language Video	Sign language is a visual language that can be used to communicate information on video to some deaf people who cannot read captions. Each country has its own sign language(s) and most hearing impaired people can not use sign language.	✓	×	×	×	✓	✓	×	✓	✓	×	5

Table 0-52 How question answers are related to requirements

Requirements	presenter audience (1a)	peak Thai (5b)	hearing aids and use lip-reading (8a)	cost is an issue for solution (9a)	background noise (10a)	prepared speech (11a)	spontaneous speech (11b)	Hearing impaired lip reader's understanding when point at an object. (12b)	Hearing impaired lip reader's understanding when inadequate lighting or eyes are blocked (12d)	difficult to hear notification (13a)
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.	✓									
4. The technology solution should help hearing-impaired visitors understand conversation in background music.					✓					
8. The technology solution should help notify hearing impaired visitors when the tour starts.										✓
11. The technology solution should help visitors to not miss information when the owner points to exhibits.								✓		
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.			✓							
17. The technology solution should help visitors to understand the shadow puppet show in the dark.									✓	
21. The technology solution should work with pre-prepared speech from the owner to the visitors.						✓				
24. The technology solution should work with spontaneous speech between the owner and the visitors.							✓			
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).				✓						
28. The technology solution should work with Thai language.		✓								

TEIF STEP 4: Identifying which technologies meet each requirement

Instruction:

1) In the space provided in Table 0-70 write the numbers of all the technology suggestions from Table 0-68 which could be used to meet each of the ten requirements listed in Table 0-69.

2) Using Table 0-69 will help you as it shows which issues identified by the answers to the questions in TEIF step 2 are relevant for which requirements whereas Table 0-68 shows which technologies are appropriate for which of these issues. Table 0-69 therefore can help you 'map' between the requirements and the issues.

Table 0-53 Identifying which technologies meet each requirement

Requirements	**Technology Suggestions**
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.	
4. The technology solution should help hearing-impaired visitors understand conversation in background music.	
8. The technology solution should help notify hearing impaired when the tour start.	
11. The technology solution should help visitors to not miss information when the owner points to exhibits.	
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.	
17. The technology solution should help visitors to understand the shadow puppet show in the dark.	
21. The technology solution should work with pre-prepared speech from the owner to the visitors.	
24. The technology solution should work with spontaneous speech between the owner and the visitors.	
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).	
28. The technology solution should work with Thai language.	

Experimental Task 2: Rating Solutions

Instruction:

1) Please read the three Technology Solution Sheets A, B, C and give a rating between 0 and 10 (Zero is the lowest rating) in the appropriate row and column of Table 0-71 for how well each solution meets each of the ten requirements that have been identified from the Interview transcript. Use the Technology Suggestions Table 4 and Table 3 to help you.

2) For each solution and requirement, please underline the words in each Technology Solution Sheet that helped you identify which requirement the solution met and write the appropriate requirement number above the underlined words in each sheet (note that if the same words help with more than 1 requirement you should write the numbers of each of the requirements).

Table 0-54 rating each solution meets each requirement

Requirements	Solution A	Solution B	Solution C
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.			
4. The technology solution should help hearing-impaired visitors understand conversation in background music.			
8. The technology solution should help notify hearing impaired visitors when the tour starts.			
11. The technology solution should help visitors to not miss information when the owner points to exhibits.			
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.			
17. The technology solution should help visitors to understand the shadow puppet show in the dark.			
21. The technology solution should work with pre-prepared speech from the owner to the visitors.			
24. The technology solution should work with spontaneous speech between the owner and the visitors.			
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).			
28. The technology solution should work with Thai language.			

Technology Solution A

The technology developer has made available a mobile web site with which Chuty can use her smart phone to enhance the visit. There is specific function called "live functionality" which assists Suchat to communicate with Chuty. The function allows Suchat to notify Chuty when the tour begins and to change the topics.

Suchat indicates that the tour is about to start by pressing the 'start' button on his mobile phone. Chuty's phone vibrates at the same time to notify her of this, and as Suchat starts speaking the pre-prepared summary Thai captions for the first topic, appear on her smartphone. As the captions are presented on the mobile website, the words are highlighted in a sentence, allowing Chuty to follow the conversation. Suchat can also notify Chuty that the topic is changing by sending a message to the server and the captions change automatically on the mobile website.

Sometimes Chuty can't catch all of the conversation but she can search for text by using keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour.

When Suchat shows the shadow puppets, he uses his mobile phone to select and indicate the captions of the show that he is currently performing. Chuty then can enjoy the show by watching the shadow puppet and she also can read the captions when she need to on her smartphone. During the tour, Chuty asks some questions, Suchat answers supported by selecting pre-prepared caption answers to frequently asked questions or by typing the answers on his smartphone using instant messaging. When Suchat point at the exhibits, to help Chuty understand Suchat's answers when she looks at the exhibits, she can use the further information displayed on her smartphone browser through the links from the QR codes on the exhibits.

Technology Solution B

The technology developer has made available a multimedia mobile phone application with which Chuty can use her smartphone to experience culture; in particular the museum exhibits. The application uses the smartphone technology and QR code technology to play the Thai sign language video with captions embedded in the video about the exhibit.

Suchat starts talking and gives the usual information about exhibits. To help Chuty understand Suchat, Chuty puts the application into scan mode, then she finds a QR code for the exhibit she is interested in. She lines it up with her smartphone. The QR code is read, prompting the application to then play the appropriate sign language video clip with captions for that exhibit.

When Suchat shows the shadow puppets, Chuty watches the show and she also can search the pre-prepared sign language video with captions when she needs to on her smartphone. Chuty asks some questions about the show, Suchat answers by talking, Chuty uses lip-reading and hearing in understanding to the answers.

Chuty asks some more questions about the exhibits, Suchat answers by talking and pointing to the exhibit. To help Chuty understands Suchat's answers, she can use her smartphone to scan through the links from the QR codes on the exhibits. After the tour, Chuty can use her smartphone to scan further information about the exhibits by walking around the museum independently. The application also offers information and updates on activities in social networks; feeds from sites such as Twitter or Facebook. So Chuty can discuss about the exhibits with people who have the same interests.

Technology Solution C

The technology developer has developed a RFID – Based Web Application for the museum. The exhibits in the museum each have an RFID tag. Chuty can use her smartphones to connect to a Bluetooth connection with the RFID reader to keep track of her positions any time using the mapping of tag IDs to navigate exhibits at the museum. There is a specific application called “a search engine for things” which assists Chuty to view where the tagged objects are or search for a particular object’s location or even record where she has been so she can return later if she has time. The application can also send an SMS reminder to Chuty when she leaves the building without the particular item that Suchat has decided as important.

Chuty sets her phone to vibrate and Suchat lets Chuty know when the tour begins by sending an SMS to alert her. When Suchat start talking about exhibits, the pre-prepared Thai summary transcript appears on the Web Applications. As the transcript is presented on the Web Applications, the text allows her to follow the conversation.

When Suchat performs the shadow puppet show, Chuty then can scan a tag to read the transcript of the story. When Chuty asks questions about the exhibits, Suchat answers by talking and pointing to the exhibits, Chuty picks out words through lip reading and hearing but she finds it is difficult to look at the exhibits and lip-read at the same time so she can use the application to ‘bookmark’ the ID tag of the exhibit and come back after the talk finishes to learn more about the exhibit by using the RFID reader to scan the tag to get the information.

Questionnaire:

Background information

1. How many years of practical experience have you had designing software?

2. Have you had any experience designing technology solutions for disabled people? If yes, please provide further details

- ○ Yes
- ○ No

………

………

Clarity of explanation of TEIF Method steps

3. Were the method steps explained clearly? If not, what was unclear?

○ Yes
○ No

………

………

4. Did you find any steps of the TEIF method difficult to carry out? If so, which ones, and in what way?

○ Yes
○ No

………

………

Evaluating whether and how the TEIF method did help you:

Please place a tick the appropriate column to show how strongly you agree or disagree with each of the following statements numbered 5-9

Statements	Strongly agree				Strongly disagree
	5	4	3	2	1
5. The TEIF method helped to improve your awareness of interaction issues involving hearing impaired people.					
6. The TEIF method helped to improve your understanding of how environment context affects interaction when hearing impaired people are involved.					
7. The TEIF method Technology Suggestions Table helped you to identify technology solutions to issues involving hearing impaired people.					
8. The TEIF method helped you in TASK 1 to evaluate requirements.					
9. The TEIF method helped you in TASK 2 to evaluate technology solution designs.					

Imagining how the TEIF method might help you in the future:

Please place a tick the appropriate column to show how strongly you agree or disagree with each of the following statements numbered 10-14

Statements	Strongly agree				Strongly disagree
	5	4	3	2	1
10. You would find the TEIF method you used for TASK 1 helpful to identify requirements for technology solutions to interaction problems involving hearing impaired people.					
11. You would find the TEIF method you used for TASK 2 helpful for designing technology solutions to interaction problems involving hearing impaired people.					
12. You would find using the whole TEIF method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the part of the method you used for TASK 2.					
13. If information was also provided about other disabilities you would find the TEIF method helpful in identifying requirements for technology solutions to interaction problems involving disabled people.					
14. If information was also provided about other disabilities you would find the TEIF method helpful for designing technology solutions to interaction problems involving disabled people.					

