Journal of Universal Computer Science, vol. 20, no. 7 (2014), 964-985
submitted: 31/1/14, accepted: 30/6/14, appeared: 1/7/14 © J.UCS

User-Centered Requirement Engineering for Accessible Chats in m-Learning

Rocío Calvo
(Universidad Carlos III de Madrid, Leganés, Spain
mrcalvo@inf.uc3m.es)

Ana Iglesias
(Universidad Carlos III de Madrid, Leganés, Spain
aiglesia@inf.uc3m.es)

Lourdes Moreno
(Universidad Carlos III de Madrid, Leganés, Spain
lmoreno@inf.uc3m.es)

Abstract: Chat applications are useful synchronous tools in mobile learning (m-learning) environments. However, these tools have accessibility problems which cannot be avoided by students and teachers with disabilities. This paper focuses on detecting these accessibility problems. Specifically, this paper presents the Requirement Engineering (RE) process carried out to obtain the requirements needed to improve the interaction for people who experience problems with the *Flow and Rhythm* of the conversation in chats. A methodological approach has been followed and Software Engineering (SE) and Human Computer Interaction (HCI) disciplines were combined in order to improve the interaction during the chat.

Keywords: Accessibility, mobile, chat, Human Computer Interaction, Software Engineering, Requirements Engineering
Categories: D.2.1, H.5.2, H.5.3

1 Introduction

Computer Supported Collaborative Learning (CSCL) tools are becoming important in carrying out activities which cannot be completed in face-to-face classes [Bicen, 13]. Moreover, mobile devices are used to support individual and CSCL learning. Students can take special advantage of the characteristics of mobile devices using them for learning, collaborating and communicating with their teachers and classmates [Uden, 07]. There are different ways of communication such as: e-mail, chat or blog. Specifically, chats are considered one of the most useful CSCL tools through mobile devices [Corlett, 05]. However, chats give rise to many accessibility problems, even more than other learning technologies [Hackett, 04]. As a result, some students cannot use these tools resulting in possible discrimination.

Previous studies have tried to solve some of these accessibility problems. Some have focused exclusively on specific disabilities [Woodfin, 06]. Others exclude users from the development process [Royle, 09]. Moreover, none of them focus on improving the users' interaction of m-learning chats. Considering all these things, the main objective of this research is to describe the disengagement from the

Requirement Engineering (RE) technology process carried out to improve the m-learning chat interaction for people who experience problems related to the *Flow and Rhythm* of the conversation. To achieve this, Software Engineering (SE) and Human Computer Interaction (HCI) disciplines were combined.

Next, the related State of Art is specified. After that, the RE process is detailed for this specific research. And finally, the conclusions and future research are presented.

2 State of art

This section specifies the chat's accessibility problems, previous accessible chats and how HCI and SE disciplines have been combined previously in the RE process.

2.1 Chat Accessibility Problems

Real time tools in learning environments can improve the informal learning and the academic development of the students [Dhir, 13]. One of the CSCL tools which supports just in time learning is Chat. This tool is really useful in communicating with other students or teachers e-learning environments [Corlett, 05]. However, chats cannot be used by everybody because of their accessibility barriers [Hackett, 04]. This problem is contravenes human rights because it does not comply with international laws, which try to preserve the human rights related to education, such as: The Special Education Needs and Disabilities Act (SENDA) in The United Kingdom [UK Law, 01] or The Disabilities Education Act (IDEA) in The United States [USA Law, 04].

Some barriers are related to the assistive technology that some people need to use because the user agents do not provide complete support for this technology. For instance, if the website is continuously auto-refreshing, it causes the screen reader to restart reading [Lazar, 07] and Braille-display users experience problems because the assistive technology reproduces the new sentences even if the previous sentence has not been enunciated completely [Hampel, 99]. Furthermore, if the technology is not used properly, people could experience other accessibility barriers [Schoeberlein, 09]

Other problems are related to the *Flow and Rhythm* of the conversation. Learners with dyslexia can feel embarrassed as they have some problems in the interaction [Woodfin, 06]. Furthermore, if one of the emitters is not able to type quickly enough, he or she might not be able to follow the conversation because the other user is writing quicker [Guenaga, 04]. Moreover, foreign students could have *Flow and Rhythm* problems because they need more time to think in other language [Noll, 10].

2.2 Previous Accessible Chat Approaches in Learning Environments

Previous researches have tried to improve the accessibility problems that users face when they interact with chats. As regards the use of chats in e-learning environments such as Learning Content Management Systems (LCMS), some of them have tried to improve more accessible chats in their tools. For instance, Moodle 2.3 has an interface which does not use frames or Javascript technology and the messages are not

autorefreshing continually [Moodle, 11]. Furthermore, ATutor introduces AChat[1] to solve some technological aspects which can be used by users who use assistive technology and provides functionalities such as specifying the auto refreshing time or refreshing messages manually among others proposals. Moreover, Blackboard[2] creates an accessible chat which allows shortcuts and better support to screen readers to be added [Blackboard, 13]. However, it does not provide "equal access" to all users; although some accessibility guidelines such as Section 508 Act [USA Law, 98] or W3C accessibility guidelines [W3C, 08] are performed by the tool [Blackboard, 12]. Another example is provided by eCollege[3] which complies with the Section 508 Act and provides a chat option for use by assistive technologies [AccessIT,04].

As regards chats in mobile devices, AssistiveChat[4] provides new features such as: predefined sentences or words for people with communication needs who have little or no functional speech disabilities. Furthermore, the PictoChat [Royle, 09] uses a chat for learning environment through a Nintendo DS console. This chat allows users to write or draw on the screen and communicate with their colleagues; it could be useful to allow users to use drawings instead of words or sentences. However, these chats are not accessible because they did not consider accessibility in its design.

2.3 Requirement Engineering combining Human Computer Interaction and Software Engineering disciplines

The RE process is really important in the software lifecycle because it can mean the failure or success of an information technology project [Lyytinen, 87]. Thus, it is important to pay attention to the RE in any system and carry it out conscientiously. Depending on the author the RE process can be divided into three [Kramer, 88] or four [Thayer, 96] phases. Based on Kramer research there are three RE phases: elicitation, specification and validation. The elicitation phase captures the requirements that the system and user needs. After that, the specification phase formalizes these requirements to be understood by engineers. Finally, the validation phase checks whether the specified requirements are correct or not. These phases must include a relationship between developers, analysts, designers, customers and users because the lack of interaction between them could bring about the failure of the final developed system [Escalona, 04]. HCI and SE methods are really important in the RE process to obtain both, the user and system requirements to create an accessible chat in mobile devices for learning environments [Jerome, 05].

