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Applying Technology Enhanced Interaction Framework to Accessible Mobile Learning

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Abstract

This paper focuses on designing accessible mobile learning interactions involving disabled people using a newly developed Technology Enhanced Interaction Framework. The framework was developed to help design technological support for communication and interactions between people, technology, and objects particularly when disabled people are involved. A review of existing interaction frameworks showed that none of them help technology designers to consider all of the possible interactions that occur at the same time and in the same place (i.e. face to face situations). The components of the framework are described and explained, and examples of interactions are provided. A method has been developed and validated using technology designer and accessibility experts to help designers apply the framework and work is now in progress to evaluate the method with technology designers.

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Keywords: Mobile Web, Interaction Framework, disability

1. Introduction

This paper focuses on designing accessible mobile learning interactions involving disabled people using a newly developed Technology Enhanced Interaction Framework. The Framework has been developed as a support for software designers in their consultations with domain experts (e.g. teachers and students) and disabled people. 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

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between people, technology and objects [1-8]. There has, however, been no framework that has helped technology designers or 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 [2, 3, 9, 10], a mobile digital guidebook has been used to enhance visitors' interaction with physical objects in museums [11, 12] and mobile devices have been used as mediators for the interaction with a physical object using QR codes, RFID tags and NFC tags [5, 13]. Many publications and projects in human computer interaction (HCI) focus on using technologies as a tool to enhance experiences: in the same place but at a different time (e.g. using systems for supporting group learning such as notice boards, questions and answers, electronic debates and collaborative learning [11]); in a different place but at the same time (e.g. using a Synchronous Communication Tool such as video conferencing, instant messaging and online chats to interact with learners to improve their communication with the Instructor [14]); and in a different place at a different time (e.g. using blended learning, students can access e-learning in order to learn in a different place at a different time [15]). The general interaction framework described in this paper has been adapted from and extending the work of Dix [12] and Gaines [16] to help design technology to support communication between people and improve interactions between people, technology and objects, particularly in complex situations. The paper is structured as follows. Section 2 reviews previous research on interaction frameworks including mobile learning, section 3 explains the Technology Enhanced Interaction Framework (TEIF), section 4 explains the TEIF method and section 5 presents a mobile web solution for a learning scenario, section 6 summarises the findings from the expert validation and review and section 7 concludes with a mention of the future work taking place to enable the framework to help developers design technology to enhance face-to-face interaction in the same time and the same place using mobile application.

2. Review of Interaction Frameworks

A review of interaction frameworks shows none of the framework has assisted technology designers and 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. Table 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 [1, 4, 12, 15, 17, 20- 21], ten frameworks mention interaction between people and technology [5-6, 10-11, 15, 18, 19-20, 23-24], eight frameworks focus on using technology to mediate interaction between people [5-7, 11-12, 15, 22, 24], and two frameworks consider using technology to enhance interaction between people and objects (P-T-O)[6, 24]. However, only the Human Activity Assistive Technology Model (HAAT) [23] considers accessibility in the interaction. The communication between people is a complex subject [12]. Bern [1] identified roles of parent, adult, and child in his theory of Transactional Analysis. The conversational framework developed by Laurillard [4] describes how the roles of teachers and students interact in the learning and teaching process. For example, in a school classroom; the teacher's role is characteristically to provide information, show examples, ask questions, and provide feedback. A student characteristically undertakes learning activities such as listening, asking and answering questions. People have abilities or disabilities which can affect their use of technology or understanding of language and which can lead to communication breakdown. For example, students may be deaf or blind, have difficulty in learning or using technology, or be international students with difficulties in understanding a non-native language of instruction. The ability or disability can also affect interaction breakdown, e.g. people may refer to particular objects and technology by pointing (this is known as deixis [12]) which a blind student would not see. There are some other frameworks that have some relevance to mobile learning. Sung et al. [6] 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. Rukzio [5] presented a physical mobile interaction framework for using mobile devices as mediator for the interaction with a physical object and discussed purpose, need, training, information overload, item headings, initial items, and activity. Klink [15] evaluated the use of synchronous and asynchronous interaction its implementation in outdoor museums.

