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Accessible Collaborative Learning Environments for Mobile Devices

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TESIS DOCTORAL

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Resumen

Las tecnologías de la información se utilizan en entornos educativos para ayudar a los estudiantes y profesores a compartir y mejorar el aprendizaje. Algunas de estas herramientas permiten a los estudiantes compartir conocimiento y aprender colaborando entre sí, y se suelen denominar herramientas de aprendizaje colaborativas. Un ejemplo de herramienta colaborativa es la aplicación Chat. A través de estas aplicaciones, los profesores y estudiantes pueden compartir recursos y conocimiento o resolver dudas en tiempo real, sin la necesidad de encontrarse en la misma aula al mismo tiempo. Estas herramientas se utilizan hoy en día en dispositivos móviles que permiten realizar colaboraciones de forma ubicua, ya que se pueden utillizar desde cualquier lugar.

Sin embargo, hoy en día las aplicaciones chats que existen en el mercado no son completamente accesibles, presentando barreras de accesibilidad que los usuarios tienen que sortear cada día. Las personas con discapacidad sufren estas barreras, a pesar de que están amparados por leyes de todo el mundo que especifican que tienen los mismos derechos que las personas sin discapacidad. Estas barreras de accesibilidad no son barreras que sólo personas con discapacidad pueden percibir, personas sin discapacidad pueden sufrir los mismos problemas cuando utilizan estas herramientas en dispositivos móviles, cuando se están desplazando o cuando utilizan los dispositivos en espacios abiertos con mucha luz.

En esta tesis doctoral se pretende estudiar las barreras de accesibilidad que presentan las aplicaciones chat en entornos educativos con dispositivos móviles. De esta forma, se trata, en la medida de lo posible, de mejorar la accesibilidad de este tipo de aplicaciones. Como resultado, personas con discapacidad y sin discapacidad podrán colaborar entre sí, sin encontrar problemas de accesibilidad.

Los tres objetivos principales de esta tesis son: primero, identificar los problemas que las personas con y sin discapacidad tienen cuando utilizan los chats; segundo, especificar los requisitos de accesibilidad que los chats deben incluir en entornos de aprendizaje utilizando dispositivos móviles; y finalmente, realizar una propuesta de mejora de accesibilidad de este tipo de aplicaciones. Todos estos objetivos se han alcanzado siguiendo para ello un diseño centrado en el usuario en el que se ha contado con la participación de más de 200 personas con y sin discapacidad para obtener cada una de las aportaciones resultado de los objetivos propuestos.

Summary

New technologies and devices are being used in learning environments by teachers and students. Some of these tools are computer supported collaborative learning tools that help them collaborate with each other and share knowledge. Chat applications are one of these tools. These tools allow sharing materials and knowledge or solve doubts in real time without the necessity of being in the same room at the same time. Especially, these tools are being used in mobile devices which make collaboration more ubiquitous because people can use them everywhere.

However, existing chat applications are not fully accessible and present accessibility barriers that users need to face every day. People with disabilities encounter these barriers every day despite of they have the same rights as people without disabilities according to multiple regulations in many countries around the World. These barriers might not be faced by people with disabilities only, people with disabilities who use mobile devices in different environments e.g. on the move or in bright environments can suffer similar problems as people with disabilities.

This thesis aims to identify the accessibility barriers that m-learning chat applications have. Besides, considering these problems, this research aims, as far as possible, to improve the accessibility of chat applications. As a result, people with and without disabilities could collaborate with each other without facing accessibility barriers that will mermaid their learning.

The main objectives of this thesis are: firstly, identify accessibility barriers that people with and without disabilities face when they use chat applications; secondly, specify the requirements that accessible m-learning chat applications should include for being accessible; and finally, provide an accessible interaction improvement for these applications. All these objectives have been achieved following a user centred design approach. As a result, more than 200 people with and without disabilities have participated in this thesis.

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Chapter 1

Introduction

Nowadays, users frequently access to the Internet through different Mobile Device (MD) and from different locations. The concept of MD has changed in the last decade; they are not only used to communicate with other people through phone calls. They can be used for accessing online services such as: communication, travel or bank services.

Specifically, in educational environments, the use of MDs has been increased in the last decade. Students and teachers use MDs as a new way of learning nowadays. For instance, they use MDs for sharing information and for communicating with each other to solve educational problems. From the point of view of communication, students use MDs as a Computer Supported Collaborative Learning (CSCL) tool to exchange instant messages; to blog; to send e-mails or to share information with other students or teachers.

One of the most common CSCL tools is the Chat, which is considered as one of the most useful CSCL applications according to students, as some research works have shown previously. The success of this tool in an educational environment is mainly due to two reasons: the students can communicate with other students or teachers instantly; and students and teachers are used to using chats in MDs because new mobile applications to exchange messages are really popular.

The use of chat applications through MDs in CSCL environments is a good and quick way of communication between students and teachers to solve specific doubts in real time. They can send a message wherever and whenever they need and the connected people (his teacher or another classmate) can help them to solve their doubts. Besides, it is a good way of communication for people who are collaborating in the same working group and are not in the same place.

However, one of the main problems with these tools is that currently they are presenting many accessibility barriers and many people cannot use them properly. Thus, this thesis is focused on improving the m-learning chat's interaction in order to avoid accessibility barriers and improve students' experiences.

1.1. Background

By 2021 there will be 1.5 MDs per capita [CISCO, 2017]. Moreover, basing exclusively in Tablets, they will make up 50% of PC market in 2014 [Canalys, 2013]. Even in developing countries where people do not have enough money to eat the number of MDs is being increased too [Nielsen, 2013]. In concrete, the use of new technologies has been increased during last years in educational environments [Krishnapillai, 2004] and the use of mobile learning systems

(m-learning systems) too [Sharples et al., 2009]. They provide more freedom for students to learn through Internet when and where they prefer. As a result, users can adapt the way of learning to their necessities.

Moreover, the use of CSCL tools, where users can collaborate with each other and share information, has been increased too. There are many tools to support CSCL such as: blogs, wikis or Chats which are really used by younger generations of students almost every day. [Hsin et al., 2014]

Previous researchers have shown the usefulness of MDs in CSCL environments Mobile Computer Supported Collaborative Learning (m-CSCL) [Sharples, 2005] or social media [Kožuh et al., 2015] ; specially, for students who are shy and prefer to ask questions through Chatss instead of using other tools as forums for instance [Xie, 2008]. Additionally, Walker [Walker, 2005] explains "What we have seen over the past two or three years is students moving away from more traditional messaging like e-mail to newer technologies such as instant messaging and text messaging" . Besides, it is important to remark that these days children are used to write through MDs [Sharples et al., 2010]; thus, they are able to interact with other people easily through instant messaging environments as Chats. Taking into account these circumstances, we ask ourselves: why not take advantage of them to allow students to learn through MDs? Why not facilitate the process of learning and do it easier? Why not make learning more collaborative and allow students to learn with their classmates whenever and wherever they want through Chats?

