Findings of Expert Validation and Review of the Technology Enhanced Interaction Framework

Kewalin Angkananon: ECS
University of Southampton
Southampton, UK
ka3e10@ecs.soton.ac.uk

Mike Wald, Lester Gilbert: ECS
University of Southampton
Southampton, UK
mw@ecs.soton.ac.uk, lg3@ecs.soton.ac.uk

Abstract—A Technology Enhanced Interaction Framework has been developed to support designers and developers designing and developing technology enhanced interactions for complex scenarios involving disabled people. Issues of motivation, time, and understanding when validating and evaluating the Technology Enhanced Interaction Framework were identified through a literature review and questionnaires and interviews with experts. Changes to content, system, and approach were made in order to address issues identified. A detailed analysis of the expert review and validation findings supported the view that the TEIF could help designers/developers design technology solutions in complex situations when disabled people are involved. The next step will be to run a motivating experiment to evaluate how and in what ways the framework helps designers/developers.

Keywords - validation; expert review; user evaluation; framework; interaction

I. INTRODUCTION

This paper focuses on the findings of expert validation and review of the Technology Enhanced Interaction Framework (TEIF) adapted from and extending the work of Dix [1] and Gaines [2] to support developers and designers designing and developing technology enhanced interactions for complex scenarios involving disabled people. Previous papers have explained: the detailed rationale behind the TEIF and a comparison with existing Frameworks [3]; the development of a seven step prototype method and process [4] to help designers/developers understand and apply the TEIF; and an example of how the TEIF could be used to develop a mobile web solution [5]. An expert validation and review was designed and involved a renowned professor in Human Computer Interaction (HCI), three designer/ developer experts and three accessibility experts to confirm that the TEIF could help designers/developers design technology solutions in complex situations when disabled people are involved. The ways in which the TEIF helps designers/developers will be investigated in future work through user evaluations using modifications to the TEIF and its associated method and process based on the expert review. Section II explains the Technology Enhanced Interaction Framework. Section III describes the example scenario. Section IV presents part of the explanation of the technology solution. Section V explains the research methodology. Section VI discusses the findings and Section VII summarises conclusions and describes future work.

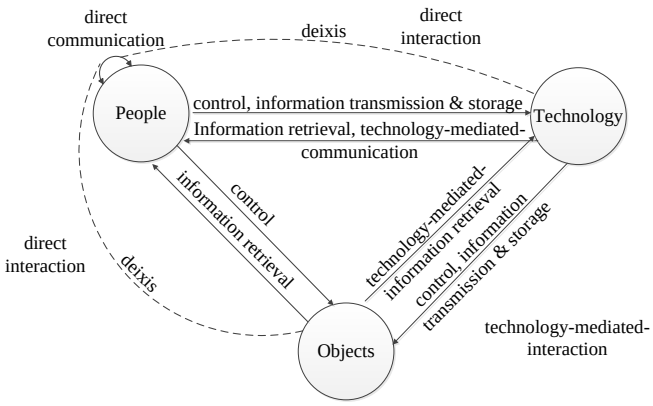

FIGURE I THE TECHNOLOGY ENHANCED INTERACTION FRAMEWORK

II. TECHNOLOGY ENHANCED INTERACTION FRAMEWORK

The TEIF supports developers and designers designing and developing technology enhanced interactions involving people, technology, and objects, and has seven main components as shown in Table I and an architecture shown in Figure I. The seven step prototype method and process consists of: a scenario; requirement questions, answers, and explanation to gather requirements; technology suggestions based on the answers from the requirement questions; a scenario technology solution; Interaction Diagram; Use case Diagram and the seventh and last step is the explanation of the technology solution. The requirement question numbers are shown next to the relevant subcomponents in Table I.

III. TECHNOLOGY SUGGESTIONS TABLE

Technology suggestions are provided to help design a technology solution to a scenario. Some of the technology suggestions for the example scenario are shown in Table II. 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. The technology suggestions in the Table II are listed in order of total score.

TABLE I. THE TECHNOLOGY ENHANCED INTERACTION FRAMEWORK

Main Component	**Main Component of Technology Enhanced Interaction Framework**	
	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 (e.g. speaker and audience, teacher and student or owner and visitor) and peer to peer (e.g. student and student or visitor and 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 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) (2)	People use technology to transmit information to assist communication with (e.g. send sms, mms, email, chat, instant message) other people.
	People-Technology -Objects (P-T-O) (2)	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 (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).