There are some methods which are specific to a discipline, others are used in both disciplines and sometimes, although they are used in both disciplines, they are used in a different way [Seffah, 05]. Moreover, previous research work has studied the gap between SE and HCI disciplines. For instance, the study provided by Sutcliffe [Sutcliffe, 13] combines both of them in the RE process. Furthermore, [Escalona, 04] specifies the main methods used in SE for each phase of the RE process and [Maguire, 01] explains the HCI methods used for each phase.

---

1 http://atutor.ca/achat/
2 http://www.blackboard.com/
3 http://www.ecollege.com/
4 http://www.assistiveapps.com

2.4 Discussion

Creating accessible software is important to avoid the barriers that students and teachers experience. Previous research has detected accessibility problems and one of the most significant problems that people face is related to follow the *Flow and Rhythm* of the conversation. Moreover, the objective of previous chats is to reduce these accessibility problems. However, they have limitations in the RE process such as not including user participation, the lack of compliance with standards and guidelines, the design for specific technologies or the lack of improvement in user interaction. Thus, the different ways of performing a suitable RE process have been analyzed in order to follow those that best involve users.

Considering all these aspects, the main goal of the research is to improve the interaction of chats for people who experience problems with the *Flow and Rhythm* of the conversation. This article presents a combination of SE and HCI methods in the RE process to improve the interaction of chats in m-learning environments.

3 Requirement Engineering of an accessible chat in Mobile Devices

This section shows how the RE phases have been performed to obtain the main requirements that a chat for mobile devices and learning environments should have to become accessible. In order to disengage the requirements from the technology, a chat has been considered which is not specific to any technology. This research is based on the study [Kramer, 88] which specifies that the RE phases are: elicitation, specification and validation . Moreover, it is based on the two studies which specify the HCI and SE methods [Escalona, 04] and the study which includes HCI in the SE process [Maguire, 01]. Table 1shows the main methods used in the RE process, their phase and the discipline or disciplines followed in each method.

The following sections present how the HCI and SE disciplines were combined in the RE process to obtain the requirements for an accessible chat in mobile devices.

3.1 Elicitation of Requirements

Our research combines the HCI and SE disciplines to elicit the requirements. This phase specifies how these methods have been carried out.

3.1.1 Analyze and identify stakeholders and users.

According to the HCI discipline, the first step in eliciting the requirements is to obtain the main users and stakeholders who use chats in m-learning. The study focuses on people with disabilities who might be able to communicate through text-conversations without having problems related to vocabulary or sentence structure. Thus, people with severe cognitive disabilities or people with hearing disabilities whose mother tongue is sign language were not considered in the study. Furthermore, to limit the research, teachers and students are the stakeholders and users of the system. They can interact with each other and teachers do not conduct the conversations.

3.1.2 Context of use analysis

In order to obtain a good solution proposal, a specific domain has been chosen to elicit accessibility requirements for m-learning chats. Thus, we analyze the users' needs for chats in m-learning environments.

The research focuses on one of the CSCL synchronous tools [IMS, 04] the chat. Moreover, it is important to emphasize that this research focuses on the synchronous way in which users are connected. Furthermore, the chat is enshrined in the two types of interaction which could be possible in a chat for m-learning purposes, learner and instructor and learner and learner. It means that students and teachers could carry out the same tasks and instructors are not the only source of knowledge.

Phase	Methods	Discipline
Elicitation	Identify stakeholders and users and stakeholder analysis	HCI, SE
	Context of use analysis	HCI
	Existing system/competitor analyzes	HCI
	Personas	HCI
	Scenarios	HCI
	Questionnaires	HCI
	User interviews	HCI
	Standards and guidelines	SE
	Categorize requirements	HCI
Formalization	Natural Language	SE
	Use Cases Diagram	SE
	Sequence UML Diagram	SE
	Templates. Use Case Description	SE
	Storyboard	HCI
	Scenarios	HCI, SE
	Mockup	HCI
Validation	Review /Audit	SE
	User Interviews	HCI
	Questionnaires	HCI
	Prototype Validation	HCI, SE

Table 1: Methods used in each Phase and the Discipline

3.1.3 Existing system/competitor analyses

Existing chat applications (in mobile and desktop devices) have been analyzed to study their functionality and accessibility problems. Related to the chat's accessibility problems in e-learning environments, accessibility evaluations of some chats used by some of the most used LCMSs around the world such as Atutor[5] or Moodle[6] have been carried out [Seffah, 05] based on WCAG 2.0 and Authoring Tool Accessibility

[5] http://atutor.ca/
[6] https://moodle.org/

Guidelines (ATAG 2.0). The results showed that the evaluated tools do not comply with the minimum legal accessibility conformance level (AA).

3.1.4 Personas and Scenario Methods

The Personas and Scenario methods were combined in order to obtain accessibility problems in the previous phases of the research. Firstly, hypothetical users were created to represent groups of users who shared behavior patterns, objectives and necessities [Cooper, 03]. And secondly, the Scenario method was used to obtain information related to how the Personas created in the previous phase interact with chats in mobile devices [Carroll, 97]

The users, who perform chats, in an m-learning environment are students and teachers with different characteristics. According to Henry in [Henry, 07], it is important to emphasize that each user has his or her own characteristics and that each user is able to perform each task depending on their abilities or disabilities, or the level of expertise, age and so on. Specifically, people, who use a chat through a mobile device, can be limited by some characteristics: the type of disability (speech, visual, physical, hearing or cognitive), age, sex, native tongue, place of birth and previous experience in mobile devices, using web, assistive software and chats. The analysis of these characteristics allows us to create and categorize the personas. The Figure 1 illustrates an example of the personas method used in this work.

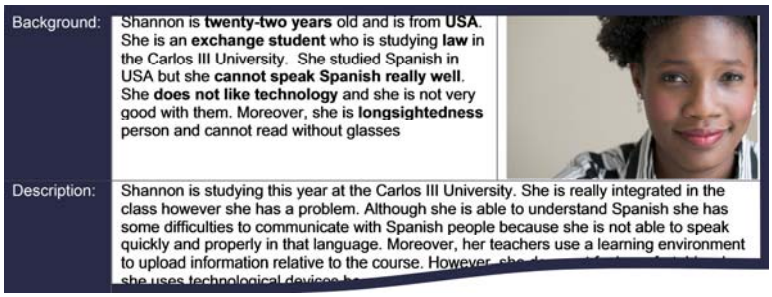

Figure 1: Example of Persona Method of HCI

Moreover, the Scenario method [Carroll, 97] is used by HCI and SE disciplines but in a different way. HCI uses it to know how people interact and SE uses it to obtain the system's requirements. Each created scenario has different characteristics and specifies the actors who interact with the application, carrying out the main tasks related to the chats, the objective of the scenario, the context in which the scenario is carried out, the handicaps that this scenario has and the people who may have the same problem as the persona who is involved in the evaluated scenario. Furthermore, all the scenarios were framed in m-learning to obtain the requirements that a chat user needs in this context [Calvo, 12]. An example of these scenarios is shown in Table 2 .