15. Do you have any other comments about the usefulness or value of the TEIF Method?

……

……

……

……

……

……..

Appendix I. User Evaluation Material - Other Methods

Participant Sheet for Other Methods Group

Study Title: User Evaluation of the Technology Enhanced Interaction Framework and Method

Researcher: Kewalin Angkananon

Ethics number: 8194

Please read this information carefully before deciding to take part in this research. If you are happy to participate you will be asked to sign a consent form.

What is the research about?

The purpose of this study is to evaluate the use of the Technology Enhanced Interaction Framework and associated method to help technology designers or developers who are not accessibility experts design technology solutions to interaction issues (i.e. problems) encountered by disabled people. This evaluation is to be achieved by asking participants questions about the materials presented. Some participants will use the Technology Enhanced Interaction Framework and others will use whatever method(s) they choose.

Why have I been chosen?

You have been approached to participate in this study because you are a technology designer or developer with a computing related qualification at degree level who is not also an accessibility expert.

What will happen to me if I take part?

From an interview transcript you will identify from the choices provided the best requirements and designs for a technology solution to the interaction issues encountered by the disabled person involved. You will also be asked to answer some questions about your experience. This study can be expected to take between one hour and one and a half hours.

Are there any benefits in my taking part?

By taking part, you have the opportunity to assist the development of a new method to help design technology for complex situations involving disabled people.

Are there any risks involved?

There is no risk involved in taking part in this study. It is important to note that you are welcome to pause for a rest, or fully withdraw from the study, at any time.

Will my participation be confidential?

Yes. Your personal details will not be included on any written materials which you are asked to provide.

What happens if I change my mind?

You have the right to withdraw at any time without your legal rights being affected.

What happens if something goes wrong?

If you have a concern or complaint, please contact the ECS School Office on school@ecs.soton.ac.uk or school@ecs.soton.ac.uk02380 592909.

Where can I get more information?

Feel free to get in touch with Kewalin Angkananon: ka3e10@ecs.soton.ac.uk

Glossary

The following glossary helps clarify the meaning of some terms used:

Term	Meaning
Disability	A physical or mental impairment that has a substantial and long-term negative effect on ability to do normal daily activities
Hearing impaired person	A person who has a permanent hearing loss or a decrease in hearing that has a substantial and long-term negative effect on their ability to hear.
Shadow Puppet	A model of a person or animal that is moved by pulling wires or strings and used in the dark with a light source to project a shadow from behind a screen
Spontaneous speech	Words spoken that have not been planned
Pre-prepared speech	Words spoken that have been planned
Lip-reading	Watching the way someone's lips move to help understand what they are saying
Sign language	A language that uses hands, face and other body movements instead of spoken words
Hearing aid	Battery-powered, electronic device consisting of a microphone, amplifier and receiver that makes sounds louder for people with a hearing loss.
Notification	The act of informing somebody about something
Background noise	Any sound that is not the sound that you are specifically listening for
Hard surface	A solid, firm, and rigid surface (e.g. Glass, Wood, Concrete)
An observer has visual access to somebody or something	There is nothing blocking the line of sight of the observer and there is adequate lighting.
presenter	A person who presents a tour or show
audience	Spectators or listeners at an event such as a show

TASK 1: Identify Requirements

A developer wishes to develop a technology solution to the disability related problems identified from the information provided in the interview transcript.

1) Please read the interview transcript, based on the information in the transcript please select from the 29 possible requirements listed below the best 10 requirements that will help the developer identify what a technology solution should achieve. Put a tick in the box ☑ by each of the 10 requirements and write the number of each of these 10 requirements above the underlined words on the interview transcript sheet (note that if the same words help with more than 1 requirement you should write the numbers of each of the requirements).

2) Underline the words in the interview transcript that helped you identify these requirements.

The technology solution should:

1. ☐ help hearing impaired visitors in the audience understand the owner present information.
2. ☐ help provide sign language for hearing impaired visitors.
3. ☐ improve mobile phone signal for hearing impaired visitors.
4. ☐ help hearing impaired visitors understand conversation in background music.
5. ☐ work with hearing impaired people who use sign language.
6. ☐ enable hearing impaired visitors to ask the owner questions.
7. ☐ help wheelchair users in the museum.
8. ☐ help notify hearing impaired visitors that the tour starts.
9. ☐ help blind visitors to the museum.
10. ☐ keep disabled visitors dry by not having to walk between buildings.
11. ☐ help visitors to not miss information when the owner points to exhibits.
12. ☐ help find parking facilities for disabled visitors.
13. ☐ improve GPS reception for hearing impaired visitors.
14. ☐work with hearing impaired visitors who wear hearing aid and use lip-reading

15. ☐ help the owner make more profit.
16. ☐ improve catering for disabled visitors.
17. ☐ help visitors to understand the shadow puppet show in the dark.
18. ☐ help hearing impaired visitor's friends email them to discuss the shadow puppet museum.
19. ☐ improve Wi-Fi facilities for hearing impaired visitors.
20. ☐ reduce costs of shadow puppet souvenirs for disabled visitors.
21. ☐ work with pre-prepared speech from the owner to the visitors.
22. ☐ improve toilet facilities for disabled visitors.
23. ☐ help find nearest toilet facilities for disabled visitors.
24. ☐ work with spontaneous speech between the owner and the visitors.
25. ☐ keep costs low by working with existing Wi-Fi and visitors' smartphones.
26. ☐ improve parking facilities for disabled visitors.
27. ☐ help find nearest food outlet for disabled visitors.
28. ☐ work in Thai language.
29. ☐ help hearing impaired visitors email friends to discuss the shadow puppet museum.

Interview Transcript:

Verbatim Transcript of Interview with Suchat Trapsin, the Thai owner of the Museum of folk art and Shadow Puppets who presents the shadow puppet show there.

Interviewer: "Can you tell me about your recent visitor"
Suchat: "*Chuty is a very successful Thai businesswoman in her 30s who has lived in Thailand all her life. She became hearing impaired in her twenties and depends completely on her hearing aids and lip-reading.*
Interviewer: "Why did Chuty visit the Shadow Puppet Museum?"
Suchat: "Her friend suggested the Shadow Puppet Museum was a good place to visit as she is very interested in Thai culture".
Interviewer: "Did she find the museum easily?"
Suchat: "No, because her GPS device lost its signal".
Interviewer: "Did she have any problems when she arrived at the museum?"
Suchat: "There is no proper car park, only a dirt drive with trees by the side. I would like to find a way to provide better parking facilities for visitors".
Interviewer: "What happened next?"
Suchat: "I was in the wooden shadow puppet theatre and picked up and rang a tiny metal bell to start the museum tour. All the visitors then came into the theatre except for except for Chuty and so I had to go and fetch her. I gave a tour by explaining about the museum in Thai. I know I talk very quietly".
Interviewer: "Did she find the exhibits interesting?"
Suchat: She asked me some questions about the shadow puppets exhibits and I answered by talking at the same time as pointing at the shadow puppets exhibit I was referring to. She touched the shadow puppets to feel the old original leather. She got very wet from the heavy rain as she walked between the separate buildings.
Interviewer: "How about the Shadow Puppet show?"
Suchat: During my performance of the shadow puppet show, there is loud background music. I also perform the show in the dark and after presenting my introduction to the show I go behind a screen to operate the puppets and talk for them. She felt quite tired as she had not eaten for many hours and so was hungry but there is no food or drink available in the museum. The prices of the puppets sold in the shop were rather high for her and it would be good if I could find a cheaper way to make them.
Interviewer: "So did she miss lots of information?"
Suchat: There is good Wi-Fi at the museum so she emailed her friend who had visited the museum and he emailed back some details about the show that [12a]she had not understood when I talked".
Interviewer: "Do you have any suggestions to help improve the museum?"
Suchat: "Oh yes. There is only one toilet for both my family and visitors which was very inconvenient for us."
Interviewer "How much money could you afford to spend on any improvements to the museum?"
Suchat: "I have very little money to spend on any devices".
Interviewer "Do you change your talk frequently?"
Suchat: "No, I have been running the museum in my home for 30 years and so now normally I present the same information in the same order every time when I gave my museum talk and shadow puppet show".
Interviewer: "Why is no written information provided for visitors?"
Suchat: "Shadow puppets are part of a verbal story telling culture".

Interviewer "Is there anything else you would like to tell me?"
Suchat: "I get very tired talking and standing all day as I am 70 years old but don't have any disability".
Interviewer: "Thank you".

Experimental Task 2: Rating Solutions

Instruction:

1) Please read the three Technology Solution Sheets A, B, C and give a rating between 0 and 10 (Zero is the lowest rating) in the appropriate row and column of Table 0-72 for how well each solution meets each of the ten requirements that have been identified from the Interview transcript. Use the Technology Suggestions Table 0-73 and Table 0-75 to help you.

2) For each solution and requirement, please underline the words in each Technology Solution Sheet that helped you identify which requirement the solution met and write the appropriate requirement number above the underlined words in each sheet (note that if the same words help with more than 1 requirement you should write the numbers of each of the requirements).