1.2. Goals

MDs are used to support individual and CSCL learning. Specially, students can take advantage of the characteristics of MDs using them for learning, collaborating and communicating with their teachers and classmates [Uden, 2007]. There are different ways of communication: e-mail, chat, blog, etc. Specifically, Chats are considered as one of the most useful CSCL tools through MDs [Corlett et al., 2005]. However, Chats present many accessibility problems, even more than other learning technologies [Hackett et al., 2004]. Some of these problems are related to: the Assistive Technology (AT) [Lazar et al., 2007] , software which is used by people with disabilities to access the technologies; to the MD [Tiresias, 2009] or to follow the *Flow and Rhythm* of the conversation [Woodfine et al., 2008] [Guenaga et al., 2004]. As a result, some students cannot use these tools in the educational environments and they could be discriminated because sometimes it is the only way for them to communicate with their classmates and teachers. This is against the law because people's rights are not complied according to the people's right declaration [UN, 1945] and according to some countries laws which have specified that Chats should be created in an accessible way [USA, 2010]. Previous studies tried to solve some of these accessibility problems. Some of them have been focused exclusively on specific disabilities and do not focus on all of the disabilities. Others exclude users from the development process [Royle et al., 2010] and none of them are focused on improving the users' interaction of m-learning chats. Besides, previous guidelines as the Guidelines for Developing Accessible Learning Applications (GDALA) [IMS, 2007] or Communication and Video Accessibility Act (CVAA) [USA, 2010] specify some requirements that Chats should comply to be accessible. However, these guidelines are really general and they are not focused on mobile environments.

The main objective of this thesis is to improve the interaction of synchronous Chats for m-learning environments where teachers and students could interact in the same conditions. To achieve it, users are involved in the whole research process; then, a User Centered Design

(UCD) approach [ISO, 2010] is followed in this research. These users will help to: elicit the current accessibility barriers in chat applications; elicit the accessibility requirements for m-learning chat applications; propose new functionalities for improving the Chats interaction; and to evaluate the new proposals. Besides, the standards and guidelines related to accessibility and learning are taken into account in order to provide some guidelines for developers to know how to create accessible Chats for m-learning. Finally, a new functionality to improve the interaction of Chats is proposed and evaluated in order to assure if this feature is useful or not for users with and without disabilities.

Due to focus the study in a specific environment and to improve its accuracy, it has been established some limitations to the thesis. The chat application considered in the study is a synchronous Chat instead of an asynchronous Chat because it has been detected previously that synchronous chat applications have more accessibility barriers. Users have to read and write in real time and the user's velocity to read and write can affect users to follow the *Flow and Rhythm* of the conversation. Moreover, the study is focused on m-learning environments because it is better to focus the study in one environment to obtain the requirements better. Furthermore, the Chat considered in the study is not a chat application which conversation is guided by teachers. Teachers and students can interact with the chat application with the same privileges and they can exchange knowledge through the chat application. This restriction is considered because the pedagogy aspects are not considered in the study. Finally, the study is withdrawn from any technology for avoiding interferences in the study.

This thesis is enshrined in two disciplines Human Computer Interaction (HCI) and Software Engineering (SE). The mix of both disciplines is adopted because one discipline could be a complement of each other. For example, the methods used to obtain users' needs could be better adopted by HCI discipline [Ko et al., 2011] and methods of SE are more formal to specify the requirements [Brown, 1997]. Thus, this thesis follows both disciplines:

1. Mobile Human Computer Interaction (HCI): this thesis aims to improve the interaction of the chat applications in MDs. Then, users are involved in all phases of the research to know their problems when they use Chats.
2. Software Engineering (SE): the use of different accessibility standards and formal specifications is really important to improve the accessibility. Thus, it is important to consider all the standards to provide formal documentation from engineering perspective which can be used by developers and designers as a guide towards a well-defined software architecture for design accessible Chats.

1.3. Research Questions

The first goal of this thesis is to understand the main problems that people with disabilities face; so, the first research question is:

> **RQ1:** Which are the main problems that people with and without disabilities face when they interact with chat applications?

Firstly, previous chat applications were analysed from the point of view of a heuristic evaluation to obtain some of the problems that people could face. In order to better understand the main problems that people experience when using chat applications, HCI methods as well as real users were involved to determine their accessibility barriers.

The findings - Chapter 3 - people without disabilities as well as people with disabilities could experience some problems when they use a Chat in MDs, when they do not have much experience or when they are getting older. The population without disabilities was divided into three main groups: people with and without experience and elder people. Different HCI and SE methods were carried out to obtain the problems that people without disabilities experience when using chat applications. Then, the problems detected that people without disabilities could face are shown in the Chapter 3. After knowing the problems that people face, the thesis's second goal was how to solve these problems.

RQ2: How could these problems be solved?

Some of these problems could be solved considering accessibility and learning standards and guidelines. To achieve it, the standards and guidelines which are more related to m-learning chat applications were selected (Chapter 4). Besides, it was necessary to analyse if some recommendations included in these standards and guidelines are overlapped or not. It means, it was analysed if some recommendations are included in one or more guideline or standard.

These standards and guidelines were extrapolated to chat applications for m-learning environments in order to elicit the accessibility requirements that chat applications should include. In addition, the accessibility barriers found previously were considered to elicit those user accessibility requirements, which will help users. These requirements will help designers and developers to avoid accessibility barriers when creating chat applications for m-learning environments.

The most common problem encountered that many users face is a problem following the *Flow and Rhythm* of the conversation because of reasons such as: they are not able to write quickly or they are not able to read quickly. A solution is proposed to this problem, the *Pause Autorefresh* feature. The last research question was emerged:

RQ3: How the *Flow and rhythm problem could be solved*?

A solution to help users avoid accessibility problems related to the *Flow and rhythm* is analysed and validated with real users in a real learning environment in order to analyse if this could be helpful for users when interacting with m-learning chat applications.

1.4. Ph.D. Contributions

Basing on the research areas explained previously, this Ph.D. provides the following contributions in order to make Chats more accessible for m-learning environments.

1. **Identify Chat's accessibility barriers**: Detect the main accessibility problems that people with disabilities, people without disabilities and elderly people experience when they use chat applications.

2. **Elicit requirements needed to create an accessible chat:** The main accessibility and learning standards and guidelines which can be applied to chat applications in m-learning are studied and those related to accessible m-learning chat applications are selected. Finally, the selected guidelines have been extrapolated for Chats to solve the accessibility problems found and the requirements needed for accessible m-learning chat applications are formally specified and validated.

3. **Proposal to improve Chats‘ interaction:** After identifying barriers that people face when using chat applications, all analysed groups - people with disabilities, elderly people and people without disabilities - recognised problems following the *Flow and Rhythm* of the conversation because of different reasons such as: they cannot write quickly or they cannot read quickly. Thus, the main contribution of this research is the proposal of a new functionality to improve the accessibility of the Chat's interaction. The functionality, *Pause Autorefresh*, improves the interaction of the chat and allows users to control the reception of new messages when they decide.