Through the scenario method, it was detected that apart from students with disabilities, people without disabilities could experience problems related to following the *Flow and Rhythm* of the conversation because these specific situations could be compared with an occasional disability. As a result, these problems are similar to the

problems that people with disabilities experience. Thus, older users, foreign students and people with little or no technological expertise may experience this difficulty too.

3.1.5 User Interviews

Qualitative research is really useful to obtain a greater depth of user opinion as users can explain their answers [Patton, 02]. Both disciplines include user interviews in a similar way to obtain both the user and system's requirements and needs.

In this work, before each interview, the interviewer explained the main goal of the experiment to the interviewee. Furthermore, some relaxed questions were asked previously to warm-up the interview. The interviews were semi-structured and followed the questions in the questionnaires distributed to users but respondents were able to specify why they chose each option. These interviews were either telephone calls or audio-conferences and the interviewees were people who were interested in becoming part of the research work. The questions were asked for one hour and they were related to their personal situation, their technological habits and the problems that they face when they use chats. All questions were open questions and the users could explain their experience when they use the chat in different environments.

ID: ChatSentences_Rosa_Antonio	
Actors:	Rosa and Antonio
Objective:	Send chat sentences
Settings:	Rosa and Antonio are chatting in different places about an exercise. As Rosa is really good at new technologies, she is able to type really fast. However, Antonio cannot type quickly because of his tremor.
Handicaps	
Task Description:	Rosa and Antonio are chatting with the mobile device. Rosa sends a message to Antonio. Rosa: "*Antonio, I do not understand the last exercise"*. Antonio starts to reply it. Rosa types more and more sentences really fast but Antonio is not able to answer quickly. As a result, Antonio is not able to follow the rhythm of the conversation. Rosa is answering even if Antonio has not answered it previously and Antonio receives more than one sentence at the same time. Antonio feels uncomfortable and leaves the chat.
Problems:	(Interaction problem) Unable to follow the *Flow and Rhythm*
Similar actors:	Shannon experienced the same problems because she is a foreigner and because of her information technology expertise. David because of his language-based learning disabilities.

Table 2: Example of scenario method according to HCI discipline

A total of ten users participated in the user interviews as detailed in Table 3. Five users were blind, two users had partial vision, two had motor impairments and one had a cognitive disability. Previous studies demonstrated that people with hearing impairments do not usually have problems in reading and writing text [Pilling, 09] or

they prefer to use sign language instead of written language [Kozˇuh, 14]. Thus, they were not included in this study. From the point of view of the technology that each user uses to access the chats in mobile devices, Table 4 shows both the assistive technology and the mobile device that the user uses.

User1 considered that when he uses chats he is wasting his time because he spends a lot of time writing messages. Moreover, if he is in a conversation, he is not able to type as quickly as the other person and consequently becomes stressed.

As regards User2, he considered that chats are really useful for him and uses different chat applications every day. When he uses chats, he experiences some difficulties and these barriers can be more or less serious, if he uses one or other chat. He considered that the use of *Facebook's* chat is easier on mobile devices than on desktop computers because surfing is easier. He also considers that the *Spotbros'* chat is completely inaccessible for him because it is not supported by screen readers.

User	Age	Gender	Disability	Chat mobile	Chat Desktop
User1	55-64	Male	Blind	Low	Low
User2	35-44	Male	Blind	High	High
User3	35-44	Male	Blind	Low	High
User4	18-24	Male	Motor	High	Medium
User5	18-24	Female	Cognitive	High	Medium
User6	35-44	Male	Partial Vision	Low	High
User7	45-54	Male	Blind	High	Medium
User8	45-54	Female	Blind	High	High
User9	35-54	Male	Motor	High	High
User10	25-34	Female	Partial Vision	High	Medium

Table 3: Interviewed Users Characteristics

User	Learn	A. T.	M.D
User1	No	Screen reader	Samsung T.G.B
User2	No	Screen reader and speak recognition	iPhone
User3	Yes	Screen reader	Nokia 6710
User4	Yes	None	Xperia J
User5	No	None	Samsung Lite
User6	Yes	Screen reader, screen magnifier and speak recognition	Samsung ACE
User7	Yes	Screen reader	Old Mobile
User8	Yes	Screen reader and speak recognition	iPhone
User9	Yes	None	Samsung Ace
User10	Yes	Screen magnifier	Xperia SP

Table 4: Interviewed Users Technology Used

User3 considered that chats are useful for him. However, he experiences some difficulties when people use emoticons to specify something in the sentences.

"When I am speaking with someone and he says 'I go to + EMOTICON', I cannot understand the meaning of the whole sentence"

Another difficulty is related to answering sentences, if he is speaking with many people, sometimes he cannot follow the conversation. In addition, this person used a chat which is not updated continually. Thus, if he wanted to know the last messages, he had to refresh the page manually and sometimes he got lost in the conversation.

User 4 uses chat every day with his classmates and he uses them in different ways depending on the people with whom he is chatting. As regards difficulties, he specified that he does not experience any. He only has one hand and he is able to write as quickly as other people and sometimes he is able to write even more quickly than other people. User5 has also experienced some difficulties when she chats with her colleagues. Most of the time she is able to communicate with her colleagues without problems; however, sometimes she experience difficulties because she wants to say something at a precise moment and she is not able to write quick enough to do so.

The sixth user, User6, had problems related to the information showed in each message. If the message shows: the image of the person, the nickname, the time and date of the message and the message; he has to spend a lot of time reading the messages information until he reads the text message.

The User7 experienced some problems because of the screen reader. Sometimes he is not able to read the conversation because the messages are on the queue and he has to move to the queue and later to the textbox and insert text. It takes him a lot of time and he has to move the finger from the top to the bottom many times. Besides, in group conversations, sometimes, he switches the mobile phone to "plane mode" to read the conversation carefully and later he turns off the mobile phone from the "plane mode" and he received the messages again. Another user, User8, experienced difficulties due to the inaccessibility of the chat. Sometimes she cannot download some files or cannot access to the chat. In group conversations, she has experienced some problems because she chats slower.

User9 faced some problems when he writes on his mobile device. Although he considers that his writing velocity is normal; sometimes, he needs to connect a Bluetooth keyboard to write better. Thus, sometimes he would like to say something in a specific moment and he could not say it. Moreover, User10 had problems reading the font size because the letter cannot always be increased. Another problem is related to the horizontal scroll, sometimes she has to move a lot to read the entire website.