Rating each solution meets each requirement

Requirements	**Solution A**	**Solution B**	**Solution C**
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.			
4. The technology solution should help hearing-impaired visitors understand conversation in background music.			
8. The technology solution should help notify hearing impaired visitors when the tour starts.			
11. The technology solution should help visitors to not miss information when the owner points to exhibits.			
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.			
17. The technology solution should help visitors to understand the shadow puppet show in the dark.			
21. The technology solution should work with pre-prepared speech from the owner to the visitors.			
24. The technology solution should work with spontaneous speech between the owner and the visitors.			
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).			
28. The technology solution should work with Thai language.			

Technology Solution A

The technology developer has made available a mobile web site with which Chuty can use her smart phone to enhance the visit. There is specific function called "live functionality" which assists Suchat to communicate with Chuty. The function allows Suchat to notify Chuty when the tour begins and to change the topics.

Suchat indicates that the tour is about to start by pressing the 'start' button on his mobile phone. Chuty's phone vibrates at the same time to notify her of this, and as Suchat starts speaking the pre-prepared summary Thai captions for the first topic, appear on her smartphone. As the captions are presented on the mobile website, the words are highlighted in a sentence, allowing Chuty to follow the conversation. Suchat can also notify Chuty that the topic is changing by sending a message to the server and the captions change automatically on the mobile website.

Sometimes Chuty can't catch all of the conversation but she can search for text by using keywords, and then visually or manually select captions based on possible keywords which are highlighted in colour.

When Suchat shows the shadow puppets, he uses his mobile phone to select and indicate the captions of the show that he is currently performing. Chuty then can enjoy the show by watching the shadow puppet and she also can read the captions when she need to on her smartphone. During the tour, Chuty asks some questions, Suchat answers supported by selecting pre-prepared caption answers to frequently asked questions or by typing the answers on his smartphone using instant messaging. When Suchat point at the exhibits, to help Chuty understand Suchat's answers when she looks at the exhibits, she can use the further information displayed on her smartphone browser through the links from the QR codes on the exhibits.

Technology Solution B

The technology developer has made available a multimedia mobile phone application with which Chuty can use her smartphone to experience culture; in particular the museum exhibits. The application uses the smartphone technology and QR code technology to play the Thai sign language video with captions embedded in the video about the exhibit.

Suchat starts talking and gives the usual information about exhibits. To help Chuty understand Suchat, Chuty puts the application into scan mode, then she finds a QR code for the exhibit she is interested in. She lines it up with her smartphone. The QR code is read, prompting the application to then play the appropriate sign language video clip with captions for that exhibit.

When Suchat shows the shadow puppets, Chuty watches the show and she also can search the pre-prepared sign language video with captions when she needs to on her smartphone. Chuty asks some questions about the show, Suchat answers by talking, Chuty uses lip-reading and hearing in understanding to the answers.

Chuty asks some more questions about the exhibits, Suchat answers by talking and pointing to the exhibit. To help Chuty understands Suchat's answers; she can use her smartphone to scan through the links from the QR codes on the exhibits. After the tour, Chuty can use her smartphone to scan further information about the exhibits by walking around the museum independently. The application also offers information and updates on activities in social networks; feeds from sites such as Twitter or Facebook. So Chuty can discuss about the exhibits with people who have the same interests.

Technology Solution C

The technology developer has developed a RFID – Based Web Application for the museum. The exhibits in the museum each have an RFID tag. Chuty can use her smartphones to connect to a Bluetooth connection with the RFID reader to keep track of her positions any time using the mapping of tag IDs to navigate exhibits at the museum. There is a specific application called "a search engine for things" which assists Chuty to view where the tagged objects are or search for a particular object's location or even record where she has been so she can return later if she has time. The application can also send an SMS reminder to Chuty when she leaves the building without the particular item that Suchat has decided as important.

Chuty sets her phone to vibrate and Suchat lets Chuty know when the tour begins by sending an SMS to alert her. When Suchat start talking about exhibits, the pre-prepared Thai summary transcript appears on the Web Applications. As the transcript is presented on the Web Applications, the text allows her to follow the conversation.

When Suchat performs the shadow puppet show, Chuty then can scan a tag to read the transcript of the story. When Chuty asks questions about the exhibits, Suchat answers by talking and pointing to the exhibits, Chuty picks out words through lip reading and hearing but she finds it is difficult to look at the exhibits and lip-read at the same time so she can use the application to 'bookmark' the ID tag of the exhibit and come back after the talk finishes to learn more about the exhibit by using the RFID reader to scan the tag to get the information.

Technology Suggestion Table

Technology Suggestions	**Descriptions**
1. Mobile web site	A Mobile Web refers to access to the world wide web, i.e. the use of browser-based Internet services, from a handheld mobile device, such as a smartphone, a feature phone or a tablet computer, connected to a mobile network or other wireless network.
2. Pre-prepared caption/subtitle	Captions are text versions of the spoken word. Captions allow the content of web audio and video to be accessible to those who do not have access to audio. Though captioning is primarily intended for those who cannot hear the audio, it has also been found to help those that can hear audio content and those who may not be fluent in the language in which the audio is presented. Anyone can easily type their own captions.
3. Frequently asked questions (FAQ)	FAQ are listed questions and answers, all supposed to be commonly asked in some context, and pertaining to a particular topic.
4. Quick Response Code (QR-code)	QR codes are commonly used to identify objects or link data to the website. There is no requirement for a special printer or scanner to print or scan QR-Codes; instead users can use smart phones to access information by installing appropriate software on their mobile phone. Users can access a website by using the URL represented by the QR codes. QR-codes are able to encode large amounts of information.
5. Instant messaging	This is a simple and convenient way of connecting through your pc or wireless device by sending text messages and pictures to show emotions.
6. Short Message Service (SMS)	SMS is a text messaging service component of phone, web, or mobile communication systems, using standardized communications protocols that allow the exchange of short text messages between fixed line or mobile phone devices.
7. Vibrating alert	A vibrating alert is a feature of communications devices to notify the user of an incoming connection. It is particularly common on mobile phones and pagers and usually supplements the ring tone.
8. Radio frequency identification (RFID)	RFID is radio technology, which can be read by a RFID receiver with a range of 5-25 cm (Proctor, 2005). If the distance is too large, the reader can't determine which item the user is browsing. The RFID tags show users where to point the RFID reader. When users move their devices near the tag, the system will identify and display the content.
9. Speech recognition	Speech recognition (SR) is the translation of spoken words into text. SR systems that do not use training are called "speaker independent speech recognition" and usually run on apps on mobile devices connected to servers while "speaker dependent" systems run on desktop or laptop computers and use "training" to fine tune the recognition of a person's speech, resulting in more accurate transcriptions. SR can make errors. SR works best if the microphone is close to the user. More distant microphones will increase the errors if there is noise or some other sound in the room. English SR systems are much more accurate than Thai SR systems. SR is much more accurate using dictated speech (e.g. 96% using English SR) than conversational speech (e.g. 70% using English SR).
10. Mobile Application (App)	A mobile application is a software application designed to run on smartphones, tablet computers and other mobile devices. They are usually downloaded to a target device through application distribution platforms, which are typically operated by the owner of the mobile operating system. Some applications do not require an Internet connection to work.
11. Sign Language Video	Sign language is a visual language that can be used to communicate information on video to some deaf people who cannot read captions. Each country has its own sign language(s) and most hearing impaired people can not use sign language.

How question answers are related to requirements

Requirements	presenter audience (1a)	peak Thai (5b)	hearing aids and use lip-reading (8a)	cost is an issue for solution (9a)	background noise (10a)	prepared speech (11a)	spontaneous speech (11b)	Hearing impaired lip reader's understanding when point at an object. (12b)	Hearing impaired lip reader's understanding when inadequate lighting or eyes are blocked (12d)	difficult to hear notification (13a)
1. The technology solution help hearing impaired visitors in the audience understand the owner present information.	✓									
4. The technology solution should help hearing-impaired visitors understand conversation in background music.					✓					
8. The technology solution should help notify hearing impaired visitors when the tour starts.										✓
11. The technology solution should help visitors to not miss information when the owner points to exhibits.								✓		
14. The technology should work with hearing impaired visitors who wear hearing aid and use lip-reading.			✓							
17. The technology solution should help visitors to understand the shadow puppet show in the dark.									✓	
21. The technology solution should work with pre-prepared speech from the owner to the visitors.						✓				
24. The technology solution should work with spontaneous speech between the owner and the visitors.							✓			
25. The technology solution should keep costs low (e.g. by working with existing Wi-Fi and visitors' smartphones).				✓						
28. The technology solution should work with Thai language.		✓								

Questionnaire:

Background information

1. How many years of practical experience have you had designing software

2. Have you any experience designing technology solutions for disabled people? If yes, please provide further details

○ Yes
○ No
………
………
………

Clarity of explanation of TEIF Method steps

3. Would you find any steps of the TEIF method difficult to carry out? If so, which ones, and in what way?

○ Yes
○ No
………
………
………

4. Were the method steps explained clearly? If not, what was unclear?

○ Yes
○ No
………
………
………

Imagining how the TEIF method might help you in the future:

Please place a tick the appropriate column to show how strongly you agree or disagree with each of the following statements numbered 5-9

Questionnaires: how the TEIF method might help you in the future

Statements	Strongly agree ⟵				⟶ Strongly disagree
	5	**4**	**3**	**2**	**1**
5. You would find the TEIF Method used for TASK 1 helpful to identify requirements for technology solutions to interaction problems involving hearing impaired people.					
6. You would find the TEIF Method used for TASK 2 helpful for designing technology solutions to interaction problems involving hearing impaired people.					
7. You would find using the whole TEIF Method more helpful for designing technology solutions to interaction problems involving hearing impaired people than just using the part of the method used for TASK 2.					
8. If information was also provided about other disabilities you would find the TEIF Method helpful in identifying requirements for technology solutions to interaction problems involving disabled people.					
9. If information was also provided about other disabilities you would find the TEIF Method helpful for designing technology solutions to interaction problems involving disabled people.					