1.5. Content Structure

This document is divided into six chapters: Introduction (Chapter 1); Literature Review (Chapter 2); Involving Users to Elicit Accessibility Barriers in Chat Applications(Chapter 3); Requirement Engineering to Elicit Accessibility Requirements for m-learning Chat Applications (Chapter 4); A New Functionality for Improving m-learning Chat Application‘s Interaction (Chapter 5); Conclusions (Chapter 6).

This first chapter, Chapter 1, explains an introduction of the thesis, the research goals, the research areas where the thesis is enshrined and the main contributions of the thesis.

Next chapter, Chapter 2, specifies a literature review of: the evolution of learning; an introduction to m-learning and CSCL; accessibility laws, standards and guidelines related to Information and Communications Technologies (ICT), Learning environments and m-learning; the types, restrictions and interactions in MDs; and previous accessible Chats and their accessibility barriers or improvements.

Chapter 3 describes the studies carried out with users to obtain the main barriers that people face when they interact with a chat applications in different environments.

Later, Chapter 4 specifies how the accessibility and learning guidelines and standards were selected and the analysis carried out to obtain which of them were overlapped. Besides, the selected standards and guidelines are used to solve the main problems found in the previous research and the requirements that accessible chat applications should have for m-learning environments are described and validated.

Basing on these guidelines and standards, a proposal to improve the main problem that people face when they interact with the m-learning Chat is provided. This problem is related to the *Flow and Rhythm* of the conversation. A new interaction functionality is proposed to solve this problem. This new functionality is *Pause Autorefresh* and allows users to pause the reception of new messages when they feel overwhelmed. Chapter 5 specifies this new feature and the user testing validation carried out to agree this is a useful solution.

Finally, the last chapter, Chapter 6, includes the main conclusions obtained in each study and the general conclusions of the thesis as well as the future research that could be carried out in the future and the publications where this thesis has been published..

Chapter 2

Literature Review

The literature review below encompasses a review of related work from the multiple areas in which this dissertation is enshrined. The chapter is divided into four different sections. The first section specifies the different ways of learning that students could choose to learn through Information and Communications Technology (ICT). The next section explains some of the accessibility standards and guidelines related to ICTs, learning and m-learning as well as the laws that these systems have to comply. The third section specifies how users interact with MDs and the ways of interaction through MDs. Next, the fourth section specifies the main problems that chats have and the previous accessibility chats that have been created to improve the accessibility. Finally, previous accessible chat approaches are studied and a discussion of their main accessibility problems is carried out to provide conclusions to the literature review and specify the importance of this dissertation.

2.1. Learning through Information Technology

Each student has different learning preferences; so, it is important to provide different ways of learning such as: traditional learning in schools, learning using computers or learning using mobile devices. As a result, students can choose the way of learning and the pedagogical resources which better fits their necessities. For example, if a student feels comfortable learning on the move, the use of mobile devices can be useful for him. On the other hand, if a student feels comfortable learning at home, computers can be a good technology for him.

2.1.1. Learning Evolution. From d-learning to m-learning

In the last decades, new ways of learning have appeared, e.g. blended learning or b-learning [Garrison and Kanuka, 2004], which could be combined with traditional learning. As a result, students have a huge variety of learning tools and materials to choose.

At the beginning, they could learn in the distance - d-learning emerged [Berge and Collins, 1995]. In the first generation of d-learning, learning resources were sent to students by mail. Students were able to learn in their houses and they did not need to attend schools or educational centres. The next distance learning generation broadcasted learning content through multimedia environments such as: TV or radio. Another important issue in the learning environments was the use of CD-ROMS and other ways of distributing educational resources.

When people started to use Internet massively, electronic learning (e-learning)[Caniëls et al., 2007] emerged. Users could connect using the Internet to their school's websites and they could download educational materials. Students had the opportunity to learn through the Internet wherever and whenever they wanted. They could connect to the Internet and use

applications collaboratively - Computer Supported Collaborative Learning (CSCL). Usually, they could use different collaborative tools such as: social networks or virtual environments [Morgado et al., 2012]. There are many definitions which define e-learning, but not many are related to CSCL and e-learning. Peñalvo [Peñalvo, 2005] includes in his definition this:

> No presence learning through technological platforms which allows and make flexible the access and the time to learn. Then, it is adapted to the abilities, necessities and availability of each student. Moreover, it guarantees the CSCL through the use of synchronous and asynchronous tools which improve the competencies process

In the last decades, the use of mobile devices has been increased in learning environments [Frohberg et al., 2009]. A new way of learning came up, mobile learning (m-learning). In m-learning, students can use their mobile devices to learn by their own everywhere.

Another way of learning through the Internet and using CSCL tools emerged recently, massive open online courses (MOOCs). MOOCs capture students and teachers attention. These courses allow free learning access to students from different parts of the world and allow students to exchange and collaborate with each other through this environment [Yuan and Powell, 2013]. This new way of learning can be very useful for students but still present accessibility issues for people with disabilities [Iniesto and Rodrigo, 2014].

2.1.2. M-learning

There are different authors who define m-learning in different ways. Next, two of these definitions are cited:

> "The intersection of mobile computing and e-learning" [...] "It is e-learning through mobile computational devices: Palms, Windows CE machines, even your digital cell phone." [Quinn, 2000]

> "Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies." [O'Malley et al., 2005]

In general, m-learning refers to the use of mobile devices to learn from everywhere and at any time. This new way of learning does not replace the traditional learning and it can be considered as a complement to e-learning [Sharples et al., 2010]. Comparing m-learning with e-learning, m-learning has some advantages and disadvantages [Asabere, 2012]. For example, the price and size of mobile devices are lower than desktop computers. Moreover, students can learn when and wherever they want. However, m-learning has some disadvantages like the screen sizes, for instance. A summary of the advantages and disadvantages of m-learning are shown in Table 2.1.

There are different institutions which have adopted this new way of learning in their high schools or Universities as a complement of their learning studies or as a unique way of knowledge provided for their students. Universities like Stanford University [1] , Ohio University[2] or the University of North Dakota [3] have started to use m-learning. Moreover, the Massachusetts Institute of Technology (MIT) [4] has created the MIT Center for Mobile Learning

[1] Stanford University. http://www.stanford.edu/
[2] Ohio University. http://www.ohio.edu/
[3] North Dakota University. http://und.edu/
[4] Massachusetts Institute of Technlogy. http://www.mit.edu/

[5] to transform education and learning to m-learning. In Spain, the Distance University of Madrid (Udima) developed an initiative to use the iPad [6] for their degree studies. Besides, the Industrial Organization School (EOI) uses a 3G Android MD for learning[7].

Advantages	**Freedom of Learning:** Learning cannot be done anywhere and anytime in e-learning as opposed to m-learning which allows learning to take place any time and at anywhere.
	Location: In e-learning education cannot be provided through Global Positioning System (GPS) as opposed to m-learning which can provide education through GPS.
	Portability: E-Learning devices are not as portable as m-learning devices, resulting in restriction of moving learning devices and equipments from a particular location.
Disadvantages	**Cost:** Desktop computers can be cheaper than new smartphones.
	Input Capabilities: Input devices in desktop computers are more user friendly in comparison to input devices in mobile devices.
	Output Capabilities: Output devices such as screens/monitors of desktops used in e-learning have a more user friendly size as compared to mobile device screens.
	Processing Power: Most desktop computers used in e-learning have a higher processing power and Central Processing Unit (CPU) speed in comparison to that of mobile devices used in m-learning.
	Memory: In terms of memory and storage most desktop computers used in e-learning store more data in comparison to mobile devices used in m-learning.