The results showed that each person experienced different problems when they interact with the chat because of their personal characteristics. Moreover, it is important to emphasize that all the interviewed users, except User4, User6 and User10 who write really quickly, experienced difficulties and most of them (All except for User2, User4, User6 and User10) were related to the *Flow and Rhythm* of the conversation.

3.1.6 Questionnaires Methods

The use of questionnaires in SE developments, which follow a user-centered design approach, is useful for obtaining the users' opinion as regards their necessities and experiences [Vredenburg, 02]. This research work uses questionnaires to obtain the

user's problems and suggestions for chats. The research is an experiment with a theoretical design and is a *Concurrent control study where participants are not randomly assigned to groups*. A questionnaire was created in three different formats (plain text file, accessible Word document and accessible web-form following the W3C guidelines [WCAG, 08]). Thus, users could decide on the best format which adapts best to their necessities; the questionnaire was disseminated through: social networks, blogs and group mailing lists. The data collection process was open for more than one month and users spent around fifteen minutes to complete each questionnaire.

As regards the questionnaire design, it was drawn up based on the guidelines provided by Kitchenham and Pfleeger [Kitchenham, 01]. The questionnaires were unsupervised surveys; thus, respondents fill in the questionnaire on their own and there is nobody to supervise the questionnaire. The questionnaire was made up of a total of sixteen questions. Fourteen of them rated scale and two of them were open-ended questions. In addition, it is important to emphasize that six of the rating scale questions were also open-ended questions where people could specify additional characteristics which were not in the options. The questionnaire was divided into different parts: personal information, their kind of mobile device and assistive technology, frequency of use of chats and types of chats and accessibility problems that they faced.

After collecting the questionnaires, the data was analyzed to check whether the data was robust or not. Thus, the questionnaires were checked to see that it was filled in correctly. And finally, wrong questionnaires were not taken into account for the survey. A total of 53 users participated in the questionnaires. But, the number of questionnaires selected was 45 because some of them were not completed properly or they were not part of the target population as they had no disability. The questionnaires were completed by 24 males and 21 females. All of them had a disability such as: visual, hearing, motor or learning and cognitive disabilities which were included in the category of other. However, four people had more than one disability. As regards to their chat expertise, more than half of the users (53.33%) use chats every day on desktop computers and 48.89% on mobile devices. On the other hand, only 2.22% do not use chats on desktop and 20% on mobile devices.

Users were asked about the main problems they face when they interact with chats. They could select barriers from the list provided in the questionnaire or specify other accessibility barriers that they found. These barriers were: I cannot identify the colors and shapes (A1); there are icons which I do not understand (A2); I cannot follow the *Flow and Rhythm* of the conversation (A3); the icons are really small (A4); I cannot write quickly (A5); and there are images without alternative text (A6).

The answers to these questions are shown in Figure 2. It can be observed that people with visual impairments experience more problems when they use chats. These problems are related to: the *Flow and Rhythm* (A5)(A3), the use of colors or shapes to identify information(A1), images, icons or buttons without alternative text (A6) or the use of small icons (A2). On the other hand, the people who experience the fewest problems are those with hearing impairments. They are used to use chats and text messages to communicate with other people [Pilling, 2009].

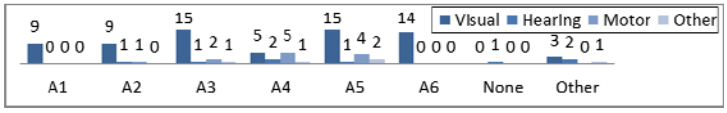

Figure 2: Chat Accessibility Problems per Disability

In general, the most usual problems that people experience are related to interaction (A5, A3). For instance, most people are not able to follow the *Flow and Rhythm* of the conversation (A3) and cannot write quickly when they are chatting (A5). The latter could be a consequence of the former as while they are answering the last message, the other person can type more messages. As a result, they can feel lost in the conversation because they do not have the opportunity to answer previous messages.

3.1.7 Related standards and guidelines

Standards and guidelines are necessary to develop accessible software. In this study, many standards and guidelines related to accessibility, mobile communications and learning were analyzed in order to obtain the most suitable standards and guidelines.

From the point of view of education, the ISO/IEC TR 29410 [ISO, 11] protocol for m-learning were followed. As regards accessibility, the standard Information technology- W3C Web Content Accessibility Guidelines (WCAG) 2.0 [WCAG, 08], which can be applied to non-web environments too [W3C, 13], is followed. Besides, the Mobile Web Accessibility Best Practices (MWABP) [W3C, 10] and Mobile Web Best Practices (MWBP 1.0) [W3C, 08] are considered for mobile device accessibility.

However, for accessibility and learning, the IMS Guidelines for Developing Accessible Learning Applications [IMS, 04] provide some specifications for accessible CSCL tools. Moreover, the UDL v2.0 guideline is followed for specifying the learning content requirements [CAST, 11].

Based on these guidelines, some requirements to improve the chat's accessibility were obtained. Table 5 shows an example of the study carried out. A specific problem is set out and a possible solution is obtained based on standards and guidelines.

Problem	Guideline	Obtained Requirement
The user cannot follow the conversation	2.2.1& 2.2.2 of WCAG, 14 of MWBP; 5, 6 & 7 of IMS	The conversations could be stopped by the user

Table 5: Guidelines related to the Scenario in Table III

Apart from the previous guideline, there were other requirements such as: *Add an Interlocutor* (Allow controlling the addition of new users to the conversation); *Predefined Sentences* (The system provides predefined sentences to avoid users writing more); *Add File* (Students should specify a description for the uploaded file); *Time Refresh* (The student can control when the messages should be auto refreshed);

or *Clean Messages* (The user should be able to clear the messages shown on the screen)

3.1.8 Categorize Requirements

Finally, the requirements obtained are classified into: Functional, Non-Functional, Data, Environment and User requirements [Preece, 01].

The methods used to obtain the accessibility problems that people face showed that many users cannot follow the *Flow and Rhythm* of the conversation because: they cannot send messages quickly, they have problems with the keyboard or they cannot read and type as quickly as the other person among other accessibility barriers. In this article, the Formalization and Validation phases, described below, focus on the suggested solution *Stop Auto-refresh Conversation* to improve the chat's interaction.

3.2 Requirement Formalization

The way in which the functional requirements are documented plays an important role in ensuring that they can be read, analyzed, written and validated [Nuseibeh, 00]. Moreover, the way in which the requirements are formalized could make developers use more or fewer lines of code [Kantorowitz, 05]. Then, SE and HCI methods were followed in this phase in order to better formalize the requirements.

3.2.1 Natural Language

The *Stop Auto-refresh Conversation* requirement is specified in natural language as a complement to the formal methods [Escalona, 04] because they could sometimes be better understood by non-technological experts.