TABLE II TECHNOLOGY SUGGESTIONS

Technology suggestions	**Which scenario 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
Mobile web site	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Pre-prepared caption/subtitle	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Quick Response Code	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Instant messaging	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Vibrating alert	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Speech recognition	✓	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	12

IV. EXAMPLE SCENARIO

The following scenario describes some problems faced by hearing impaired visitors at a museum and is used to provide experts and users with requirements for a technology solution to be developed using the Framework.

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 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. Chuty (who has been hearing impaired since birth) and her parents (who have some hearing loss due to their age) are local people who visit the museum. Suchat starts the talk by explaining about the exhibits. During the talk, Chuty and her parents find it 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 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.

V. EXPLANATION OF TECHNOLOGY SOLUTION

The explanation of the technology solution is:

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. 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. 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. 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.

TABLE II. PILOT STUDY FINDINGS

Category of changes	Result of changes
Content	
Spelling and grammar mistakes	Correct and more understandable
Rewrite instructions	Clearer
Rewrite descriptions	Clearer
Add explanation of the technology suggestion tables	Help respondents understand why technologies have ticks or crosses in cells corresponding to requirements
Improve content	Make it clear and understandable without assuming knowledge
Change the image tables to html tables	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
System	
Remove the logic and always display comment box and question	System 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
Choice, force entry to move on or just reminder	remind the respondents to provide the answer but allow blank entry

VI. RESEARCH METHODOLOGY ISSUES

A. Pilot Study

Validation and review of the framework by experts was undertaken using an online system before the next step of engaging with the users (designers). The combination of online questionnaire on the system and interviewing were chosen because the experts need some time to complete the questionnaire, they can choose their preferred time and place and also can stop and return to the questionnaire whenever they want. Using the online questionnaire helps experts to see a 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 framework. For example, in the pilot test respondents gave comments about the slow response of the online 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 doesn't 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. Having constructed the questionnaire, it is important to pilot it before giving it to experts to validate and review as it is difficult even for an experienced questionnaire designer to get a questionnaire completely right at the first time. To pilot the validation and review, one experienced accessibility expert and two experienced designers/ developers took the online questionnaire through the system. Based on their responses changes were made to improve the questions, response times and layout as summarised in Table II. The pilot study participants were shown all these changes and confirmed that they were satisfied with them.

B. Triangulation

Triangulation is a technique used to ensure the validity and credibility of the results [6-8] and methodological triangulation was used based on theory of existing frameworks, expert validation and review, and user evaluation. Validation is an important process particularly when an instrument is being developed to measure the construct in the context of the concepts being studied [6]. Without validation, untested data may need revision in a future study [9]. Checking reliability normally comes at the question wording and piloting stage as if an item is unreliable, then it must also lack validity [9, 10]. An expert review is a process asking the opinions, suggestions, feedback or comments from experts. For example, subject matter experts are asked to check content of questionnaires or appropriateness of wording and terminology of items [11].

The validation of the Technology Enhanced Interaction Framework was considered by two groups of experts: designer/developer experts and accessibility experts. The design experts focused on the main and sub-components while accessibility experts focused on checking the accessibility aspects. In addition the opportunity arose to discuss the TEIF with a professor who is world renowned in the HCI field. After the expert review and validation user evaluation involving real users (designers) will be used to evaluate the Technology Enhanced Interaction Framework.

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 [12].

VII. EXPERT VALIDATION AND REVIEW FINDINGS AND DISCUSSION

If the majority of experts answer "Yes" to the questions this will be considered as a successful validation.

A. *Technology Enhanced Interaction Framework (TEIF)*

TABLE VII EXPERTS VALIDATING TEIF

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

The TEIF table was successfully validated by the experts (Table V) but as a result of the comments from the three designer experts and the expert professor the following changes to the framework components are planned.

The "Objects" component

One expert 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. 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.

The "Weather Condition" sub-component

One expert found this "Oddly Specific" and so more examples of how weather condition could affect technology interactions will be provided.