Table 2.1: Advantages and Disadvantages of M-learning [Asabere, 2012]

Some of these educational centers have created their own m-learning environments, and others use educational-based authoring tools to manage their m-learning courses. With regard to the educational-based authoring tools, there are two important categories to classify them: free open source and commercial tools.

The free open source tools such as: Moodle [8] or uMobile [9] help institutions to create m-learning environments for their courses. On the other hand, commercial tools such as: BlackBoard [10] or Desire2Learn [11] provide similar functionalities. However, institutions have to pay for them and some universities cannot afford them.

2.1.3. Computer Supported Collaborative Learning (CSCL)

After the evolution of Internet to Web 2.0, the interaction between users through Internet changed. This concept can be extrapolated to e-learning too. Today, students are not static users who connect to the Internet to get information. They are able to connect to the Internet and share their own knowledge. As a result, the teacher is not the only source of knowledge

[5] MIT Center for Mobile Learning. http://mitmobilelearning.org/

[6] Udima Proyecto iPad.http://www.udima.es/es/arranca-proyecto-ipad-udima-colaboracion-fundacion-vodafone-espa%C3%B1a.html

[7] Mlearning EOI. http://www.eoi.es/blogs/mlearning/m-learning-eoi/

[8] Moodle. http://moodle.org

[9] Umobile. Jasig. http://www.jasig.org/umobile

[10] BlackBoard. http://www.blackboard.com/

[11] Desire2Learn. http://www.desire2learn.com/

[Peters and Armstrong, 1998]; the teacher is a user who learns too [Mazyad and Tnazefti-Kerkeni, 2010]. Considering these things, students and teachers can exchange their knowledge with each other and learn.

Communication tools are becoming more and more powerful in CSCL environments. Due to it, collaboration is up-to-date because people are joined to environments such as: social networks or blogs where people collaborate with each other to share information and knowledge. Collaboration is really important in learning environments from a pedagogical point of view [Bruffee, 1993]. The study of [Johnson and Johnson, 1987] demonstrated that our individual knowledge is not useful because people need to collaborate with each other to solve problems. There are different definitions for CSCL. For example, according to [Stahl et al., 2006], CSCL is defined as:

> "Computer-supported collaborative learning (CSCL) is an emerging branch of the learning sciences concerned with studying how people can learn together with the help of computers."

Classification of CSCL

CSCL can be classified into different categories from the point of view of different variables: year of creation, interaction and synchronisation time.

- **Year of creation:** From the point of view of the period of time in which these tools were created, two different groups of tools are considered [Beldarrain, 2006] [Godwin-Jones, 2003]: the first and the second generation of collaborative tools. The first group includes tools such as: chat applications, email applications, discussion boards, voice and videoconferencing applications, whiteboards tools, live presentation tools or application sharing. The second generation includes tools such as: blog, wiki or podcasts applications.
- **Interaction time:** According to [Ebner, 2007] and centering on the ways of communication between users in e-learning tools, a new classification is provided. The main ways of interaction in e-learning systems are: learner and computer; learner and instructor (Computer Mediated Communication (CMC)); or learner and learner (Computer Supported Collaborative Learning)).
- **Synchronization time:** CSCL tools can be classified into synchronous or asynchronous. Synchronous tools are tools which allow people communicate in real time and asynchronous are not in real time [IMS, 2007] [Martínez, 2005].

Next table, Table 2.2, shows a summary of the most used CSCL tools and their classification according to time and space.

2.1.4. Computer Supported Collaborative Learning in Mobile Devices

These days, mobile devices are used to support individual and collaborative learning. Students can take advantage of mobile devices's characteristics to learn, collaborate and communicate with their teacher or other classmates through mobile devices in CSCL (m-CSCL)[Reychav and Wu, 2015].

There are some technical and pedagogical projects which integrate m-CSCL tools in their learning environments. For instance, the study provided by [Zurita et al., 2001] implements m-CSCL with primary school children. Moreover, the study of Musex implements a CSCL in

		Time	
		Same time (Synchronous)	**Different time (Asynchronous)**
Space	**Same space**	Spontaneous collaborations, formal meeting and classrooms	Design rooms, projects scheduling
	Distributed	Video Conferences, Phone Calls, Share Boards, Decision Support Systems, Instant Message Systems or Chats, Discussion Boards, Voice, Videoconferencing, Whiteboards, Live. Multi-user Domain Object Oriented environments (MOOS)	Emails, Blogs, Authoring, Fax, Voice Email, Newsgroups and Mailing-lists, Wikis, RSS, Presentation Tools, Group Calendars, Edition Collaborative Systems, Document Management Systems, Workflow systems, Hypertext

Table 2.2: Classification of CSCL Tools

a museum with PDAs [Yatani and Truong, 2009] and the MoLE Project [12] uses the mobile devices to deliver content. Another example is the project implemented in the Arizona University, which uses mobile devices to support a student group project. The students were able to improve their oral and written skills among other capabilities [Yau et al., 2003]. Other ways to improve m-CSCL include new techniques - e.g. augmented-reality [Ke and Hsu, 2015] or gaming [Sánchez and Olivares, 2011] to improve learning.

Focusing on CSCL as a way of communication through mobile devices, it is important to specify the main purpose of the system in order to choose the best communication tools and pedagogical strategies for it. Some of these purposes are: socialization, coordination, collaboration, giving mutual awareness or facilitation [Frohberg and Schwabe, 2006].

There are different tools to communicate such as: e-mail, chat or blogs. The project MoULe proposes a m-CSCL environment based on Learning Content Management Systems (LCMS) - e.g. Moodle - which includes tools such as: chat applications, or forums. However, this project does not consider accessibility in any part of the study. Focusing on chat applications, these tools are considered as one of the most useful CSCL tools for mobile devices according to the study provided by [Corlett et al., 2005]. In this study, some tasks executed in mobile devices were compared. The results shown that the applications "e-mail" and "chat" are complementary, because they are always mentioned together. Besides, another study [Kadirire, 2007] proposes a web prototype which implements some important features such as: the use of instant synchronous or asynchronous chat applications. Moreover, other study uses chats as a CSCL tool for learning Irish [Cooney and Keogh, 2007]. It demonstrated that 95% of users enjoy the task and they preferred the communication through it instead of face-to-face because they suffered less pressure. Additionally, the study provided by [Mühlpfordt and Wessner, 2005] proposes the use of chats as a CSCL tool to share material through it and assign explicit references through a learning material.