Table 1. Summarising a review of frameworks of interactions

	Transactional analysis [1]	Conversational Framework [4]	Conversation Analysis [17]	Interaction Analysis [20]	Role of Artefacts in Mediated Communication [7]	Computer supported cooperative work - A framework [12]	The Physical Mobile Interaction Framework (PMIF) [5]	Designing an electronic guild book for learning engagement in a museum of history [6]	Multimodal Interaction Framework W3C 2003, [10]	Norman's model of Interaction, [19]	The Interaction Model, [20]	A Ecological Model of the Communication Process [21]	a time/space matrix to classify synchronous and asynchronous technology [22]	Human Activity Assistive Technology Model, [23]	Systems for supporting group learning [11]	A Conceptual Framework for Person-Computer Interaction in Distributed Systems, [18]	Blended Interaction, [24]	Blended Learning [15]	Technology Enhanced Interaction Framework
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 interaction																			
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														✓					✓

Lee et al. [11] focused on the use of asynchronous computer mediated communication (CMC) systems for supporting group learning and identified as critical success factors: educational 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). Gaines [16] presented 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 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. Norman's model of interaction [19] 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 doesn't 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. Abowd and Beale [20] extended Norman's model to include the input and output components of the user interface.

There is a framework that addressed the issue about accessibility [23] which 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). The extensive guidelines for accessibility and usability [35] (e.g. WCAG 2.0, BS8878, Nielsen's usability heuristics, Shneiderman's 8 golden rules etc. W3C MWBP etc.) refer only to the interactions between people and technologies and not the other types of interactions identified in Table 1. However, no other current framework addresses all of the interactions identified in Table 1. The TEIF addresses this, as explained in the next section. The concepts of accessibility, usability and user experience 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.

3. The Technology Enhanced Interaction Framework (TEIF)

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 designers to consider all of the possible interactions that occur at the same time and in the same place. The TEIF can be extrapolated to different environments and in this paper it is centred in learning environments.

3.1. Terminology

- **Communication** is the process of passing information from one person to another [25].
- **Technology** is a tool that helps people achieve their purpose.
- **People** means anyone involved in direct communication or interaction with an object, technology, or people.
- **Object** is 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).

3.2. Main Components

There are seven main components in the TEIF. 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). 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)). 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: P-P - people in one way or two way communication with people.
 2) Direct Interaction: P-T - people can control technology and may also use it to store or retrieve information; P-O - People can control objects and retrieve information from objects.
 3) Technology Mediated Interaction: P-T-P -technology can mediate communication between people (e.g. people using their smart phones to communicate to each other by sending SMS or MMS messages, calling, sending email, sharing information through Bluetooth, or text chatting through mobile applications.); P-T-O - people can control objects with technology and may also be enabled to use objects to store and retrieve information (e.g. people controlling their mobile phones to take photos of a building or scan QR codes on the building). Time and Place can be divided into four categories [22]: 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, and weather conditions. The role played by the interactions and communication may be classified into one of six interaction layers, adapted from Gaines [16] as shown by the example of pressing of the letter ‘h’ on the keyboard when typing “hello” as a greeting when sending a text message:

- Cultural layer includes countries, tradition, language, and gesture (e.g. hello is greeting used in the culture).
- Intentionality layer involves understanding, purpose and benefit (e.g. greeting).
- Knowledge layer involves facts, concepts, and principle [16] (e.g. how to spell the word “hello”).
- Action layer involves actions and procedures [25] (e.g. pressing key ‘h’).
- Expression layer describes how actions are carried out (e.g. pressing the correct key).
- Physical layer is the lowest layer at which people interact with the physical world (e.g. button is depressed sending letter code to the application).

3.3. Architecture of the Technology Enhanced Interaction Framework

The overall architecture of the TEIF involves people, technology and objects (Fig. 1). 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.

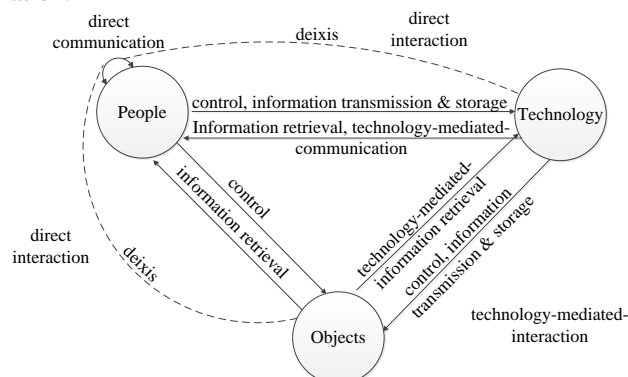


Fig. 1 The Technology Enhanced Interaction Framework extended from Dix [12]