10. Do you have any other comments about the usefulness or value of the TEIF Method?

………
………
………
………
………
………
………
………

Appendix J. Statistical Test Used

There are some statistical terms and tests are used in this research. Explanations are as follows:

1. *Level of significance or critical p-value*
   P-values are often coupled to a significance or alpha (α) level, which is also set ahead of time, usually at 0.05 (5%). If a p-value was found to be less than 0.05, then the result would be considered statistically significant. In this research, a level of significance of 5% was used.

2. *Effect size*
   An effect size is a standardized measure of the magnitude of an observed effect (Field, 2000). In this research, the effect size was 1. This represents a relatively large effect size.

3. *Statistical Power*
   Statistical power analysis exploits the relationships between the four variables: sample size (N), significance criteria, population effect size and statistical power (Cohen, 1988). The expected sample size for each experiment each based on these variables.   In this research the value of statistic power was 0.8.

4. *One Sample T-Test*
   A one sample t-test was used to compare the mean score of a sample to a known value. In this experiment study, a one sample t-test was used to determine whether the mean rating for each dependent variable against the approach was significantly higher or lower than 3. This gives the answer to question 5-9 (questionnaire). A value of 3 indicates 'Neither agree nor disagree' on the Likert scale that was used.

5. *Independent Sample T-Test*
   The experiment compares the results of two independent groups, one using the TEIF Method, and the second using the Other Methods, and so means can be compared using independent sample t test.

6. *Chi-Square*
   The numbers of participants selecting particular solutions were compared using Chi-Square to test whether there were significant differences between groups.

7. *Two Way Repeated Measure*
   Two Way Repeated Measure is a two way where the subjects provide measures at all level of one or both factors. For analysis of relationship between two variables (e.g. method and solution), two way repeated measure was used.

8. *Three Way Repeated Measure*
   Three Way Repeated Measure is a one or two or three way where the subjects provide measures at all level of one or both factors. For analysis of relationship between three variables (e.g. method, solution, and requirement), three way repeated measure was used.

9. *Multivariate Tests*
   Multivariate analysis was used before univariate analysis, as it is a more robust test than univariate and if the results are not significant then the univariate test is not considered.

10. *Univariate Tests*
    Univariate makes assumptions about the variance of the data, if Sphericity has been violated, corrections must be applied.

11. *Mauchly's Test of Sphericity*
    Mauchly's test is used to determine whether Sphericity has been violated.

12. *Tests of Within-Subjects Effects*
    Within-subjects effects examines differences within the same group of participants (e.g. the TEIF Method or the Other Methods).

13. *Tests of Between-Subjects Effects*
    Between-subjects effect examines differences between different groups of participants (i.e. the TEIF Method and the Other Methods).

14. *Syntax '/EMMEANS'*
    Syntax '/EMMEANS' was used to test simple simple main effects.

15. *Interaction Effects*
    An interaction effect is an effect of variables on other variables (e.g *method * solution* is the effect of method on solution and solution on method).

16. *Main Effects*
    Main effects is the main effect of each level of second factor.

17. *Simple Main Effects*
    A simple main effects is a main effect at each level of second factor.

18. *Simple Simple Main Effects*
    A simple simple main effect is a simple main effect at each level of second and third factors.

19. *Pairwise Comparisons*
    Pairwise comparison is used to compare differences between pairs of variables (e.g. requirement 1 and requirement 2).

20. *Degrees of freedom*
    Degree of freedom is the number of independent observations for a source of levels of two or more treatments parameters estimated in computing the variation.

21. *Expected value*
    Expected value is the long run average of a random variable over an indefinite number of samplings. The expected value [$E(X) = \sum X\ p(X)$ = mean of X. It should be noted from the above definition that an expected value may be a value that the random variable could not actually have.

22. *Interaction*
    Interaction is two treatments are said to interact if scores obtained under levels of one treatment behave differently under different levels of the other treatment.

23. *Effect size*
    An effect size is a standardized measure of the magnitude of an observed effect (Field, 2000, 32-33). In this research, the number of effect size was 1. This represents a relatively large effect size.

Appendix K. User Evaluation Results

Differential A-B

The full Table 9-70 is shown in Table 0-55.

Table 0-55 Univariate test of tests between-subjects effects of *method* on *differential amount* and *differential direction* A-B

Measure	requirements		Sum of Squares	df	Mean Square	F	Sig.
dif_amount	1	Contrast	16.000	1	16.000	3.219	.082
		Error	169.000	34	4.971		
	2	Contrast	2.778	1	2.778	.928	.342
		Error	101.778	34	2.993		
	3	Contrast	215.111	1	215.111	20.712	.000
		Error	353.111	34	10.386		
	4	Contrast	12.250	1	12.250	2.154	.151
		Error	193.389	34	5.688		
	5	Contrast	20.250	1	20.250	1.868	.181
		Error	368.500	34	10.838		
	6	Contrast	1.000	1	1.000	.137	.713
		Error	248.000	34	7.294		
	7	Contrast	.111	1	.111	.014	.907
		Error	273.444	34	8.042		
	8	Contrast	26.694	1	26.694	1.657	.207
		Error	547.611	34	16.106		
	9	Contrast	14.694	1	14.694	3.421	.073
		Error	146.056	34	4.296		
	10	Contrast	11.111	1	11.111	1.130	.295
		Error	334.444	34	9.837		
dif_direction	1	Contrast	1.361	1	1.361	2.141	.153
		Error	21.611	34	.636		
	2	Contrast	4.000	1	4.000	5.856	.021
		Error	23.222	34	.683		
	3	Contrast	12.250	1	12.250	49.000	.000
		Error	8.500	34	.250		
	4	Contrast	1.361	1	1.361	1.718	.199
		Error	26.944	34	.792		
	5	Contrast	1.361	1	1.361	1.807	.188
		Error	25.611	34	.753		
	6	Contrast	1.000	1	1.000	1.259	.270
		Error	27.000	34	.794		
	7	Contrast	.250	1	.250	.344	.562
		Error	24.722	34	.727		
	8	Contrast	1.778	1	1.778	4.250	.047
		Error	14.222	34	.418		
	9	Contrast	1.000	1	1.000	4.500	.041
		Error	7.556	34	.222		
	10	Contrast	.000	1	.000	.000	1.000
		Error	8.556	34	.252		

Each F tests the simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Differential A-C

The multivariate tests of simple simple main effects of *method* at each level of *requirement* for differential A-C is shown in Table 0-56.

Table 0-56 Multivariate tests of simple simple main effects of *method* at each level of *requirement* for differential A-C

Requirement		Value	F	Hypothesis df	Error df	Sig.
1	Pillai's trace	.113	2.109[a]	2.000	33.000	.137
	Wilks' lambda	.887	2.109[a]	2.000	33.000	.137
	Hotelling's trace	.128	2.109[a]	2.000	33.000	.137
	Roy's largest root	.128	2.109[a]	2.000	33.000	.137
4	Pillai's trace	.096	1.751[a]	2.000	33.000	.189
	Wilks' lambda	.904	1.751[a]	2.000	33.000	.189
	Hotelling's trace	.106	1.751[a]	2.000	33.000	.189
	Roy's largest root	.106	1.751[a]	2.000	33.000	.189
8	Pillai's trace	.431	12.482[a]	2.000	33.000	p<.001
	Wilks' lambda	.569	12.482[a]	2.000	33.000	p<.001
	Hotelling's trace	.756	12.482[a]	2.000	33.000	p<.001
	Roy's largest root	.756	12.482[a]	2.000	33.000	p<.001
11	Pillai's trace	.031	.526[a]	2.000	33.000	.596
	Wilks' lambda	.969	.526[a]	2.000	33.000	.596
	Hotelling's trace	.032	.526[a]	2.000	33.000	.596
	Roy's largest root	.032	.526[a]	2.000	33.000	.596
14	Pillai's trace	.076	1.366[a]	2.000	33.000	.269
	Wilks' lambda	.924	1.366[a]	2.000	33.000	.269
	Hotelling's trace	.083	1.366[a]	2.000	33.000	.269
	Roy's largest root	.083	1.366[a]	2.000	33.000	.269
17	Pillai's trace	.010	.165[a]	2.000	33.000	.849
	Wilks' lambda	.990	.165[a]	2.000	33.000	.849
	Hotelling's trace	.010	.165[a]	2.000	33.000	.849
	Roy's largest root	.010	.165[a]	2.000	33.000	.849
21	Pillai's trace	.003	.044[a]	2.000	33.000	.957
	Wilks' lambda	.997	.044[a]	2.000	33.000	.957
	Hotelling's trace	.003	.044[a]	2.000	33.000	.957
	Roy's largest root	.003	.044[a]	2.000	33.000	.957
24	Pillai's trace	.247	5.421[a]	2.000	33.000	.009
	Wilks' lambda	.753	5.421[a]	2.000	33.000	.009
	Hotelling's trace	.329	5.421[a]	2.000	33.000	.009
	Roy's largest root	.329	5.421[a]	2.000	33.000	.009
25	Pillai's trace	.019	.321[a]	2.000	33.000	.727
	Wilks' lambda	.981	.321[a]	2.000	33.000	.727
	Hotelling's trace	.019	.321[a]	2.000	33.000	.727
	Roy's largest root	.019	.321[a]	2.000	33.000	.727
28	Pillai's trace	.039	.678[a]	2.000	33.000	.515
	Wilks' lambda	.961	.678[a]	2.000	33.000	.515
	Hotelling's trace	.041	.678[a]	2.000	33.000	.515
	Roy's largest root	.041	.678[a]	2.000	33.000	.515

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the marginal means.
a. Exact statistic

Differential B-C

The full Table 9-94 is shown in Table 0-57.