3.2.2 Sequence UML diagram and Use Case Description

The UML sequence diagrams and the use case description methods were combined in order to formalize the *Stop Auto-refresh* requirement. The UML sequence diagram method is used to specify the behavior of the users with the system in a diagram.Figure *3* shows the UML Sequence diagram for the *Stop Auto-refresh* conversation use case which represents the interaction of two students with the chat. The use of this method cannot be used alone because there is some semantic which is lost. Then, the *Use Case Description* method is used as a complement. The Use Case Description method has been used following the template provided by Cockburn [Cockburn, 01] to detail cases of use in an effective way.

3.2.3 Scenarios

UML Sequence Diagrams and Use Case Description methods do not completely specify the user interactions. Thus, they must be complemented with the Scenario method, represented with natural language. For example, the *Stop Auto-refresh requirement* is represented with the Scenario method as follows:

> *Rosa and Antonio are chatting. Rosa* types*: "Antonio, I do not understand the last exercise". Antonio starts to type and before he finishes it Rosa sends a message again. Antonio does not feel comfortable and he stops the*

conversation. He presses the 'Stop auto-refresh' button. The system shows the message 'Antonio is busy' to Rosa. Rosa realized that Antonio writes slower than her; she waits. Then, Antonio sends the message "Yes. You are right. They are similar and …" Next the system shows Antonio all the messages that Rosa sent since Antonio pressed the button" Stop Auto-refresh".

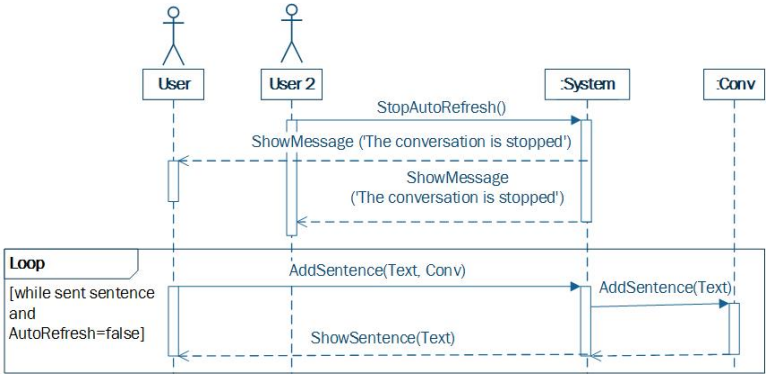

Figure 3: Sequence UML diagram: Stop the Reception of new messages

3.2.4 Storyboard

Some interaction requirements are really difficult to describe using natural language, formal methods or templates. The *Stop Auto-Refresh* functionality is really complex and has been represented with a Storyboard [Landay, 96] too, see Figure 4.

3.2.5 Prototype

According to Maguire [Maguire, 01], at least a low fidelity prototype should be implemented and iterative prototyping is useful to check whether the tool accomplishes the user's requirements continually. HCI and SE disciplines use prototypes; HCI discipline uses them to evaluate the user interface's requirements while SE centers on evaluating the system requirements [Escalona, 04]. This work uses prototyping to evaluate both the user's and system's requirements.

Furthermore, prototyping should be used to evaluate the ideas and design solutions by users [Nielsen, 93]. Thus, a mockup prototype was created to design the interface. The mockup prototype is an informal, fast and easy to change prototype which is useful in an early development cycle to explore ideas on how the product might seem. This prototype is built to provide a proposal for the design of the chat's user interface. Figure 5 shows the mockup screenshots of the chat.

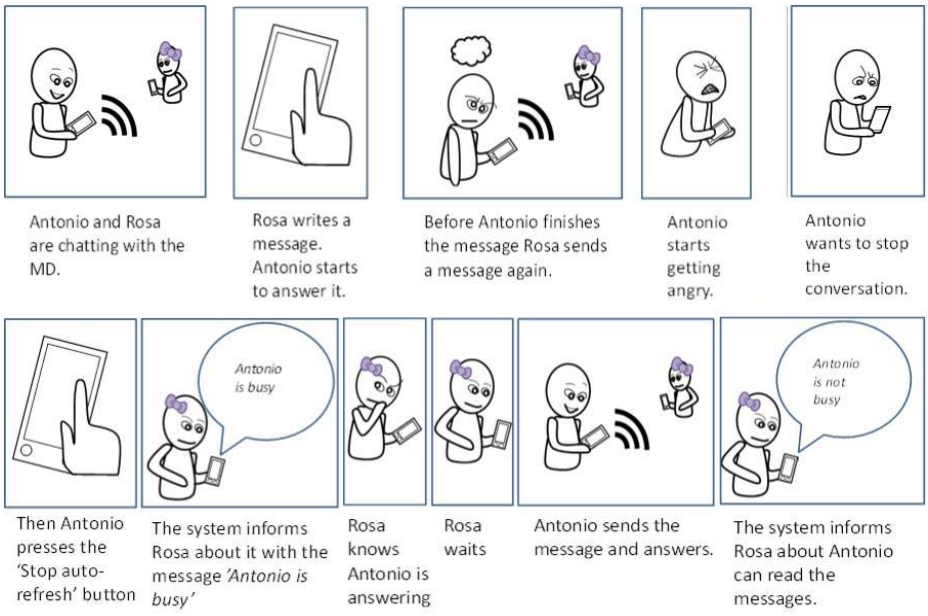

Figure 4: Hypothetical situation: User needs to Stop Auto-Refresh functionality.

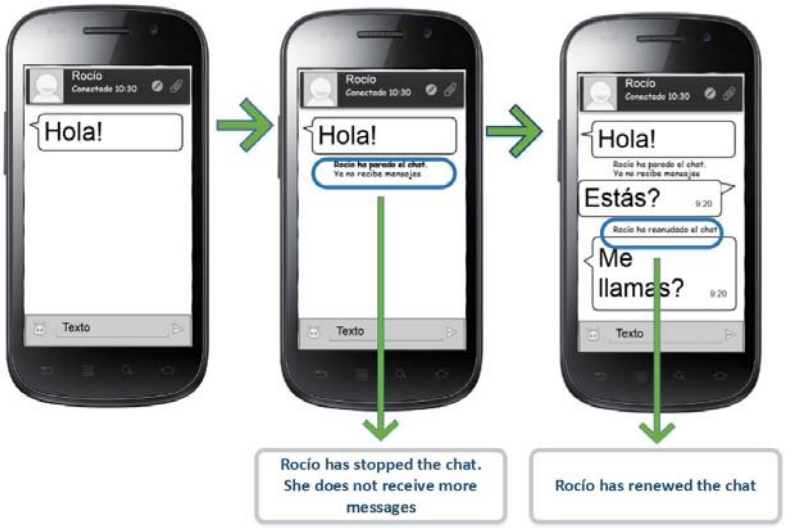

Figure 5: Mockup perspective of the user who not stop the reception of messages

3.3 Validating the requirements

After the elicitation and formalization phases, the validation phase is carried out in order to validate the requirements proposed. As has been explained previously, this step also focuses on the *Stop Auto-refresh Conversation* requirement.