4. The TEIF Method

The TEIF Method has been developed based on TEIF, to help a designer who is not an accessibility expert to understand the problems and solutions faced by disabled people so that the designer can ensure that their designs are suitable for all users. The TEIF method consists of 19 multiple choice questions to elicit requirements based on the components of the TEIF. Designers analyse their scenario and answer the questions. The answers will suggest relevant technologies. The technology developer decides on the solution based on the technology suggestions and discussions with their client. The example of how to design a possible technology solution is shown in the technology solution scenario (Table 2) and interaction diagram (Fig. 2). In order to explain how the framework is instantiated in the TEIF method, the following example accessible mobile learning scenario is provided which 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, a group of University students including Chuty (who has been hearing impaired since birth) and their lecturer visit the museum as part of their tourism module to learn more about it. Suchat starts the talk by explaining about the exhibits. 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 is watching the shadow puppet show, she 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 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.

4.1. Requirement questions, answers, and explanations

- 1) **What is the main purpose of 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 at the Museum of Folk Art and Shadow Puppets, Thailand on 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 presenter and audience members are there?** Answer: a. one presenter – many audience members, **Explanation:** Suchat is a person who gives the information to Chuty and her parents.
- 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 hearing impairments.
- 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 audience 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. P-P and b. P-O, **Explanation:** Suchat communicates with Chuty and her parents (P-P) and Chuty and her parents watch the shadow puppet show (P-O).
- 12) **What type of technology would be appropriate for the solution to the scenario?** Answer: a. online, **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.

15) Are audio or video recordings shown in the scenario? Answer: c. neither, **Explanation:** there are no audio or video recordings 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 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 have a limitation of cost in designing technology? Answer: a. Yes, **Explanation:** Suchat would like to use audience' 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.

4.2. Technology Suggestions Table

The key requirements answers from the gathering requirement stage link to the Technology Suggestions Tables (Table 2) which indicate possible technology suggestions. Table 2 shows 10 technology suggestions from the 22 available. Note that the column furthest to the right (Total score) shows the number of scenario requirements met by each technology suggestion. Tick (indicating the requirement is met by suggested technology) and cross (indicating the requirement is not met by suggested technology) are shown in Table 2. One of highest scoring technologies is the mobile web site which addresses all of the problems and requirements but the decision about technologies to implement would depend on their cost and prioritization of the relative importance of requirements. To help designers and developers understand how to follow the suggestions, an example Mobile Web Solution is provided which also includes other suggested technologies in designing the solution.

Table 2 Technology Suggestions

Technology suggestions	Which scenario requirements the technology meets															Total Score	
	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 phones
Mobile web site	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Pre-prepared caption	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
FAQ	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
QR-codes	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Instant messaging	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Short Message Service	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Vibrating alert	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Speech recognition	✓	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	12
Internet Protocol Relay	✓	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	×	✓	11
Voice Carry Over	✓	×	✓	×	×	✓	✓	×	✓	✓	✓	✓	✓	×	×	×	10

5. Mobile Web Solution for Scenario

The Mobile Web Solution Scenario presented in Fig. 2 is a part of the example of how the Technology Suggestion Tables can help in the design of technology solutions. From the Mobile Web Solution, Suchat has a role in the communication which is important because he can control technology to send an instant message to Chuty's phone to make it vibrate to let Chuty know when the conversation starts. The technology solution selected to enable this is instant messaging which was chosen over SMS because it is free using wireless and smartphones [26-28]. Moreover, it can also vibrate Chuty's Smartphone which is better than turning lights in the room on and off to notify her 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 [29-33]. Thai speech recognition is not very accurate for spontaneous speech [30] 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 is 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 asks 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 [34].

