DESIGNING MOBILE WEB SOLUTIONS FOR INTERACTION SCENARIOS INVOLVING DISABLED PEOPLE

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ABSTRACT

This paper focuses on designing Mobile Web Solutions for interactions involving disabled people. The Mobile Web solution for an example scenario is described, designed using a new Technology Enhanced Interaction Framework. The framework was developed to help design technological support for communication and interactions between people, technology, and objects. A review of existing interaction frameworks showed that none of them help technology designers and developers to consider all of the possible interactions that occur at the same time and in the same place. The components of the framework are described and explained, and examples of interactions are provided. A tool was developed to provide advice on design and development factors for technological support particularly when disabled people are involved. Work is now in progress to validate the framework and the tool with expert designers and accessibility experts before evaluating it with technology designers.

KEY WORDS
Mobile Web, Interaction Framework, disability

1. Introduction

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 objects [1, 2, 3, 4, 5, 6, 7]. There has, however, been no framework that has helped 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 many frameworks focus on people to people communication in the same time and at the same place but not using technology to enhance communication. Some frameworks address many interactions between humans and computers [3, 6] but no current framework addresses all of the interactions identified in Table 1 and so the Technology Enhanced Interaction Framework was developed to addresses this, as explained in the next sections. This paper focuses on the development of a mobile web solution to a complex scenario involving disabled people by using a newly developed framework adapted from and extending the work of Dix [10] and Gaines [18]. The paper is structured as follows. Section 2 explains the Technology Enhanced Interaction Framework, section 3 describes a Thai local museum scenario and presents the Framework questions and the corresponding answers with explanations based on the scenario's requirements. Section 4 describes the Framework's suggestions for designing a technology solution for the scenario. Section 5 describes and explains the chosen solution while section 6 describes future work to validate the framework and the tool with expert designers and accessibility experts.

2. The Technology Enhanced Interaction Framework

The Technology Enhanced Interaction Framework supports developers and designers to design and develop technology enhanced interactions.

2.1 Terminology

- **Communication** is the process of passing information from one person to another [21].
- **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 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).

2.2 Main Components

There are seven main components in the Technology Enhanced Interaction Framework as shown in Table 2.

Table 1 Summarising a review of frameworks of interactions

	Transactional analysis [1]	Conversational Framework (Laurillard, 1993) [4]	Conversation Analysis Harvey Sacks (Silverman, 1998) [8]	Interaction Analysis, (Flanders, 1960) [9]	Role of Artefacts in Mediated Communication (Vyas et al., 2008) [7]	Computer supported cooperative work - A framework (Dix, 1994) [10]	The Physical Mobile Interaction Framework (PMIF) (Rukzio, 2008) [5]	Designing an electronic guild book for learning engagement in a museum of history (Sung et al., 2010) [6]	Multimodal Interaction Framework W3C 2003 11, (Larson et al., 2003) [11]	Norman's model of Interaction, (Norman and Draper, 1986) [12]	The Interaction Model, (Abowd and Beale, 1991) [13]	A Ecological Model of the Communication Process (Foulger, 2004) [14]	Aristotle's Model of Communication (Aristotle, 1952) [15]	Human Activity Assistive Technology Model, (Cook and Hussey, 1995) [16]	System for supporting group learning (Lee et al., 2009) [17]	A Conceptual Framework for Person-Computer Interaction in Distributes Systems, (Gaines, 1988) [18]	Schramm's Model of Communication, (Schramm, 1954) [19]	Human Computer Interaction (Dix et al., 2004) [3]	Blended Learning (Klink, 2006) [20]	Technology Enhanced Interaction Framework
Direct Communication																				
People-People	✓	✓	✓	✓		✓						✓	✓				✓		✓	✓
Interactions																				
People-Technology							✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓
People-Object																				✓
People-technology-people					✓	✓	✓	✓							✓			✓	✓	✓
People-technology-object								✓												✓
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														✓						✓

Table 2 Main and sub-component of Technology Enhanced Interaction Framework

Main Component	Main and sub-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 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 (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 (D).
	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).

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. 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)
2) Direct Interaction: People to Technology (P-T); People to Objects (P-O)
3) Mediated Interaction using Technology: People to Technology to People (P-T-P); People to Technology to Objects (P-T-O).