3.3.1 Review/ Audit

The document with the formalized requirement is checked by other experts to avoid future problems related to the ambiguity of the requirements. Thus, three accessibility and RE experts have reviewed this documentation.

3.3.2 User Interviews

User interviews related to the *Stop Auto-Refresh* functionality were carried out. The method followed was the same as that in the requirement elicitation phase for user interviews. Users answered questions related to the new functionality and expressed their opinion of it. The interviewer described their opinion with regard to the *Stop Auto-refresh* functionality.

The participants were the same users (see Table 3) who participated in user interviews of the elicitation phase. The user's opinions can be divided into three groups: users who consider the new functionality useful (User1, User3, User4, User6, User7, User8, User9 and User10), users who consider the new functionality useful in one-to-one conversations (User2) and people who consider the new functionality useless (User6). Table 6 below, shows a summary of the results obtained in the interviews.

User	One-to-one?	Group	Write more sentences?	Embarrassed?
User1	Yes	Yes	No	No
User2	Yes	Yes*	Yes	No
User3	Yes	Yes	Yes	No
User4	Yes	Yes	Depends on conversation	No
User5	Yes	Yes	No	No
User6	No	No	Yes	No
User7	Yes	Yes	Only one more	No
User8	Yes	Yes	Yes	No
User9	Yes	Yes	Yes	No
User10	Yes	Yes	No	No

Table 6: Results of User Interviews on the New Functionality

The new functionality could be useful: eight out of ten users considered the new functionality useful. For example, User 3 specified that it could be useful for him especially in environments where many people interact. Furthermore, User 4 has no difficulty in writing quickly on the mobile device. However, he considered that it could be useful for him in some situations such as learning environments to read the conversation carefully. In addition, User 5 would use it in similar situations. On the other hand, she said that she would get angry if someone else used it. User 7 specified

that he would use this new functionality in some situations. Moreover, it is important to emphasize that the user already uses "his own Stop Autorefresh functionality". He changes the mobile mode to "Flight mode" to not receive more messages. Besides, User 8 considers it useful; however, she would like to receive only the important messages. Moreover, User 10 specified that it could be useful in group conversations, and she considered that it would be important to be informed about the situation.

The new functionality might not be useful in group conversations: User 2 considered that the use of this feature could be useful but depending on the number of users. If there were more than two users, the *Flow and Rhythm* of the conversation could be affected, meaning that the other people could not type more messages.

The new functionality is not useful: User 6 specified that the use of this new button could be disrespectful because it could mean that the other person does not want to chat with him. Moreover, he said that if the conversation were a really important situation it could be a waste of time because the conversation would be stopped.

To conclude, people with less experience or those who write more slowly in chats considered that this new functionality could be useful for them because they could stop the reception of messages. Furthermore, none of them would feel embarrassed if they accessed the button and informed other users about this circumstance.

3.3.3 Questionnaires

The method used to fill in the questionnaires was the same, as was explained in the elicitation phase, to obtain the users' accessibility barriers. However, the user had to specify their opinion of the new *Stop Auto-Refresh* conversation functionality.

Users were explained a situation in which they were chatting with someone and receiving many messages at the same time. Thus, users could use the new functionality, *Stop Auto-Refresh.* Later, users were able to specify what should happen later and what the other user should do. The answers could be: the other user can type more messages and they will be shown together when I renew the conversation (AP1); the other user can type more messages and they will be showed one by one when I renew the conversation (AP2); the other user cannot type more messages until I decide to renew the conversation (AP3); the other user can type only one message more which will be shown when I renew the conversation (AP4); and the other user can type a new message which cannot be sent until I decide to renew the conversation (AP5).

It has been identified that 80.36% of users have a preference for the other users to continue typing messages to each other while they stopped the converstion (AP1, AP2 and AP4). Furthermore, most of them wish that the new messages were shown all together (AP1) (44.64%) instead of one by one (AP2) (25%). In contrast, people do not like that other users were unable to continue writing (AP3, AP5) (19.64%). From the point of view of each disability (visual, motor and hearing impairments), the most selected option was that all the messages should be shown together (AP1). Moreover, other users provided new suggestions as regards this new functionality. Some people suggested the transcription of the messages from voice-to-text and audio-to-text and another person specified that users should decide the best feature for them. In the author's opinion, users should be able to configure the chat preferences.

Another question was related to the usefulness of the new feature. This question uses a 5 point Likert scale [Likert, 32] (from 0 to 4; from "really not useful" to "really useful"). Most users (74%) think that the new feature is really useful or useful. From the point of view of group disabilities, people with visual (67.6%) and motor impairments (88.9%) consider it a useful feature. On the other hand, people with hearing disabilities consider that it is not useful for them (50%). However, if this disability is combined with other disabilities this feature could be useful for them (100%).

Furthermore, it is interesting to evaluate how they would feel if they used this functionality. This question uses a 5 point Likert scale (from "Really not ashamed" to "Really ashamed"). Most users consider that they would not be ashamed (79%) if they use this new feature and 22.2% of people considered they would be ashamed. Considering disabilities, (14.7%) of people with visual impairments, (22.2%) of people with motor impairments, (20%) of people with hearing impairments will be ashamed. In contrast, (100%) of people with other impairments will be ashamed. However, only two users with other impairments answered the questionnaire.

Considering these results, most of users consider that this functionality could be useful for them and they would not be ashamed to use it. Moreover, most users prefer other user/s to be able to write more messages after they stopped receiving messages.

3.3.4 Prototype Validation

The Mockup was validated by users to obtaining their opinion of the interface and the system's behavior. Seven participants validated the Mockup, *Table 7* specifies the participants' characteristics. Users were shown the prototype and they were instructed on how to use the system's navigation. Users with visual impairments could not see the Mockup; then, the situation of the new button, how the new button was identified, the messages shown by the system in each screen and the behavior of the system was explained to them. Next, users answered questions related to the system behavior, the message's order [Opt1. (System Message | Other User's | My messages) or Opt2. (System Message | My messages | Other User's)] and layout from the point of view of a user who stops receiving new messages.*Table 8* below specifies the user's answers.