Italic means face to face communication,
Normal means Technology Enhanced Interaction

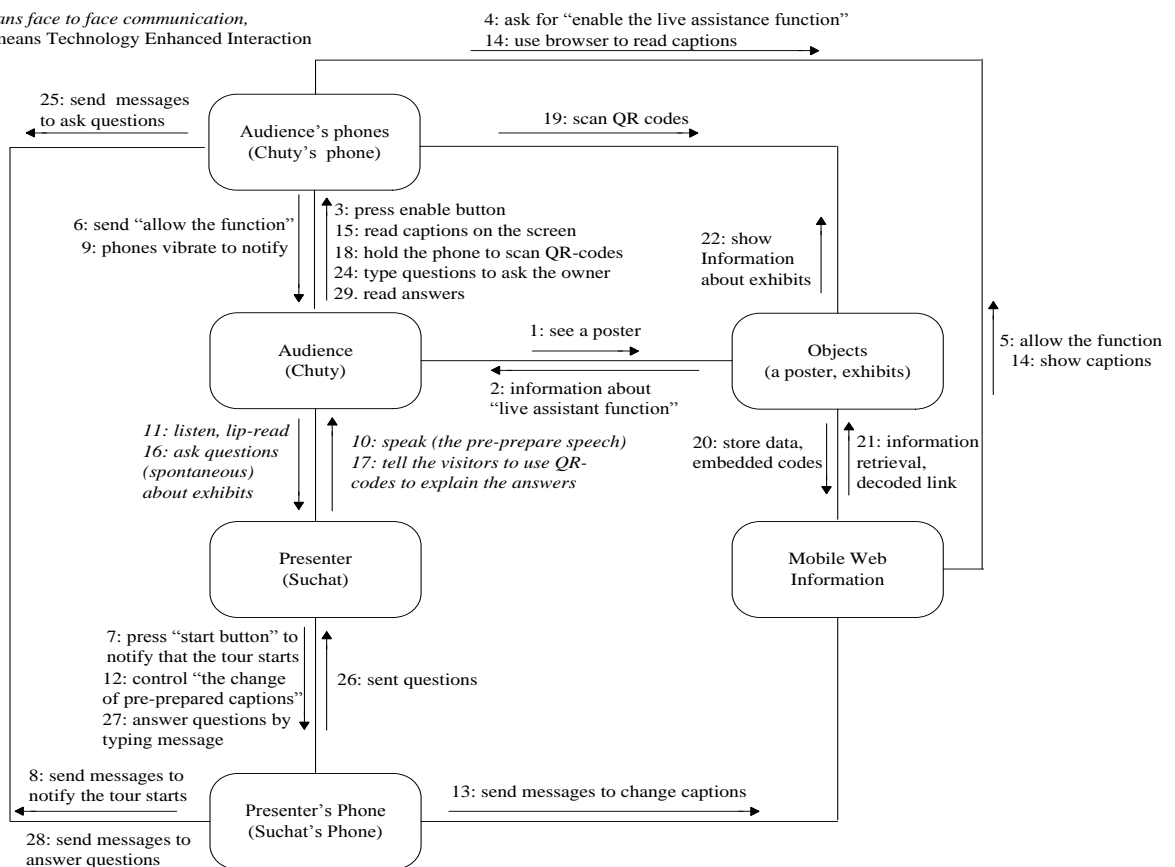


Fig. 2 Interaction Diagram

6. Expert Validation and Review Findings

Six experts (with over five years experience) were chosen to review and validate the TEIF framework and method based on their expertise. Three experts were technology designer experts; the other three were accessibility experts. Both groups of experts were asked to validate and review the framework and method via an online survey. The technology designer experts focused on the framework and interaction diagram, whereas the accessibility experts were also asked to check the descriptions and explanations of the technology suggestions. The experts made suggestions for improvement to both the content and the system and their answers and suggestions are discussed below.

6.1. Expert Validation and Review of TEIF

The TEIF was successfully validated by the three technology designer experts. The experts' suggestions about the TEIF framework were: more detailed explanation of "object"; more examples of how weather condition could affect technology interactions; 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 Technology to People interactions.

6.2. Experts Validation and Review of TEIF method

The TEIF method was successfully validated by the three technology designer experts and three accessibility experts. The expert's suggestions about the method were: more information and improve grammar/spelling/rewording and layout/presentation; remove question 1 choice 'f'; explain relationship between requirements and subcomponents; investigate easier movement between sections; improve numbering and re-ordering of actions in Mobile Web Interaction Diagram; present framework method and process in easier smaller steps; consider Framework components as index for case based solutions.

7. Conclusion and Future Work

The scenario and accessible mobile web learning solution described in this paper demonstrates how the Technology Enhanced Interaction Framework and its associated method addresses the issue that, until now, there has been no framework to support technology designers and developers considering all of the interactions that might occur in face to face situations involving disabled people. The Technology Enhanced Interaction Framework and Method have been validated and reviewed by technology designer and accessibility experts and will now be evaluated by technology designers.

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