Most recently, researches have corroborated this theory. For example, the study conducted in Hong Kong depicted students shown positive perception when using Whatsapp as a m-CSCL tool only when this tool was used in school hours [So, 2016]. Other instant text messaging

[12]MoLE. http://www.mole-project.net

tools which allow less number of characters - e.g. Twitter - have been used to test if they are as useful as common instant text messaging tools - e.g. Skype. The results showed the number of messages sent did not affect negatively the group performance [Isari et al., 2016]. Besides, the study conducted by [Wald et al., 2014] shows how the use of Twitter can be helpful to make notes and tag live learning sessions for students.

These studies use chat applications as a m-CSCL tool and they show that chats are useful in learning environments. However, they do not consider accessibility in these researches and do not provide new features to solve accessibility interaction problems.

2.2. Accessibility

The concept of Accessibility has different meanings and there are different definitions. According to [Thorén and Bergner-Samuelsson, 1993], accessibility is defined as:

> "Accessibility is here defined as a set of properties that are built into the product, service or system from the outset, enabling people within the widest range of abilities and circumstances as is commercially practical to access and use it."

Specifically in web sites, one of the most extended accessibility definitions is the definition provided by World Wide Web Consortium (W3C) [13] [Henry, 2005]:

> "People with disabilities can perceive, understand, navigate, and interact with the Web, and that they can contribute to the Web."

This means that people with disabilities will have the same opportunities to access to the information shown on the Internet. Thus, any people's right is not violated [UN, 1945]. If the ICTs were created in an accessible way, people with disabilities would be fewer discriminated because they could access to all the information. As a result, people with disabilities would be more independent and more integrated into the society.

Moreover, a part from creating accessible ICTs, there are solutions, which help people with disabilities to access to ICTs. These solutions are named Assistive Technology (AT). They help people with different disabilities to use ICTs. For example, people with huge visual impairments cannot see the information shown in a screen. They need to use screen readers as an AT which transforms the content shown on the screen to speech. However, there are some difficulties that they could face when they use screen readers [Lazar et al., 2007]. For instance, if there were some information on the website which was not properly tagged, users could not understand the information. People with motor impairments is another group of people who is affected by accessibility issues. They might have problems to type text because of this they use speech recognition software to type text quickly and dictate commands [Havstam et al., 2003]. Considering all these things, accessible software and websites combined with ATs allow users with disabilities to access to the ICTs.

However, it is important to emphasise that accessibility is not exclusively helpful for people with disabilities exclusively; there are other circumstances that can make everybody vulnerable when they use ICTs. For example, if the Internet connection is not too fast, people could experience accessibility problems to download files or watch videos. Besides, if the mobile device is really old, people could experience problems to run some files because this file might not be supported by the mobile device. Furthermore, there are some temporal circumstances

[13] W3C. World Wide Web Consortium. http://www.w3.org/

that provoke us "temporal disabilities" - see Figure 2.1; it means, we cannot have the same abilities that we usually have for different reasons. Some of these temporal circumstances could be: accidents which provoke us a broken leg or arm; knowledge problems because the country and language are different; and so forth. Also, as the years gone by some abilities - e.g. vision or hearing - are deteriorated [Hanson, 2009]. Considering all these circumstances creating accessible environments helps everybody regardless of their disabilities. Moreover, people with disabilities can get a profit of this.

Figure 2.1: Temporal Disabilities

2.2.1. Information Technologies

Everybody should be able to access to ICTs in spite of their disabilities, age, environment or circumstances. Thus, there are accessibility standards, guidelines and laws which normalise or regulate access to ICTs, learning environments and m-learning. Next subsections explain which are these standards, guidelines and laws.

Information Technologies: Laws

There are laws which protect the rights of people with disabilities when they are using ICTs. Since 1999, Europe has developed plans such as: eEurope 2002 [Comission, 2002a], eEurope 2005 [Comission, 2002b] e i2010 [Comission, 2005] and Europe 2020 [Comission, 2010] to allow people with disabilities accessing the information showed on ICTs.

Some European countries have created their own laws to protect people's right. For instance, Spain created the general law of rights for people with disabilities and social inclusion (Ley General de Derechos de las Personas con Discapacidad y de su Inclusión Social) [Spain, 2013] which globalises three previous laws related to protect people's rights. Besides, the Equality Act 2010 provided by the UK protects people with disabilities from discrimination in a range of circumstances such as: the provision of goods, facilities and services, the exercise of public functions, premises, work, education, and associations [UK, 2010]. Furthermore, Ireland (The Disability Act) [Ireland, 2005], Germany (Act on Equal Opportunities for Disabled Persons) [Germany, 2002] and Italy (Provisions to Support the Access to Information Technologies for the Disabled) [Italy, 2004] among other countries have developed their accessibility laws.

Outside of Europe, USA has created laws to protect people with disabilities' rights and to ensure that electronic and information can be accessed and used by individuals with disabilities. These laws are: Section 508 [USA, 2017] which has been recently reviewed and updated, the Americans with Disabilities Act (ADA) [USA, 1990] and the Twenty-First Century Communications and Video Accessibility Act (CVAA) of 2010 [USA, 2010]. This last law, CVAA, needs special attention because it specifies that electronic messaging services must be accessible. These services are defined as:

> Electronic messaging service means a service that provides real-time or near real-time non-voice messages in text form between individuals over communications network.

Thus, Chats are included in this category and they must be accessible to allow users use them.

Besides, other developed and non-european countries have created laws to protect human's rights. For example, Canada [Canada, 1985] and Australia [Australia, 1992] have created their own laws to protect human rights too.

Even developing countries such as: Brazil [Brazil, 2004] or Puerto Rico [Rico, 2003] are worried about people's rights and have created their own laws to protect people with disabilities.

Thus, everybody have to obey these laws to guarantee that all users have the same opportunities to access to the ICTs without facing barriers. Moreover, from a commercial point of view, the creation of inaccessible tools decreases the number of customers that could access to the software.

Information Technologies: Accessibility Standards and Guidelines

From the point of view of websites, W3C has developed guidelines to create accessible Webs. Some of these guidelines are: Web Content Accessibility Guidelines 2.0 (WCAG 2.0) [W3C, 2008b] which specify how the content of the website needs to be created to avoid accessibility issues; WAI Authoring Tool Accessibility Guidelines 2.0 (ATAG 2.0) [W3C, 2013a] which specify how to create accessible authoring tools; or WAI Accessible Rich Internet Applications (WAI-ARIA) [W3C, 2014a] to create dynamic content in an accessible way.

The ISO organization has developed other standards to create accessible ICTs. For instance, ISO 9241-20 Accessibility guidelines for information/communication technology (ICT) equipment and services [ISO, 2008b] which provide guidelines to improve the accessibility of ICT equipment and services; and the ISO 9241-171 Ergonomics of human-system interaction – Part 171: Guidance on software accessibility [ISO, 2008a] provides ergonomics guidance and specifications for the design of accessible software for use at work, in the home, in education and public places. Furthermore, the ISO organization has developed the standard ISO/IEC 40500:2012 Information technology – W3C Web Content Accessibility Guidelines (WCAG) 2.0 [ISO, 2012].