User	Age	Gender	Disability	Use	Assistive Technology	Mobile
U1	45-54	M	Blind	Low	Screen reader	Old Mobile
U2	35-44	M	Motor	High	None	Samsung
U3	25-34	F	Partial Vision	High	Magnifier	Sony SZ
U4	25-34	M	Blind	Low	Screen reader	Old Mobile
U5	55-64	F	Partial vision	High	Magnifier	Samsung SII
U6	25-34	M	Cognitive	High	None	LG L3
U7	25-54	M	Cognitive	High	None	Xperia

Table 7: Mockup Interviewed Users Characteristics

User	Button vs Command	Button Position	Button identification	Mes. after Stop	Mes. Refresh	Order Message
U1	Button	Bottom	Pause/Renew	Fine	None	Opt. 1
U2	Button	Top	Stop/Continue	Shorter	None	Opt. 1
U3	Button	Bottom	Pause/ Renew	Fine	Fine	Opt. 1
U4	Both	Top	Pause/ Renew	Shorter	Shorter	Opt. 1
U5	Button	Bottom	Pause/ Renew	Fine	Fine	Opt. 1
U6	Button	Bottom	Hand/Renew	Fine	Fine	Opt. 1
U7	Button	Bottom	Hand/Renew	Shorter	Shorter	Opt. 1

Table 8: Mockup Interviewed Users Answers

The Mockup was used to avoid future problems of incomprehension of the system. Next, based on the user's opinion, the interface was improved. For example, the messages' order and the *Stop Autorefresh* button are modified.

4 Conclusions and Future work

In this paper, the RE process to improve the interaction of chats for m-learning is described. HCI and SE methods were then combined following a methodological approach. The requirement elicitation, formalization and validation phases and the methods used in each phase are described in detail. After the elicitation phase, it has been detected that the most common problem that people face is related to the *Flow and Rhythm* of the conversation. People are not able to follow the conversation for many reasons which have been explained. To solve it, a new functionality, *Stop Auto-refresh*, is added to improve the interaction. This study obtained users' opinion about it; and it shows that this functionality could be useful for people with disabilities.

This research work is currently validating a software prototype by users and experts to assure the usefulness of the *Stop Auto-refresh*.

Acknowledgements

This research was partially supported by the MA2VICMR (S2009/TIC-1542) project. Also, our thanks to all users who took part in the study.

References

[AccessIT, 04] National Center on Accessible Information Technology in Education (AccessIT) How Do Courseware Products Differ on Accessibility?, 2004 http://net.educause.edu/ir/library/pdf/EDU03115e.pdf

[Bicen, 13] The Use of Social Networking Sites in Education: A Case Study of Facebook. Journal of Universal Computer Science, 19(5),2013, 658-671

[Blackboard, 12] Blackboard Collaborate. Blackboard IM Accessibility Guide. Enterprise instant messaging. V 4.1. Accessibility Guide. 2012. http://www.blackboard.com/Platforms/Collaborate/Services/On-Demand-Learning-Center/Enterprise-Instant-Messaging.aspx

[Blackboard,13] Blackboard. Accessibility.
http://www.blackboard.com/Platforms/Learn/Resources/Accessibility.aspx

[Booch, 99] Booch, G., Rumbaugh, J., and Jacobson, I.: The Unified Modeling Language User Guide. Addison-Wesley, Reading, MA, 1999

[Calvo, 12] Calvo, R., Moreno, L., Iglesias, A.: Requirements elicitation for designing an accessible chat, Revista Española de Innovación, Calidad e Ingeniería del Software, 8(1), 2012, 7-21

[Calvo, 13] Calvo, R., Gil, A., Iglesias, B., Iglesias,A.:2013). Are Chats and Forums accessible in e-learning systems? A heuristic evaluation comparing four Learning Content Management Systems. In Proc. ACM SIGCSE Conf. on Innovation and Technology in Computer Science Education, July, 2013, 342-342

[CAST, 11] Universal Design for Learning Guidelines version 2.0. Wakefield, MA: Author..

[Chen, 10] Chen, T., Yesilada, y., and Harper, S. What input errors do you experience? Typing and pointing errors of mobile Web users. Int. J. Human Computer Studies, 68(3), 2010, 138-157

[Carroll, 97] Carroll, J.M.: Scenario-Based Design. Handbook of Human-Computer Interaction, North-Holland, Amsterdam, 1997

[Cockburn, 01] Cockburn, A.Writing Effective Use Cases. Addison-Wesley Boston. 2001

[Cooper, 03] Cooper, A. and Reimann, A.: About Face 2.0: The Essentials of Interaction Design. Wiley Publishing, Chichester, 2003

[Corlett, 05] Corlett, D., Sharples, M., Bull, S. and Chan, T. Evaluation of a mobile learning organizer for university students. Journal of Computer Assisted Learning. 21(3), 2005, 162-170

[De Paula, 03] De Paula, M.G.; Barbosa, S.D.J.; de Lucena, C.J.P. Relating Human-Computer Interaction and Software Engineering Concerns: Towards Extending UML Through an Interaction Modeling Language, PUC. 2003

[Dhir, 13] Dhir, A., Buragga, K. and Boreqqah, A. Tweeters on Campus: Twitter a Learning Tool in Classroom?, Journal of Universal Computer Science,19(5), 2013, 672-691

[Escalona, 04] Escalona, M.J. and Koch, N. Requirements engineering for web applications-a comparative study. Journal of Web Engineering, 2 2004, 193-212

[Guenaga, 04] Guenaga, M., Burguer, D. and Oliver, J. Accessibility for e-learning environments. In Proc. Int. Conf. Computers Helping People with Special Needs. July 2004, 626

[Hackett, 04] Hackett, S., Parmanto, B. and Zeng, X. Accessibility of Internet websites through time. In Proc. Int. ACM SIGACCESS Accessibility and Computing. Sept 2003, 18-20.

[Hampel, 99] Hampel, T., Keil-Slawik, R., Claassen, B., Plohmann, F. and Reimann, C. Pragmatic solutions for better integration of the visually impaired in virtual communities. In Proc. Int. ACM SIGGROUP Conf. on Supporting group work , November 1999, 258- 266

[Henry, 07] Henry, S. Just Ask. Integrating Accessibility Throughout Design. February 2007

[IEEE, 90] Institute of Electrical and Electronic Engineers. IEEE Standard Glossary of Software Engineering Terminology . New York, NY: Institute of Electrical and Electronics Engineers, 1990.

[Imaz, 07] Imaz, M. and Benyon D. Desıgnıng wıth blends. Conceptual foundations of human-computer interaction and software engineering. The MIT Press, 2007.