Table 0-57 The simple simple main effects of *method* at each level of *requirement* for differential B-C

Measure	requirements		Sum of Squares	df	Mean Square	F	Sig.
dif_amount	1	Contrast	18.778	1	18.778	3.543	.068
		Error	180.222	34	5.301		
	2	Contrast	14.694	1	14.694	3.238	.081
		Error	154.278	34	4.538		
	3	Contrast	386.778	1	386.778	34.059	.000
		Error	386.111	34	11.356		
	4	Contrast	.694	1	.694	.134	.717
		Error	176.278	34	5.185		
	5	Contrast	1.778	1	1.778	.193	.664
		Error	313.778	34	9.229		
	6	Contrast	9.000	1	9.000	1.759	.194
		Error	174.000	34	5.118		
	7	Contrast	14.694	1	14.694	2.761	.106
		Error	180.944	34	5.322		
	8	Contrast	11.111	1	11.111	1.696	.202
		Error	222.778	34	6.552		
	9	Contrast	5.444	1	5.444	.453	.505
		Error	408.444	34	12.013		
	10	Contrast	10.028	1	10.028	4.319	.045
		Error	78.944	34	2.322		
dif_direction	1	Contrast	.444	1	.444	.618	.437
		Error	24.444	34	.719		
	2	Contrast	.444	1	.444	2.000	.166
		Error	7.556	34	.222		
	3	Contrast	23.361	1	23.361	104.358	.000
		Error	7.611	34	.224		
	4	Contrast	.694	1	.694	.797	.378
		Error	29.611	34	.871		
	5	Contrast	.000	1	.000	.000	1.000
		Error	7.222	34	.212		
	6	Contrast	.111	1	.111	.531	.471
		Error	7.111	34	.209		
	7	Contrast	.028	1	.028	.033	.857
		Error	28.722	34	.845		
	8	Contrast	.000	1	.000	.000	1.000
		Error	8.556	34	.252		
	9	Contrast	.028	1	.028	.046	.832
		Error	20.722	34	.609		
	10	Contrast	1.361	1	1.361	10.818	.002
		Error	4.278	34	.126		

Each F tests the simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

Differential and Method effects for requirement 1

The full Table 9-120 is shown in Table 0-58.

Table 0-58 Multivariate simple effects of *method* at each level of *differential*

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	12.722	2	6.361	14.897	.000
		Greenhouse-Geisser	12.722	1.949	6.529	14.897	.000
		Huynh-Feldt	12.722	2.000	6.361	14.897	.000
		Lower-bound	12.722	1.000	12.722	14.897	.000
	Amount	Sphericity Assumed	39.019	2	19.509	6.279	.003
		Greenhouse-Geisser	39.019	1.788	21.819	6.279	.004
		Huynh-Feldt	39.019	1.937	20.148	6.279	.004
		Lower-bound	39.019	1.000	39.019	6.279	.017
Differential * Method	Direction	Sphericity Assumed	3.574	2	1.787	4.185	.019
		Greenhouse-Geisser	3.574	1.949	1.834	4.185	.020
		Huynh-Feldt	3.574	2.000	1.787	4.185	.019
		Lower-bound	3.574	1.000	3.574	4.185	.049
	Amount	Sphericity Assumed	15.685	2	7.843	2.524	.088
		Greenhouse-Geisser	15.685	1.788	8.771	2.524	.094
		Huynh-Feldt	15.685	1.937	8.100	2.524	.090
		Lower-bound	15.685	1.000	15.685	2.524	.121
Error(Differential)	Direction	Sphericity Assumed	29.037	68	.427		
		Greenhouse-Geisser	29.037	66.255	.438		
		Huynh-Feldt	29.037	68.000	.427		
		Lower-bound	29.037	34.000	.854		
	Amount	Sphericity Assumed	211.296	68	3.107		
		Greenhouse-Geisser	211.296	60.803	3.475		
		Huynh-Feldt	211.296	65.843	3.209		
		Lower-bound	211.296	34.000	6.215		

Table 0-59 shows multivariate simple effects of *differential* at each level of *method.* The full Table 9-103 is shown in Table 0-60.

Table 0-59 Multivariate simple effects of *differential* at each level of *method*

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.522	8.448[a]	4.000	31.000	.000
	Wilks' lambda	.478	8.448[a]	4.000	31.000	.000
	Hotelling's trace	1.090	8.448[a]	4.000	31.000	.000
	Roy's largest root	1.090	8.448[a]	4.000	31.000	.000
other method	Pillai's trace	.735	21.518[a]	4.000	31.000	.000
	Wilks' lambda	.265	21.518[a]	4.000	31.000	.000
	Hotelling's trace	2.777	21.518[a]	4.000	31.000	.000
	Roy's largest root	2.777	21.518[a]	4.000	31.000	.000

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.

a. Exact statistic

Table 0-60 Univariate tests of *differential*method* for requirement 1

Differential		Value	F	Hypothesis df	Error df	Sig.
A-B	Pillai's trace	.089	1.604[a]	2.000	33.000	.216
	Wilks' lambda	.911	1.604[a]	2.000	33.000	.216
	Hotelling's trace	.097	1.604[a]	2.000	33.000	.216
	Roy's largest root	.097	1.604[a]	2.000	33.000	.216
A-C	Pillai's trace	.113	2.109[a]	2.000	33.000	.137
	Wilks' lambda	.887	2.109[a]	2.000	33.000	.137
	Hotelling's trace	.128	2.109[a]	2.000	33.000	.137
	Roy's largest root	.128	2.109[a]	2.000	33.000	.137
B-C	Pillai's trace	.094	1.719[a]	2.000	33.000	.195
	Wilks' lambda	.906	1.719[a]	2.000	33.000	.195
	Hotelling's trace	.104	1.719[a]	2.000	33.000	.195
	Roy's largest root	.104	1.719[a]	2.000	33.000	.195

Each F tests the multivariate simple effects of Method within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Differential and Method effects for requirement 4

Table 0-61 Multivariate simple effects of differential at each level of method

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.308	3.448[a]	4.000	31.000	.019
	Wilks' lambda	.692	3.448[a]	4.000	31.000	.019
	Hotelling's trace	.445	3.448[a]	4.000	31.000	.019
	Roy's largest root	.445	3.448[a]	4.000	31.000	.019
other method	Pillai's trace	.601	11.676[a]	4.000	31.000	.000
	Wilks' lambda	.399	11.676[a]	4.000	31.000	.000
	Hotelling's trace	1.507	11.676[a]	4.000	31.000	.000
	Roy's largest root	1.507	11.676[a]	4.000	31.000	.000

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Table 0-62 Univariate tests of *differential*method* for requirement 4

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.815	34.174[a]	4.000	31.000	.000
	Wilks' lambda	.185	34.174[a]	4.000	31.000	.000
	Hotelling's trace	4.410	34.174[a]	4.000	31.000	.000
	Roy's largest root	4.410	34.174[a]	4.000	31.000	.000
other method	Pillai's trace	.908	76.253[a]	4.000	31.000	.000
	Wilks' lambda	.092	76.253[a]	4.000	31.000	.000
	Hotelling's trace	9.839	76.253[a]	4.000	31.000	.000
	Roy's largest root	9.839	76.253[a]	4.000	31.000	.000

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

Differential and Method effects for requirement 8

Table 0-63 shows the simple simple main effects of *method*.

Table 0-63 Multivariate simple effects of *differential* at each level of *method*

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	3.019	2	1.509	2.730	.072
		Greenhouse-Geisser	3.019	1.424	2.119	2.730	.092
		Huynh-Feldt	3.019	1.513	1.995	2.730	.088
		Lower-bound	3.019	1.000	3.019	2.730	.108
	Amount	Sphericity Assumed	298.296	2	149.148	30.970	.000
		Greenhouse-Geisser	298.296	1.525	195.562	30.970	.000
		Huynh-Feldt	298.296	1.629	183.079	30.970	.000
		Lower-bound	298.296	1.000	298.296	30.970	.000
Differential * Method	Direction	Sphericity Assumed	2.056	2	1.028	1.859	.164
		Greenhouse-Geisser	2.056	1.424	1.443	1.859	.176
		Huynh-Feldt	2.056	1.513	1.359	1.859	.174
		Lower-bound	2.056	1.000	2.056	1.859	.182
	Amount	Sphericity Assumed	38.889	2	19.444	4.038	.022
		Greenhouse-Geisser	38.889	1.525	25.495	4.038	.033
		Huynh-Feldt	38.889	1.629	23.868	4.038	.030
		Lower-bound	38.889	1.000	38.889	4.038	.052
Error(Differential)	Direction	Sphericity Assumed	37.593	68	.553		
		Greenhouse-Geisser	37.593	48.427	.776		
		Huynh-Feldt	37.593	51.431	.731		
		Lower-bound	37.593	34.000	1.106		
	Amount	Sphericity Assumed	327.481	68	4.816		
		Greenhouse-Geisser	327.481	51.861	6.315		
		Huynh-Feldt	327.481	55.397	5.912		
		Lower-bound	327.481	34.000	9.632		

The full Table 9-115 is shown in Table 0-64.