Moreover, some countries have developed standards which are based on the WCAG 2.0 guidelines. For instance, the Spanish Association for Standardization and Certification, AENOR, has developed the standard UNE 139803:2012 Web content accessibility requirements standard [UNE, 2012] to create content accessible for people with disabilities based on the WCAG 2.0 and the ISO/IEC 40500:2012[ISO, 2012]; or UNE 139802:2009 - Guidance on software accessibility [AENOR, 2009] based on [ISO, 2008a]. France created the standard Référentiel Général Daccessibilité des Administrations (RGAA) standard [France, 2016] based on WCAG 2.0 guidelines and Germany created the standard [Germany, 2011] should be applied in all German government websites.

Following these standards and guidelines, the creation of accessible tools will be easier and the access to the ICTs will be increased because everybody could use these ICTs.

2.2.2. Learning Environments

Education is an important area for the development of a person. Everybody should have the same rights to access to it and to learn regardless of their abilities or disabilities.

Learning environments are used nowadays by almost every educational centre. However, most of these environments present some accessibility problems and some people with disabilities cannot use them [Muilenburg and Berge, 2005]. As we have specified in the previous section, there are some laws, standards and guidelines specific for ICTs to protect people's rights. Although some learning environments are ICTs, there are specific laws, standards and guidelines which protect human rights for students. The following subsections detail the laws, standards and guidelines related to learning environments.

Learning Environments: Laws

In Europe there are some accessibility laws for education that learning systems have to accomplish. United Kingdom has specified the laws Disability Discrimination Act (DDA) [UK, 1995] and the Special Educational Needs and Disability Act [UK, 2001] for education. These laws guarantee that nobody will be discriminated because of their disabilities. Besides, students should have the same rights to access to all educational resources. Spain has created another law to protect students' rights: LOE (La Ley Orgánica 2/2006, de 3 de mayo, de Educación) [Spain, 2006]. The law specifies principles such as: education quality or no discrimination. Moreover, in the convention to protect and promote the diversity of cultural expressions in 2005 [UNESCO, 2005] they agreed that it is necessary to promote the intercultural and the diversity of cultural expressions and recognise the importance of culture in developing countries.

Outside of Europe, many countries have decided to create laws for educational environments. For instance, USA has reflected it in the law Individuals with Disabilities Education Act (IDEA) [USA, 2004] and in the law Equal Educational Opportunity Act (EEOA) [USA, 1974]. Moreover, Australia approved the law Disability Standards for Education [Australia, 2005] which specifies the obligations of education and training providers to ensure that students with disabilities are able to access and participate in education and training on the same basis as those without disability.

Developing countries have been working in creating laws to provide education for everybody nevertheless of their abilities. For example, Costa Rica created the 7600 law *"Igualdad de Oportunidades para Personas con Discapacidad"* [Rica, 1996], Mexico created the law "*Para las Personas con Discapacidad del Distrito Federal*" [Mexico, 1995] or Nigeria created the law Nigerians with Disability Decree [Nigeria, 1993]. All these countries have created laws to provide education for everybody nevertheless of their abilities.

Learning Environments: Accessibility Standards and Guidelines

There are different standards and guidelines that are useful for developers and designers to create e-learning tools. It is important to use standards to create e-learning environments in order to normalise the use of pedagogical materials and be able to integrate them in different technologies, systems and organizations; because the materials are not specific for a unique technology, the information can be exchanged between organizations [Hilera and Hoya, 2010]. Furthermore, if we focus on accessibility, the standards and guidelines can improve user's experiences because these learning materials and environments can be used by everybody.

For instance, Instructional Management System project (IMS) provides standards for users to create accessible learning environments such as: Access for All meta-data [IMS, 2004] to provide mechanisms to modify or adapt materials for students; IMS Learner Information Package Accessibility for LIP [IMS, 2003] to modify the User Interface (UI) for user's necessities.

Besides, the IMS Access For All v2.0 Final Specification [IMS, 2003] was converted in an ISO Standard, ISO/IEC 24751 Individualized adaptability and accessibility in e-learning, education and training [ISO, 2008e] to satisfy the necessities of all users, specially, for people with disabilities. Moreover, the guidelines Universal Design Learning (UDL) v2.0 [CAST, 2011] explain how to reduce barriers to access learning content.

With regard to collaboration, there are some standards that have been created to favour the exchange and the interoperability between students, teachers and other users. For example, the ISO/IEC 19778: Collaborative workplace [ISO, 2008c] aims to do this. Moreover, the ISO/IEC 19780-1 Collaborative Learning Communication [ISO, 2008d] aims to name and to define expressions that are used for e-learning research. Another guideline useful to develop accessible learning tools is the IMS Guidelines for Developing Accessible Learning Applications which specifies how to create accessible CSCL tools (e.g. Chats)[IMS, 2007].

2.2.3. M-learning

M-learning tools have to be accessible because they are ICT systems and because they are pedagogical tools. There are not specific laws for m-learning environments but as they are ICTs they have to follow laws related to ICTs. Besides as they are learning environments, they have to meet laws related to learning environments. These laws have been explained previously in the Information Technologies: Laws and Learning Environments: Laws sections.

Moreover, the m-learning environments have to follow standards and guidelines related to learning environments, for ICT software and Mobile Devices. Because of this, the standards provided in previous sections related to e-learning and to ICTs must be considered for m-learning environments too. However, there are some accessibility standards and guidelines which are specific for m-learning. UNESCO [UNESCO, 2013] has created some policy guidelines for mobile learning which include strategies to provide equal access for all. Furthermore, the ISO organisation has created other standards such as: the standard ISO/IEC TS 29140-1:2011 [ISO, 2011a] which provides guidance regarding learning, education and training (LET) situations in which learners are nomadic; or ISO/IEC TR 29410 part2 [ISO, 2011b] for m-learning which provides a learner information model specific to m-learning.

Besides, as m-learning consists on e-learning using Mobile Devices, these environments have to comply standards and guidelines related to mobile devices. W3C has developed some guidelines to guide in the creation of accessible mobile applications - e.g. Mobile Web Application Best Practices (MWABP) [W3C, 2010] and accessible applications Mobile Web Best Practices (MWBP) 1.0 [W3C, 2008a] - which propose recommendations to developers and designers to create accessible tools.

The European Telecommunications Standards Institute (ETSI) has some Specialist Task Forces (STF) teams which have provided guidelines to design mobile applications for people with limited cognitive, language and learning abilities. The "Human Factors (HF); Functional needs of people with cognitive disabilities when using mobile ICT devices for an improved user experience in mobile ICT devices" standard and the "Human Factors (HF); Recommendations: for the design and development of mobile ICT devices and their related applications for people with cognitive disabilities" are two standards which have been developed to create better designs for people with cognitive and learning disabilities. These guidelines are under development but it is planned to be published by the end of 2016 [ETSI, 2016].

Furthermore, some mobile Operating System (OS) provide guidelines and recommendations

to create accessible applications. Some of these recommendations are provided by: Android OS [Android, 2012], Blackberry [Blackberry, 2013], Apple [Apple, 2012], Nokia [Nokia, 2012] or Windows Mobile [Microsoft, 2010]. Finally, other organizations such as: BBC [BBC, 2014], Funka Nu [Nu, 2012] and [Nu, 2014] or the Mobile Manufacturers Forum [Forum, 2014] have created guidelines to create accessible mobile application or websites.