[IMS, 04] IMS Guidelines for Developing Accessible Learning Applications, 2004. http://www.imsglobal.org/accessibility/accessiblevers/index.html

[ISO, 08] ISO 9241-171:2008 Ergonomics of human-system interaction -- Part 171: Guidance on software accessibility.
http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=39080

[ISO, 11] ISO/IEC TS 29140:2011. Information technology for learning, education and training -- Nomadicity and mobile technologies
http://www.iso.org/iso/home/store/catalogue_ics/catalogue_detail_ics.htm?csnumber=45163&ics1=35&ics2=240&ics3=99

[ISO, 12] ISO/IEC 40500:2012 Information technology -- W3C Web Content Accessibility Guidelines (WCAG) 2.0.
http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=58625

[Jerome, 05] Jerome, B. and Kazman, R. Surveying the solitudes: An investigation into the relationships between human computer interaction and software engineering in practice. Human-Centered Software Engineering—Integrating Usability in the Software Development Lifecycle, 8, 2005, 59-70.

[Juristo, 07] Juristo, N., Moreno, A. and Sanchez-Segura, M. Guidelines for Eliciting Usability Functionalities. IEEE Transactions on Software Engineering. 33, . 2007, 744-758.

[Kantorowitz, 05] Kantorowitz, E. and Lyakas, A. Use-case components for interactive information systems. Science of Computer Programming. 56(1-2), 2005, 5-21.

[Kitchenham, 01] Kitchenham, B. and Pfleeger, S. Principles of survey research: parts 1-6. ACM SIGSOFT Software Engineering Notes. 2, 5. 2001.

[Kozˇuh, 14] Kozˇuh, I., Hintermair, M., Holzinger, A. Volcˇicˇ, Z. And Debevc, M. Enhancing universal access: deaf and hard of hearing people on social networking sites. Universal Access in the Information Society, 1-9.

[Kramer, 88] Kramer, Jeff, Ng, Keng, Potts, Colin, and Whitehead, Ken. Tool Support for Requirements Analysis. Software Engineering Journal, 3, 1988, 86-96.

[Landay, 96] Landay, J. and Myers, B.: Sketching storyboards to illustrate interface behaviors. In Proc. Conf. Companion on Human Factors in Computing Systems. April 1996, 193-194.

[Lazar, 07] Lazar, J., Allen, A. , Kleinman, J. And Malarkey C. What Frustrates Screen Reader Users on the Web:A Study of 100 Blind Users. Int. Journal of Human-computer Interaction, 22(3), 2007, 247–269.

[Likert, 32] Likert, R. 1932. *A Technique for measurement attitudes*. Archives of Psychology. 22, 140.

[Lyytinen, 187] Lyytinen, K. And Hirschheim, R. Information systems failures—a survey and classification of the empirical literature. Oxford Surveys in Information Technology. Pp. 257-309. Oxford University Press. 1987.

[Maguire, 01] Maguire, M. Methods to support human-centred design. International Journal of HumanComputer Studies, 55 (4), 2001. 587-634

[Moodle, 11] Moodle. Using chat. http://docs.moodle.org/23/en/Chat

[Nielsen, 93] Nielsen, J. and Hackos, J. Usability Engineering. Academic press San Diego, 1993

[Noll, 10] Noll, J., Beecham, S. and Richardson, I.: Global Software Development and Collaboration Barriers and Solutions, ACM Inroads. 1(3), 2010, 66-78

[Nuseibeh, 00] Nuseibeh, B.; Easterbrook, S. Requirements engineering: a roadmap ACM, 2000

[Patton, 02] Patton, M. 2002. Qualitative research and evaluation methods. Thousand Oaks, CA: Sage

[Pilling, 09] Pilling, D. and Barrett, P. 2009 Text Communication Preferences of Deaf People in the United Kingdom. Journal Deaf Students Deaf Education. 13(1), 2009, 92-103.

[Preece, 02] Preece, J., Rogers, Y., and Sharp, H.. Interaction Design: Beyond Human-Computer Interaction. 2002

[Pressman, 92] Pressman, R.S. and Ince, D., Software engineering: A practicioners appoach. McGraw-hill New York, 1992

[Robertson, 06] Robertson, ,S. and Robertson J. Mastering the Requirements Process, 2006

[Rosson, 02] Rosson, M.B. and Carroll, J.M. Scenario-based usability engineering In Proc. Conf. on Designing interactive systems: processes, practices, methods, and techniques, 2002, 413-413

[Royle, 09] Royle, K., Jenkins, C. and Nickless J. Using PictoChat on the Nintendo DS to Develop Children's Exploratory Talk through Productive Learning Conversations during Collaborative Group Work. Journal of the Research Center for Educational Technology. 6 (1), 2009, 76-93

[Schoeberlein, 09] Schoeberlein, J. and Wang, Y. Evaluating Groupware Accessibility. In Universal Access in Human-Computer Interaction. Applications and Services, 2009, 414–423

[Seffah, 05] Seffah, A. Gulliksen J. and Desmarais, M. Human centered software engineering. Integrating Usability in The Software Development Lifecycle. Springer. 2005

[Sutcliffe, 03] Sutcliffe, A. Scenario-based Requirements Engineering. In Proc. IEEE Int. Requirements Engineering Conference, Sept. 2013, 320-329

[Sutcliffe, 13] Sutcliffe, A. Requirements Engineering. In: Soegaard, Mads and Dam, Rikke Friis (eds.). "The Encyclopedia of Human-Computer Interaction, 2nd Ed.". Aarhus, Denmark: The Interaction Design Foundation.

[Thayer, 97] Thayer, R.; Dorfman, M. Software Requirements Engineering. Wiley-IEEE Press. 1997

[Tiresias,09] Tiresias. Mobile Phones, 2009
http://www.tiresias.org/research/guidelines/telecoms/mobile.htm

[Uden, 07] Uden, L.: Activity theory for designing mobile learning. Int. Journal Mobile Learning and Organisation, 1(1), 2007, 81–102.

[UK Law, 01] Special Educational Needs and Disability Act (SENDA) 2001. http://www.legislation.gov.uk/ukpga/2001/10/contents

[USA Law, 04] Individuals with Disabilities Education Act (IDEA) of 2004. http://idea.ed.gov/

[Vredenburg, 02] Vredenburg, K., Mao, J. , Smith, P. and Carey, T. 2002. A survey of user-centered design practice. In Proc. SIGCHI Conf. on Human Factors in Computing Systems, 2002, 471-478.

[W3C, 08] W3C. Web Content Accessibility Guidelines, 2008 http://www.w3.org/TR/WCAG/

[W3C, 13] W3C. Guidance on Applying WCAG 2.0 to Non-Web Information and Communications Technologies, 2013. http://www.w3.org/TR/wcag2ict/

[W3C, 10] W3C. Mobile Web Application Best Practices 1.0, 2010, http://www.w3.org/TR/mwabp/

[W3C, 08] W3C. Mobile Web Best Practices 1.0, 2008 http://www.w3.org/TR/mobile-bp/

[Woodfin, 06] Woodfin, B., Nunes, M. and Wright, D. Text-based synchronous e-learning and dyslexia: Not necessarily the perfect match! Computers and Education. 50(3),703-717