Table 0-64 Univariate tests of *differential*method* for requirement 8

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	3.852	2	1.926	12.364	.000
		Greenhouse-Geisser	3.852	1.940	1.985	12.364	.000
		Huynh-Feldt	3.852	2.000	1.926	12.364	.000
		Lower-bound	3.852	1.000	3.852	12.364	.001
	Amount	Sphericity Assumed	1970.074	2	985.037	220.445	.000
		Greenhouse-Geisser	1970.074	1.646	1197.135	220.445	.000
		Huynh-Feldt	1970.074	1.769	1113.493	220.445	.000
		Lower-bound	1970.074	1.000	1970.074	220.445	.000
Differential * Method	Direction	Sphericity Assumed	24.889	2	12.444	79.888	.000
		Greenhouse-Geisser	24.889	1.940	12.827	79.888	.000
		Huynh-Feldt	24.889	2.000	12.444	79.888	.000
		Lower-bound	24.889	1.000	24.889	79.888	.000
	Amount	Sphericity Assumed	360.074	2	180.037	40.291	.000
		Greenhouse-Geisser	360.074	1.646	218.803	40.291	.000
		Huynh-Feldt	360.074	1.769	203.515	40.291	.000
		Lower-bound	360.074	1.000	360.074	40.291	.000
Error(Differential)	Direction	Sphericity Assumed	10.593	68	.156		
		Greenhouse-Geisser	10.593	65.974	.161		
		Huynh-Feldt	10.593	68.000	.156		
		Lower-bound	10.593	34.000	.312		
	Amount	Sphericity Assumed	303.852	68	4.468		
		Greenhouse-Geisser	303.852	55.952	5.431		
		Huynh-Feldt	303.852	60.155	5.051		
		Lower-bound	303.852	34.000	8.937		

Differential and Method effects for requirement 11

The full Table 9-123 is shown in Table 0-65.

Table 0-65 Univariate tests of simple main effect of *differential* for requirement 11

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
differential	direction	Sphericity Assumed	12.519	2	6.259	13.648	.000
		Greenhouse-Geisser	12.519	1.764	7.097	13.648	.000
		Huynh-Feldt	12.519	1.908	6.562	13.648	.000
		Lower-bound	12.519	1.000	12.519	13.648	.001
	amount	Sphericity Assumed	21.907	2	10.954	2.979	.058
		Greenhouse-Geisser	21.907	1.853	11.824	2.979	.062
		Huynh-Feldt	21.907	2.000	10.954	2.979	.058
		Lower-bound	21.907	1.000	21.907	2.979	.093
differential * Method	direction	Sphericity Assumed	.963	2	.481	1.050	.356
		Greenhouse-Geisser	.963	1.764	.546	1.050	.349
		Huynh-Feldt	.963	1.908	.505	1.050	.353
		Lower-bound	.963	1.000	.963	1.050	.313
	amount	Sphericity Assumed	4.019	2	2.009	.546	.582
		Greenhouse-Geisser	4.019	1.853	2.169	.546	.568
		Huynh-Feldt	4.019	2.000	2.009	.546	.582
		Lower-bound	4.019	1.000	4.019	.546	.465
Error(differential)	direction	Sphericity Assumed	31.185	68	.459		
		Greenhouse-Geisser	31.185	59.972	.520		
		Huynh-Feldt	31.185	64.865	.481		
		Lower-bound	31.185	34.000	.917		
	amount	Sphericity Assumed	250.074	68	3.678		
		Greenhouse-Geisser	250.074	62.994	3.970		
		Huynh-Feldt	250.074	68.000	3.678		
		Lower-bound	250.074	34.000	7.355		

The full Table 9-124 is shown in Table 0-66.

Table 0-66 Pairwise comparisons of simple main effects of differentials for requirement 11

Measure	(I) differential	) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
direction	1	2	-.722*	.170	.000	-1.150	-.295
		3	-1.001E-013	.127	1.000	-.320	.320
	2	1	.722*	.170	.000	.295	1.150
		3	.722*	.177	.001	.278	1.166
	3	1	1.001E-013	.127	1.000	-.320	.320
		2	-.722*	.177	.001	-1.166	-.278
amount	1	2	.861	.427	.148	-.212	1.934
		3	-.167	.511	.984	-1.450	1.117
	2	1	-.861	.427	.148	-1.934	.212
		3	-1.028	.411	.051	-2.060	.004
	3	1	.167	.511	.984	-1.117	1.450
		2	1.028	.411	.051	-.004	2.060

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Sidak.

Differential and Method effects for requirement 14

The full Table 9-128 is shown in Table 0-67.

Table 0-67 Univariate tests of simple main effects of *differential* for requirement 14

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
differential	direction	Sphericity Assumed	19.500	2	9.750	20.839	.000
		Greenhouse-Geisser	19.500	1.847	10.559	20.839	.000
		Huynh-Feldt	19.500	2.000	9.750	20.839	.000
		Lower-bound	19.500	1.000	19.500	20.839	.000
	amount	Sphericity Assumed	196.685	2	98.343	11.024	.000
		Greenhouse-Geisser	196.685	1.829	107.551	11.024	.000
		Huynh-Feldt	196.685	1.984	99.124	11.024	.000
		Lower-bound	196.685	1.000	196.685	11.024	.002
differential * Method	direction	Sphericity Assumed	.685	2	.343	.732	.485
		Greenhouse-Geisser	.685	1.847	.371	.732	.475
		Huynh-Feldt	.685	2.000	.343	.732	.485
		Lower-bound	.685	1.000	.685	.732	.398
	amount	Sphericity Assumed	6.685	2	3.343	.375	.689
		Greenhouse-Geisser	6.685	1.829	3.656	.375	.670
		Huynh-Feldt	6.685	1.984	3.369	.375	.687
		Lower-bound	6.685	1.000	6.685	.375	.545
Error(differential)	direction	Sphericity Assumed	31.815	68	.468		
		Greenhouse-Geisser	31.815	62.787	.507		
		Huynh-Feldt	31.815	68.000	.468		
		Lower-bound	31.815	34.000	.936		
	amount	Sphericity Assumed	606.630	68	8.921		
		Greenhouse-Geisser	606.630	62.178	9.756		
		Huynh-Feldt	606.630	67.464	8.992		
		Lower-bound	606.630	34.000	17.842		

Differential and Method effects for requirement 17

The full Table 9-133 is shown in Table 0-68..

Table 0-68 Univariate tests of simple main effect of *differential* on each measure for requirement 17

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
differential	direction	Sphericity Assumed	19.241	2	9.620	23.488	.000
		Greenhouse-Geisser	19.241	1.554	12.385	23.488	.000
		Huynh-Feldt	19.241	1.662	11.577	23.488	.000
		Lower-bound	19.241	1.000	19.241	23.488	.000
	amount	Sphericity Assumed	194.667	2	97.333	18.662	.000
		Greenhouse-Geisser	194.667	1.558	124.960	18.662	.000
		Huynh-Feldt	194.667	1.667	116.775	18.662	.000
		Lower-bound	194.667	1.000	194.667	18.662	.000
differential * Method	direction	Sphericity Assumed	.907	2	.454	1.108	.336
		Greenhouse-Geisser	.907	1.554	.584	1.108	.325
		Huynh-Feldt	.907	1.662	.546	1.108	.328
		Lower-bound	.907	1.000	.907	1.108	.300
	amount	Sphericity Assumed	10.667	2	5.333	1.023	.365
		Greenhouse-Geisser	10.667	1.558	6.847	1.023	.350
		Huynh-Feldt	10.667	1.667	6.399	1.023	.354
		Lower-bound	10.667	1.000	10.667	1.023	.319
Error(differential)	direction	Sphericity Assumed	27.852	68	.410		
		Greenhouse-Geisser	27.852	52.820	.527		
		Huynh-Feldt	27.852	56.509	.493		
		Lower-bound	27.852	34.000	.819		
	amount	Sphericity Assumed	354.667	68	5.216		
		Greenhouse-Geisser	354.667	52.966	6.696		
		Huynh-Feldt	354.667	56.679	6.257		
		Lower-bound	354.667	34.000	10.431		

Differential and Method effects for requirement 21

The full Table 9-138 is shown in Table 0-69.