2.3. Mobile Devices

The use of mobile devices has been increased in the last years [CISCO, 2017]. Besides, there is a huge variety of Mobile Devices as tabletPC or smartphones and each one support different ways of interaction. Due to this diversity, they can have different accessibility barriers. Next sections explain the main kind of mobile devices that exist nowadays, the restrictions that they have and the ways of interaction.

2.3.1. Types and Restrictions

There are different types of Mobile Devices which can be used in m-learning environments. According to different authors, they can be diverse. The classification provided by [Yuen and Wang, 2004] defines three different types of mobile devices: PDAs; smartphones; tabletPC's; e-book readers or hybrid devices; or MP3/MP4 players and handheld gaming devices [Gupta and Goyal, 2011]. Each student can select the mobile device which better fits their necessities. Next, Figure 2.2 shows the different types of mobile devices that users can use in m-learning environments.

Figure 2.2: Types of Mobile Devices

- **Personal Digital Assistant (PDA):** a palmtop computer which main function is a personal organizer but also provides e-mail and Internet access.
- **Smartphone:** a cellular phone that is able to perform many of the functions of a computer, typically having a relatively large screen and an operating system capable of running general-purpose applications.
- **TabletPC:** a computer that accepts input directly onto an LCD screen rather than via a keyboard or mouse.
- **E-book:** a dedicated device for reading electronic versions of printed books.
- **MP3/MP4 Players:** a portable media player, or digital audio player, is a consumer electronics device that is capable of storing and playing digital media such as: audio clips, images, videos or documents.

- **Handheld gaming devices:** a small electronic device for playing computerized video games.

Most of these Mobile Devices allow users access to the Internet everywhere. However, the access to the Internet through mobile devices has some limitations because of different factors. These limitations can be divided into: wireless restrictions, mobility restrictions and portability restrictions [Forman and Zahorjan, 1994] [Harper, 2008] [Yesilada, 2013]. The limitations are showed next in Table 2.3.

	Wireless	**Mobility**	**Portability**
Restrictions	Disconnection Low bandwidth Heterogeneous network Variability Security risks	Address migration Migrating locality Location-dependent information	Battery Risks to data Small storage capacity Small user interface
Advantages	Connect everywhere	Social Interactivity	Small size and weight

Table 2.3: Restrictions of mobile devices

These technological limitations can provoke problems for people without disabilities too when they use mobile devices. These restrictions can provoke similar accessibility problems to the barriers that users with disabilities have when they connect to the Internet [Newell and Gregor, 1999] [Yesilada, 2013] [Tiresias, 2009]. For instance, if the images do not have alternative text, low band width provokes the same accessibility problems for people without disabilities as the accessibility problems that a user with visual problems have when he tries to surf the Internet. Besides, as keys of the keyboard are small, people without disabilities, who use the mobile device on the move, can have problems to press the keys and can experience the same problems that people with motor impairments experience when they surf on the Internet using desktop computers. These limitations are proved by some experiments; for instance, [Chen et al., 2010] confirms that mobile Web users and people with motor impairments who use desktop computers share similar problems. However, people with disabilities can experience even more accessibility problems because of these limitations. For example, users with visual impairments cannot use tactile screens without AT [Kane et al., 2008]. In addition, people with motor impairments could have problems to press some keys of the keyboards because they are really small [Belatar and Poirier, 2008].

Although some companies are trying to solve these problems, most of them are difficult to solve. For instance, Emporia [14] has developed a mobile phone with big numbers and loud speaker for older people. Others companies have tried to add new functionalities like screen readers or gestures for people with disabilities [15]. However, mobile brands sometimes do not take into account these problems and as a result people with disabilities, people with temporal disabilities or people without disabilities who use mobile devices can face accessibility problems and can experience barriers when they use them.

2.3.2. Human Computer Interaction in Mobile Devices

Due to the increase use of Mobile Devices in the last years, users have changed their way of executing some tasks like connecting to the Internet because mobile devices allow users more freedom to execute these tasks everywhere and whenever they want. For instance,

[14] Emporia Life. http://www.emporialife.co.uk/
[15] Apple. iPhone. http://www.apple.com/es/accessibility/ios/

some researches explained that users execute some tasks faster using this type of devices than executing these tasks through a desktop [Lorenz et al., 2009]. Because of this, it is important to reconsider how people interact with mobile devices and how they surf using mobile devices [Johnson, 1998].

Mobile Interaction Methods and its Accessibility Problems

Users could interact with Mobile Devices using different input methods such as: touch-based input, keyboard-based input [MacKenzie and Soukoreff, 2002] or speech recognition [Huggins-Daines et al., 2006].

Users can use keyboards to introduce text. If the MD provides a QWERTY keyboard with physical buttons, users suffer fewer accessibility problems because this keyboard is similar to the desktop keyboard [MacKenzie and Tanaka-Ishii, 2007]. However, if the mobile provides other kind of keyboard with less keys, the user could have problems related to ambiguity because the user should press one key more than once to select a character [Smith and Goodwin, 1971].

Nowadays the use of tactile interfaces is being increased. However, these screens are not accessible for everybody. The screen‘s sizes of the mobile devices, is a problem that could affect all type of users and in different situations. For example, cold ambient temperatures could cause mobility problems for users who want to interact with their mobile device [Sarsenbayeva et al., 2016]. These problems are accentuated for users with motor impairments and older people because of the smaller buttons [Brewster et al., 2007] [Colle and Hiszem, 2004]. Moreover, soft keyboards include other problems such as: the user cannot lose the attention of the keyboard; it is difficult to identify typing errors; and the user loses control over the distribution of letters [MacKenzie and Soukoreff, 2002]. Previous specified problems could be accentuated when users are on the move or eyes-free or hand-free way [Schildbach and Rukzio, 2010] [Hoggan et al., 2008].

Users with mobility impairments suffer problems when using tactile screens with only one hand. For instance, people who have reduced thumb mobility could experience problems to interact with some parts of the mobile screens [Wiegand and Patel, 2015]; and sometimes, users have to complete the operation with two hands [Vogel and Baudisch, 2007].

Another way of interaction is speech recognition. Users could use this way of interaction in eyes-free or hands-free environments [Melto et al., 2008] [AbilityNet, 2007]. Besides, people with visual or motor impairments could use it to type text on Mobile Devices easily [Abascal and Civit, 2000] [Freitas and Kouroupetroglou, 2008]. However, speech recognition presents some limitations because recognition software is still not as accurate as expected [Azenkot and Lee, 2013] and because this software does not work properly in noisy environments[Zaykovskiy, 2006].

Mobile User‘s Preferences

Surfing on the Internet using mobile devices is different than using desktop computers. Apart from the input differences specified in the previous section, there are other difficulties and preferences that people face when they are navigating mobile Web pages or using mobile applications.

Users present different search behaviours and device usage depending on the environment and context. For example, people prefer to use mobile devices when eating or the information

searched is different depending on the hour [Wang et al., 2016].