The "Examples" sub-heading

An expert suggested it was unclear what the examples were and what were the explanations and so the sub-heading will be changed to "Explanations and examples".

People being aware of other interactions

This aspect will be added as a sub-component to the context component as the professor 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).

Identity of an object

The identity of an object will be added to the sub-component "Property" as an example as suggested by the professor.

User Perception

An explanation will be provided that as pointed out by the professor, users may have the perception that technology (e.g. a robotic device triggered by the person walking past it) talking to them is a "Technology to People" interaction (T-P) whereas the TEIF categorises it as a "People – Technology-People" interaction (P-T-P).

Framework components as index for case based solutions

The Professor agreed that the framework components could be useful as an index for case based solutions. This aspect will be considered for the user evaluation.

Instructions

The majority of experts suggested proving more information about the purpose of the framework. 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.

B. *Scenario, Questions, and Answers*

Experts 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

Two accessibility experts were unclear what "instructions" referred to (Table VI). Therefore the wording will be changed to clarify this.

TABLE VIII EXPERTS VALIDATING INSTRICTIONS OF PART 1

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

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

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.

Change multiple choices options and answers

Some experts 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 component of the framework.

Question 1 : what is the main purpose of technology solution? (☐ means can select more than 1 choices)

- ☐ a. improve communication and interaction
- ☐ b. make the service more interesting and exciting
- ☐ c. improve the service efficiency in term of time and easy to use
- ☐ d. improve the storage and retrieval information
- ☐ e. make the service more realistic and authentic
- ☐ f. improve users' experiences in using the service

One expert 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.

Question 13: what type of technology devices would be appropriate for the solution to the scenario? (O means can select only 1 choice)
- O a. mobile devices
- O b. non-mobile devices
- O c. I don't know

Regarding requirement question 18 one expert 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.

Question 18: does the customer require a low cost solution?
- O a. yes
- O b. no

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 (Table VII). Having the requirement numbers next to the sub-component did not help the majority of experts (Table VII). The framework 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. One expert 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.

TABLE VIIII EXPERTS VALIDATING INSTRICTIONS OF PART 1

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

C. Technology Suggestion Tables

The technology suggestion tables were successfully validated (Table VIII). The problem the experts had with the time required to validate all the information will not be a problem with the future user evaluation because they 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 “People to objects” column should be removed by the more detailed explanations that will be provided in the framework.

TABLE VIIII EXPERTS VALIDATING INSTRICTIONS OF PART 1

Questions	**% of experts answering “Yes”**	**Successful validation**
1. Are the descriptions in the technologies tables clear?	67%	Yes
3. Do you agree that the ticks correctly identify the requirements met	60%	Yes

The professor’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 framework was being developed but it was decided that this could be a refinement for future work.

D. Scenario Technology Solution

The Scenario Technology Solution was successfully validated (Table IX). 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.

TABLE IX 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

E. Mobile Web Interaction Diagram

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

TABLE X EXPERTS VALIDATING 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

F. Use Case Diagram

The Use Case Diagram was successfully validated (Table XI). The login and logout functions will be added as suggested.

TABLE XI EXPERTS VALIDATING USE CASE DIAGRAM

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

G. Chosen Solution and Explanations

The Chosen Solution and Explanations was successfully validated (Table XII). As suggested by the experts more information will be provided, the layout/presentation will be improved and the framework method and process will be broken down into easier smaller steps.

TABLE XII EXPERTS VALIDATING 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 designers design technology to enhance interactions particularly in complex situations involving disabled people?	83%	Yes

VIII. CONCLUSION AND FUTURE WORK

Issues of motivation, time and understanding when validating and evaluating the TEIF were identified through a literature review and piloting questionnaires and interviews. Changes to content, system and approach were made in order to address these issues. Future work will involve the implementation of a motivating user evaluation approach. The work undertaken so far confirms such a TEIF be developed based on existing frameworks, theories and principles. The results of the expert validation and review by the Professor and three designer/developer experts and three accessibility experts following the methodology explained in section IV supported the view that the TEIF could help designers/developers design technology solutions in complex situations when disabled people are involved. Future Work will be to run an experiment to determine how and in what ways the framework helps designers/developers using evaluation with designers using a motivating approach.

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