Table 0-69 Univariate tests of simple main effects of *differential* on measures amount and direction for requirement 21

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
differential	direction	Sphericity Assumed	1.556	2	.778	1.972	.147
		Greenhouse-Geisser	1.556	1.279	1.216	1.972	.164
		Huynh-Feldt	1.556	1.347	1.155	1.972	.163
		Lower-bound	1.556	1.000	1.556	1.972	.169
	amount	Sphericity Assumed	60.167	2	30.083	7.121	.002
		Greenhouse-Geisser	60.167	1.879	32.029	7.121	.002
		Huynh-Feldt	60.167	2.000	30.083	7.121	.002
		Lower-bound	60.167	1.000	60.167	7.121	.012
differential * Method	direction	Sphericity Assumed	.296	2	.148	.376	.688
		Greenhouse-Geisser	.296	1.279	.232	.376	.595
		Huynh-Feldt	.296	1.347	.220	.376	.606
		Lower-bound	.296	1.000	.296	.376	.544
	amount	Sphericity Assumed	8.574	2	4.287	1.015	.368
		Greenhouse-Geisser	8.574	1.879	4.564	1.015	.364
		Huynh-Feldt	8.574	2.000	4.287	1.015	.368
		Lower-bound	8.574	1.000	8.574	1.015	.321
Error(differential)	direction	Sphericity Assumed	26.815	68	.394		
		Greenhouse-Geisser	26.815	43.501	.616		
		Huynh-Feldt	26.815	45.783	.586		
		Lower-bound	26.815	34.000	.789		
	amount	Sphericity Assumed	287.259	68	4.224		
		Greenhouse-Geisser	287.259	63.870	4.498		
		Huynh-Feldt	287.259	68.000	4.224		
		Lower-bound	287.259	34.000	8.449		

The full table of Table 9-139 is shown in Table 0-70.

Table 0-70 Pairwise comparisons of differential on measure amount for requirement 21

Measure	(I) differential	(J) differential	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
direction	1	2	.222	.161	.442	-.182	.627
		3	-.056	.078	.860	-.251	.140
	2	1	-.222	.161	.442	-.627	.182
		3	-.278	.184	.363	-.739	.183
	3	1	.056	.078	.860	-.140	.251
		2	.278	.184	.363	-.183	.739
amount	1	2	1.583*	.501	.010	.326	2.840
		3	1.583*	.526	.015	.263	2.904
	2	1	-1.583*	.501	.010	-2.840	-.326
		3	.000	.421	1.000	-1.056	1.056
	3	1	-1.583*	.526	.015	-2.904	-.263
		2	.000	.421	1.000	-1.056	1.056

Based on estimated marginal means
*. The mean difference is significant at the
b. Adjustment for multiple comparisons: Sidak.

Differential and Method effects for requirement 24

Table 0-71 shows the multivariate simple simple main effects of *method* for requirement 24.

Table 0-71 Multivariate tests of *differential* for requirement 24

Method		Value	F	Hypothesis df	Error df	Sig.
TEIF	Pillai's trace	.810	33.042[a]	4.000	31.000	.000
	Wilks' lambda	.190	33.042[a]	4.000	31.000	.000
	Hotelling's trace	4.264	33.042[a]	4.000	31.000	.000
	Roy's largest root	4.264	33.042[a]	4.000	31.000	.000
Other	Pillai's trace	.851	44.099[a]	4.000	31.000	.000
	Wilks' lambda	.149	44.099[a]	4.000	31.000	.000
	Hotelling's trace	5.690	44.099[a]	4.000	31.000	.000
	Roy's largest root	5.690	44.099[a]	4.000	31.000	.000

Each F tests the multivariate simple effects of Differential within each level combination of the other effects shown. These tests are based on the linearly independent pairwise comparisons among the estimated marginal means.
a. Exact statistic

The full Table 9-141 is shown in Table 0-92.

Table 0-72 Univariate tests of *differential*method* for requirement 24 on each measure

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	25.407	2	12.704	85.750	.000
		Greenhouse-Geisser	25.407	1.629	15.601	85.750	.000
		Huynh-Feldt	25.407	1.749	14.524	85.750	.000
		Lower-bound	25.407	1.000	25.407	85.750	.000
	Amount	Sphericity Assumed	3251.352	2	1625.676	192.415	.000
		Greenhouse-Geisser	3251.352	1.638	1984.380	192.415	.000
		Huynh-Feldt	3251.352	1.761	1846.428	192.415	.000
		Lower-bound	3251.352	1.000	3251.352	192.415	.000
Differential * Method	Direction	Sphericity Assumed	1.185	2	.593	4.000	.023
		Greenhouse-Geisser	1.185	1.629	.728	4.000	.031
		Huynh-Feldt	1.185	1.749	.678	4.000	.028
		Lower-bound	1.185	1.000	1.185	4.000	.054
	Amount	Sphericity Assumed	37.463	2	18.731	2.217	.117
		Greenhouse-Geisser	37.463	1.638	22.865	2.217	.127
		Huynh-Feldt	37.463	1.761	21.275	2.217	.124
		Lower-bound	37.463	1.000	37.463	2.217	.146
Error(Differential)	Direction	Sphericity Assumed	10.074	68	.148		
		Greenhouse-Geisser	10.074	55.370	.182		
		Huynh-Feldt	10.074	59.476	.169		
		Lower-bound	10.074	34.000	.296		
	Amount	Sphericity Assumed	574.519	68	8.449		
		Greenhouse-Geisser	574.519	55.708	10.313		
		Huynh-Feldt	574.519	59.870	9.596		
		Lower-bound	574.519	34.000	16.898		

Differential and Method effects for requirement 25

The full Table 9-149 is shown in Table 0-73.

Table 0-73 Univariate tests of simple main effect of *differential* for requirement 25

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
differential	direction	Sphericity Assumed	32.722	2	16.361	53.450	.000
		Greenhouse-Geisser	32.722	1.765	18.534	53.450	.000
		Huynh-Feldt	32.722	1.910	17.135	53.450	.000
		Lower-bound	32.722	1.000	32.722	53.450	.000
	amount	Sphericity Assumed	1032.056	2	516.028	99.866	.000
		Greenhouse-Geisser	1032.056	1.628	634.002	99.866	.000
		Huynh-Feldt	1032.056	1.748	590.255	99.866	.000
		Lower-bound	1032.056	1.000	1032.056	99.866	.000
differential * Method	direction	Sphericity Assumed	1.130	2	.565	1.845	.166
		Greenhouse-Geisser	1.130	1.765	.640	1.845	.171
		Huynh-Feldt	1.130	1.910	.592	1.845	.168
		Lower-bound	1.130	1.000	1.130	1.845	.183
	amount	Sphericity Assumed	21.907	2	10.954	2.120	.128
		Greenhouse-Geisser	21.907	1.628	13.458	2.120	.138
		Huynh-Feldt	21.907	1.748	12.529	2.120	.135
		Lower-bound	21.907	1.000	21.907	2.120	.155
Error(differential)	direction	Sphericity Assumed	20.815	68	.306		
		Greenhouse-Geisser	20.815	60.027	.347		
		Huynh-Feldt	20.815	64.929	.321		
		Lower-bound	20.815	34.000	.612		
	amount	Sphericity Assumed	351.370	68	5.167		
		Greenhouse-Geisser	351.370	55.347	6.349		
		Huynh-Feldt	351.370	59.449	5.910		
		Lower-bound	351.370	34.000	10.334		

Differential and Method effects for requirement 28

The full Table 9-152 is shown in Table 0-74.

Table 0-74 Univariate tests of *differential*method* at each measure for requirement 28

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Differential	Direction	Sphericity Assumed	.907	2	.454	4.503	.015
		Greenhouse-Geisser	.907	1.705	.532	4.503	.020
		Huynh-Feldt	.907	1.838	.494	4.503	.017
		Lower-bound	.907	1.000	.907	4.503	.041
	Amount	Sphericity Assumed	49.463	2	24.731	5.836	.005
		Greenhouse-Geisser	49.463	1.344	36.795	5.836	.013
		Huynh-Feldt	49.463	1.421	34.815	5.836	.011
		Lower-bound	49.463	1.000	49.463	5.836	.021
Differential * Method	Direction	Sphericity Assumed	.907	2	.454	4.503	.015
		Greenhouse-Geisser	.907	1.705	.532	4.503	.020
		Huynh-Feldt	.907	1.838	.494	4.503	.017
		Lower-bound	.907	1.000	.907	4.503	.041
	Amount	Sphericity Assumed	25.019	2	12.509	2.952	.059
		Greenhouse-Geisser	25.019	1.344	18.611	2.952	.081
		Huynh-Feldt	25.019	1.421	17.610	2.952	.078
		Lower-bound	25.019	1.000	25.019	2.952	.095
Error(Differential)	Direction	Sphericity Assumed	6.852	68	.101		
		Greenhouse-Geisser	6.852	57.959	.118		
		Huynh-Feldt	6.852	62.502	.110		
		Lower-bound	6.852	34.000	.202		
	Amount	Sphericity Assumed	288.185	68	4.238		
		Greenhouse-Geisser	288.185	45.706	6.305		
		Huynh-Feldt	288.185	48.305	5.966		
		Lower-bound	288.185	34.000	8.476		

TEIF Method differential closer to expert

The full Table 9-159 is shown in Table 0-75.