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.

Interactions and communication may take place at one or more of six interaction layers, adapted from Gaines [18] as follows:

- Cultural layer includes countries, tradition, language, and gesture.
- Intentionality layer involves understanding, purpose and benefit.
- Knowledge layer involves facts, concepts, and principle [23].
- Action layer involves actions and procedures [23].
- 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.

2.3 Architecture of the Technology Enhanced Interaction Framework

The overall architecture of the Technology Enhanced Interaction Framework involves people, technology and objects (Figure 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.

3. Scenario, Questions and Answers

In order to explain how the framework is instantiated in a tool, the following example scenario is provided.

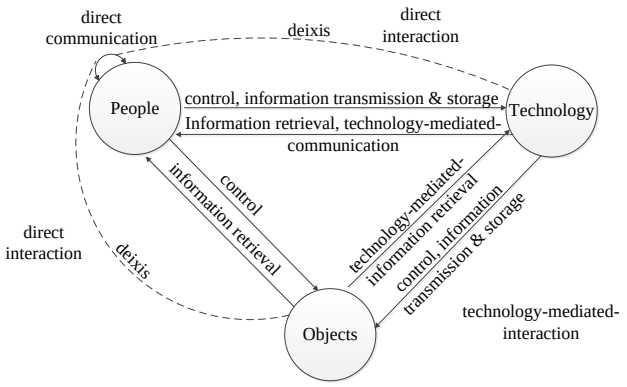

Figure 1. The Technology Enhanced Interaction Framework extended from Dix [10]

3.1 Scenario

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. It 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.

The example scenario provides problems faced by the visitors, the museum's owner and requirements for a technology solution.

3.2 Framework Tool Questions

The Technology Enhanced Interaction Framework can help designers to design technology solutions to meet Suchat's requirements. The tool, which is based on the framework, helps 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 tool asks nineteen multiple choice questions to elicit requirements based on

the sub-components of the framework and the number of the requirement is shown in the Table 3. Developers and designers analyse their scenario and answer the questions. The relevant questions, answers, and explanations for the provided scenario are as follows:

1) What is the main purpose of technology solution?
Answer: a. improve communication
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
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
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
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
Suchat doesn't have any disability.
6) What language does the presenter use?
Answer: b. Thai
Suchat talks to Chuty and her parents in Thai.
7) What language does the audience use?
Answer: b. Thai
Chuty and her parents are local people who live in Thailand.
8) Does the audience have a disability?
Answer: a. Yes
Chuty and her parents have hearing impairments.
9) What kind of disability does the audience have?
Answer: a. hearing impaired
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
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 - people and b. people - objects
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
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
Suchat would like to use Chuty's and her parents' smartphones.
14) Has the presenter planned what he wants to say?
Answer: a. Yes
Suchat has already prepared what to talk to the visitors about (pre-prepared speech).
15) Are audio or video recordings shown in the scenario?
Answer: c. neither
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
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
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
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
Suchat would like to have a technology solution that makes it easier for Chuty and her parents to understand him using their smartphones.

4. Technology Suggestions

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 3. The technology suggestions are based upon an analysis of answers to the tool's questions. Note that the column furthest to the right (Total score) shows the number of scenario requirements met by each technology suggestion.

All the technology suggestions shown in Table 3 improve communication which is the requirement expressed in the answer to question 1. The suggestions in the table are listed in order of total score. 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 18 and 19.

Table 3 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
Frequently asked questions (FAQ)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Quick Response Code (QR-codes)	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	16
Instant messaging	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Short Message Service (SMS)	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Vibrating alert	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	15
Speech recognition	✓	✓	✓	×	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	✓	12

5. Chosen Solution and Explanations

The highest scoring technology is the mobile web site which addresses all of the problems and requirements. However 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 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 that incorporates some of the other technology suggestions shown in Table 3.

5.1 Mobile Web Solution for Scenario

The technology developer has decided based on the Framework's suggestions and discussions with their client Suchat to make available a mobile web site 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 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 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 a mobile website, 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 to the server causing the captions to automatically change 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. 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 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 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 understand Suchat's answers she can use the further information displayed on her smartphone browser through the links from the QR codes on the exhibits.

5.2 Mobile Web Interactions

To help designers and developers understand the scenario solution's interactions, they are presented in Figure 2.

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 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 [24],[25],[26]. 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 [27],[28],[29],[30]. Thai speech recognition is not very accurate for spontaneous speech [31] 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 [32].

6. Conclusion and Future Work

The scenario and mobile web solution described in this paper demonstrates how the Technology Enhanced Interaction Framework and its associated tool addresses the issue that, until now, there has been no framework to support technology designers and developers in considering all of the interactions that might occur. Work is now in progress to validate the tool that helps apply the framework to create technology solutions to complex communication and interaction problems and situations, particularly those occurring at the same time and in the same place involving disabled people.

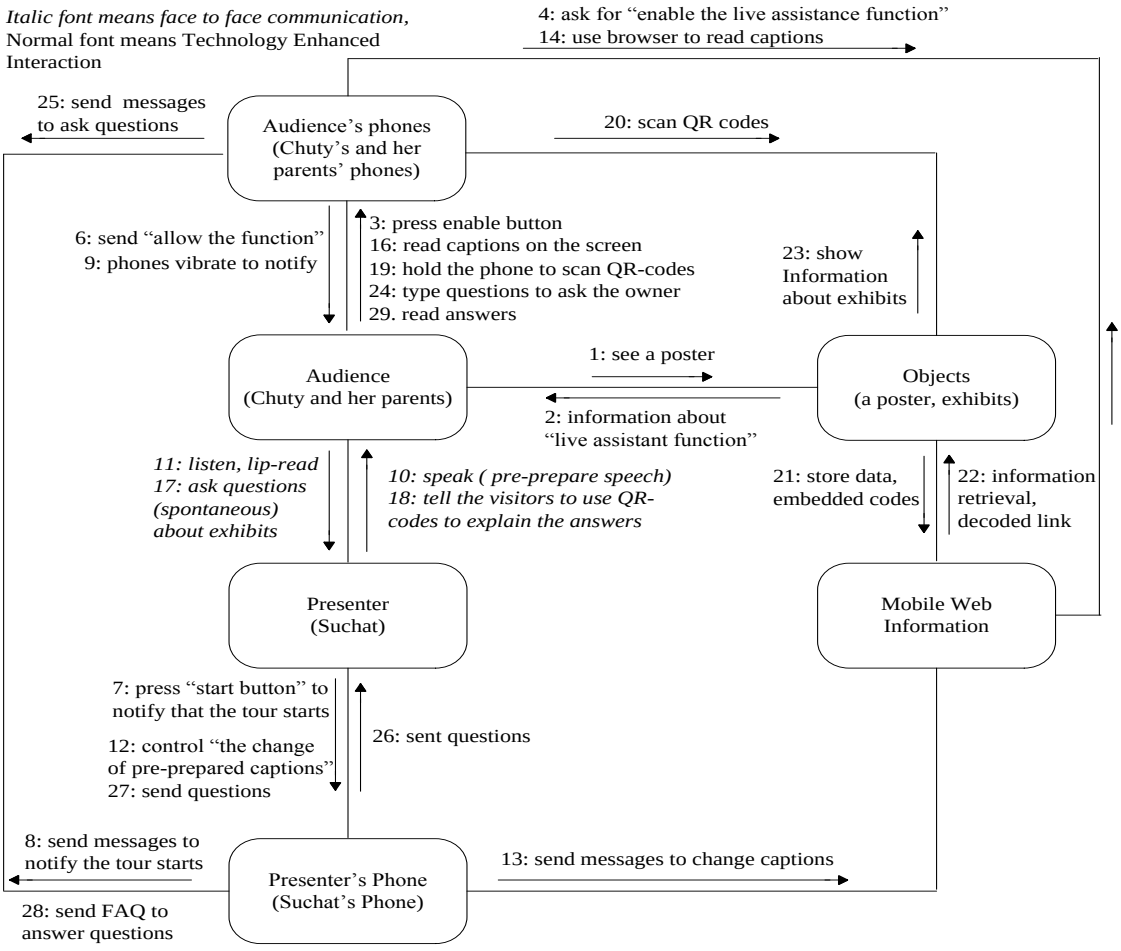

Figure 2 Mobile Web Interactions Diagram

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