Table 0-75 Multivariate tests of *requirement*differential* for TEIF Method

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Requirement	Pillai's Trace	1.124	21.822	18.000	306.000	.000
	Wilks' Lambda	.164	24.834[c]	18.000	304.000	.000
	Hotelling's Trace	3.345	28.061	18.000	302.000	.000
	Roy's Largest Root	2.692	45.763[d]	9.000	153.000	.000
Differential	Pillai's Trace	.763	10.494	4.000	68.000	.000
	Wilks' Lambda	.374	10.466[c]	4.000	66.000	.000
	Hotelling's Trace	1.303	10.424	4.000	64.000	.000
	Roy's Largest Root	.889	15.117[d]	2.000	34.000	.000
Requirement * Differential	Pillai's Trace	.898	13.842	36.000	612.000	.000
	Wilks' Lambda	.254	16.675[c]	36.000	610.000	.000
	Hotelling's Trace	2.340	19.758	36.000	608.000	.000
	Roy's Largest Root	2.048	34.821[d]	18.000	306.000	.000

a. Design: Intercept
Within Subjects Design: Requirement + Differential + Requirement * Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

The full Table 9-161 is shown in Table 0-76.

Table 0-76 Univariate tests of *requirement*differential* for TEIF Method

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement	Direction	Sphericity Assumed	77.267	9	8.585	11.985	.000
		Greenhouse-Geisser	77.267	5.173	14.937	11.985	.000
		Huynh-Feldt	77.267	7.703	10.030	11.985	.000
		Lower-bound	77.267	1.000	77.267	11.985	.003
	Amount	Sphericity Assumed	2532.178	9	281.353	24.354	.000
		Greenhouse-Geisser	2532.178	4.465	567.135	24.354	.000
		Huynh-Feldt	2532.178	6.252	405.030	24.354	.000
		Lower-bound	2532.178	1.000	2532.178	24.354	.000
Error(Requirement)	Direction	Sphericity Assumed	109.600	153	.716		
		Greenhouse-Geisser	109.600	87.937	1.246		
		Huynh-Feldt	109.600	130.957	.837		
		Lower-bound	109.600	17.000	6.447		
	Amount	Sphericity Assumed	1767.556	153	11.553		
		Greenhouse-Geisser	1767.556	75.903	23.287		
		Huynh-Feldt	1767.556	106.281	16.631		
		Lower-bound	1767.556	17.000	103.974		
Differential	Direction	Sphericity Assumed	14.700	2	7.350	13.909	.000
		Greenhouse-Geisser	14.700	1.604	9.164	13.909	.000
		Huynh-Feldt	14.700	1.746	8.422	13.909	.000
		Lower-bound	14.700	1.000	14.700	13.909	.002
	Amount	Sphericity Assumed	267.478	2	133.739	13.348	.000
		Greenhouse-Geisser	267.478	1.514	176.725	13.348	.000
		Huynh-Feldt	267.478	1.630	164.094	13.348	.000
		Lower-bound	267.478	1.000	267.478	13.348	.002
Error(Differential)	Direction	Sphericity Assumed	17.967	34	.528		
		Greenhouse-Geisser	17.967	27.270	.659		
		Huynh-Feldt	17.967	29.674	.605		
		Lower-bound	17.967	17.000	1.057		
	Amount	Sphericity Assumed	340.656	34	10.019		
		Greenhouse-Geisser	340.656	25.730	13.240		
		Huynh-Feldt	340.656	27.711	12.293		
		Lower-bound	340.656	17.000	20.039		
Requirement * Differential	Direction	Sphericity Assumed	35.411	18	1.967	5.476	.000
		Greenhouse-Geisser	35.411	7.211	4.911	5.476	.000
		Huynh-Feldt	35.411	13.055	2.713	5.476	.000
		Lower-bound	35.411	1.000	35.411	5.476	.032
	Amount	Sphericity Assumed	2221.411	18	123.412	26.000	.000
		Greenhouse-Geisser	2221.411	7.428	299.058	26.000	.000
		Huynh-Feldt	2221.411	13.759	161.447	26.000	.000
		Lower-bound	2221.411	1.000	2221.411	26.000	.000
Error(Requirement*Differential)	Direction	Sphericity Assumed	109.922	306	.359		
		Greenhouse-Geisser	109.922	122.583	.897		
		Huynh-Feldt	109.922	221.927	.495		
		Lower-bound	109.922	17.000	6.466		
	Amount	Sphericity Assumed	1452.456	306	4.747		
		Greenhouse-Geisser	1452.456	126.277	11.502		
		Huynh-Feldt	1452.456	233.910	6.209		
		Lower-bound	1452.456	17.000	85.439		

Other Methods differential closer to expert

The full table is shown in Table 0-77.

Table 0-77 Multivariate tests of *requirement*differential* for Other Methods

Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.
Requirement	Pillai's Trace	1.158	23.385	18.000	306.000	.000
	Wilks' Lambda	.156	25.817[c]	18.000	304.000	.000
	Hotelling's Trace	3.383	28.381	18.000	302.000	.000
	Roy's Largest Root	2.614	44.435[d]	9.000	153.000	.000
Differential	Pillai's Trace	.830	12.067	4.000	68.000	.000
	Wilks' Lambda	.304	13.437[c]	4.000	66.000	.000
	Hotelling's Trace	1.851	14.805	4.000	64.000	.000
	Roy's Largest Root	1.569	26.680[d]	2.000	34.000	.000
Requirement * Differential	Pillai's Trace	1.072	19.653	36.000	612.000	.000
	Wilks' Lambda	.166	24.681[c]	36.000	610.000	.000
	Hotelling's Trace	3.598	30.383	36.000	608.000	.000
	Roy's Largest Root	3.141	53.389[d]	18.000	306.000	.000

a. Design: Intercept
Within Subjects Design: Requirement + Differential + Requirement * Differential
b. Tests are based on averaged variables.
c. Exact statistic
d. The statistic is an upper bound on F that yields a lower bound on the significance level.

The full Table 9-176 is shown in Table 0-78.

Table 0-78 Univariate tests of *requirement*differential* for Other Methods

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
Requirement	Direction	Sphericity Assumed	58.511	9	6.501	13.572	.000
		Greenhouse-Geisser	58.511	4.392	13.321	13.572	.000
		Huynh-Feldt	58.511	6.112	9.573	13.572	.000
		Lower-bound	58.511	1.000	58.511	13.572	.002
	Amount	Sphericity Assumed	3549.304	9	394.367	38.559	.000
		Greenhouse-Geisser	3549.304	5.040	704.216	38.559	.000
		Huynh-Feldt	3549.304	7.418	478.457	38.559	.000
		Lower-bound	3549.304	1.000	3549.304	38.559	.000
Error(Requirement)	Direction	Sphericity Assumed	73.289	153	.479		
		Greenhouse-Geisser	73.289	74.669	.982		
		Huynh-Feldt	73.289	103.908	.705		
		Lower-bound	73.289	17.000	4.311		
	Amount	Sphericity Assumed	1564.830	153	10.228		
		Greenhouse-Geisser	1564.830	85.681	18.263		
		Huynh-Feldt	1564.830	126.110	12.408		
		Lower-bound	1564.830	17.000	92.049		
Differential	Direction	Sphericity Assumed	11.626	2	5.813	13.686	.000
		Greenhouse-Geisser	11.626	1.567	7.420	13.686	.000
		Huynh-Feldt	11.626	1.698	6.847	13.686	.000
		Lower-bound	11.626	1.000	11.626	13.686	.002
	Amount	Sphericity Assumed	358.893	2	179.446	26.294	.000
		Greenhouse-Geisser	358.893	1.816	197.641	26.294	.000
		Huynh-Feldt	358.893	2.000	179.446	26.294	.000
		Lower-bound	358.893	1.000	358.893	26.294	.000
Error(Differential)	Direction	Sphericity Assumed	14.441	34	.425		
		Greenhouse-Geisser	14.441	26.637	.542		
		Huynh-Feldt	14.441	28.864	.500		
		Lower-bound	14.441	17.000	.849		
	Amount	Sphericity Assumed	232.041	34	6.825		
		Greenhouse-Geisser	232.041	30.870	7.517		
		Huynh-Feldt	232.041	34.000	6.825		
		Lower-bound	232.041	17.000	13.649		
Requirement * Differential	Direction	Sphericity Assumed	106.300	18	5.906	20.012	.000
		Greenhouse-Geisser	106.300	6.878	15.455	20.012	.000
		Huynh-Feldt	106.300	12.034	8.833	20.012	.000
		Lower-bound	106.300	1.000	106.300	20.012	.000
	Amount	Sphericity Assumed	4794.885	18	266.383	53.270	.000
		Greenhouse-Geisser	4794.885	6.163	777.990	53.270	.000
		Huynh-Feldt	4794.885	10.052	476.985	53.270	.000
		Lower-bound	4794.885	1.000	4794.885	53.270	.000
Error(Requirement* Differential)	Direction	Sphericity Assumed	90.300	306	.295		
		Greenhouse-Geisser	90.300	116.928	.772		
		Huynh-Feldt	90.300	204.576	.441		
		Lower-bound	90.300	17.000	5.312		
	Amount	Sphericity Assumed	1530.181	306	5.001		
		Greenhouse-Geisser	1530.181	104.774	14.605		
		Huynh-Feldt	1530.181	170.892	8.954		
		Lower-bound	1530.181	17.000	90.011		