Depending on the study, users prefer the use of the mobile website or not. For instance, the study provided by [Schmiedl et al., 2009] concluded that users prefer to use the mobile version. In contrast, the study provided by [MacKay et al., 2004] assured that people, who were used to surf on desktop computers, preferred the mobile version.

With regard to the users‘ preferences while they use mobile devices, users face problems to communicate using email or online communities [Cui and Roto, 2008]. However, the study concludes that users do not prefer to answer emails using their mobile, if it is not an urgent email, and users prefer websites with less information.

2.4. Chat Applications: a Collaborative Tool for Learning Environments

Chat is a useful tool to communicate with students or teachers in learning environments. Previous researchers have shown that the use of chats for learning can improve students' experience. This is even more helpful for students, who are shy, because they can express their doubts without fear [Xie, 2008]; so, they consider chats as one of the most useful tools [Corlett et al., 2005].

There are many definitions of chats; however, only few definitions include accessibility on it. For instance, [AccessIT, 2004] defines a chat and its accessibility problems:

> Text chat is a synchronous tool, which allows several users to communicate via typed text in real time.

According to different authors, the use of chat applications as a CSCL tool has advantages and disadvantages for students and teachers. A summary of these advantages and disadvantages and the authors, who identified them is shown in Table 2.4.

Apart from the advantages and disadvantages that chats have, they have accessibility problems, which are a handicap for different people. Next section explains the main barriers that people have to face when they use chat applications to communicate with other people.

2.4.1. Chats: Accessibility Problems

Chats present accessibility barriers for a huge variety of people. This tool presents even more specific problems than other ICT systems [Hackett et al., 2004]. These problems could be divided into four different accessibility catogories - see Figure 2.3. These categories are: people face problems because of the assistive technology used; problems related to the *Flow and Rhythm* because they cannot read and write quickly; problems related to the technology used in the creation of the application; and specific problems related to the mobile device.

Assistive Technology

People who use screen readers have accessibility problems when the website is auto-refreshed continuously. As a result, the screen reader restarts and reads the page again [Lazar et al., 2007]. The reason of this is the screen reader reads the content sequentially [Leporini and Buzzi, 2007]. Another important problem is related to the use of Ajax technology with live regions. People, who use screen readers experience some problems when the content is updated

Advantages	**Communication**. Facilitates the development of CSCL communities, and the communication between students and teachers [Cochrane, 2006] [Kadirire, 2007]
	Increase of the Participation. For all students and it is a particular benefit to non-native speakers. [Pilkington and Walker, 2003]
	Improve self-confidence. Helps engage reluctant learners and raise their self-confidence [Kadirire, 2007] and can be inclusive for shy and disadvantages students [Xie, 2008]
	Generate new knowledge. Facilitates the creation of new knowledge between students [Morán, 2008] [Ngaleka and Uys, 2013]
	Critical attitude. Students can take different roles in debates [Pilkington and Walker, 2003]
	Develop new skills. They have to develop it to be able to follow parallel threads and students acquire more responsibility to manage these threads [Pilkington and Walker, 2003]
	Improve social interactions. Chats facilitate social and affective interactions with their colleagues [Kim et al., 2014]
	Communication from different places. Students and teachers do not need to stay in the same place to communicate with each other [Andujar, 2016]
	Negotiate turns. Users are able to manage turns in multiple threads [Pilkington and Walker, 2003]
	More time for response. It gives them more time to consider the correct response, and removes some of the emotional stress of telephone or face-to-face support. [Heathcote, 2016]
Disadvantages	**Participation**. Some students do not participate in the activity [Divitini et al., 2005]
	Formality. Reduces the formality of the learning experience [Kadirire, 2007]
	Feedback. Lack of simultaneous feedback, which is especially important for the grounding strategies in spoken communication [Mühlpfordt and Wessner, 2005]
	Problems to manage turns. Students can experience problems to specify turns when interacting with their colleagues [Brandt and Jenks, 2013]
	Incoherences. The content of the messages might be incoherent due to different reasons - e.g. lack of simultaneous feedback [Herring, 1999]
	Parallel threads. People can interrupt each other so parallel threads can be created [Pilkington and Walker, 2003]

Table 2.4: Advantages and Disadvantages of Chats

and this content is not tagged properly [Thiessen and Chen, 2007]. Using ARIA technology will avoid this problems and users will not experience these difficulties [Moreno et al., 2011]. Moreover, if a new Window is opened when a new button is pressed, the user could be disoriented. For example, users of WebCT and BlackBoard experience these problems [Harrison, 2002]. Besides, some chats do not provide support for text-to-speech or text-to-braille which is useful for screen reader users [Schoeberlein and Wang, 2009]. Furthermore, Braille-display users experience problems because the AT speaks the new sentences even if the previous sentence has not been spoken completely [Hampel et al., 1999]. As a result, people with visual

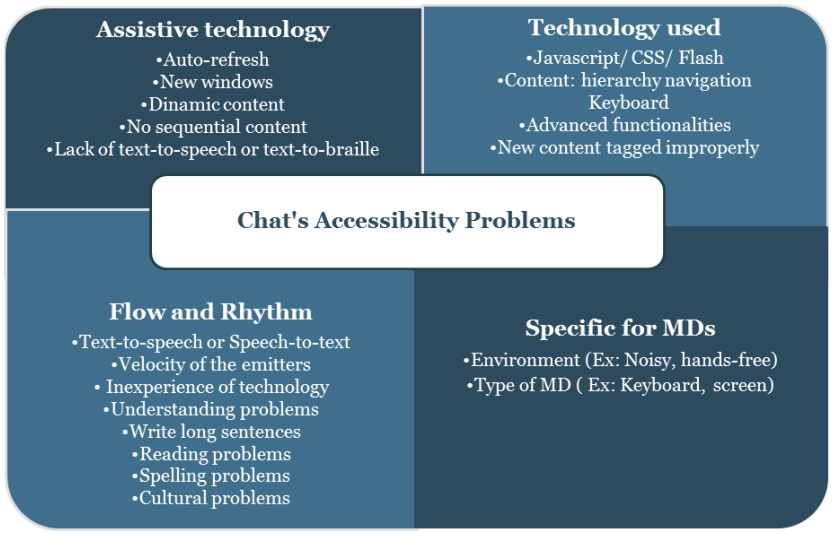

Figure 2.3: Chat's Accessibility Problems

impairments could have many problems to use chats.

Flow and Rhythm

One of the main accessibility problems that users experience when using chat applications is related to follow the *Flow and Rhythm* of the conversation. This issue is enshrined in accessibility issue but at some point, this issue can be related to usability as well because learning and cognitive could affect it.

Users might have difficulties to communicate using chat applications because they cannot type messages or they cannot read messages as quickly as their colleagues. As a result, they might have problems to follow the conversation and participate actively in the conversation or follow the *Flow and Rhythm* of the conversation. Besides, users can have problems if parallel threads appear in the same conversation because they might not know when they need to interact. This can be related to previous researches that have confirmed some communication principles need to be established in order to make CSCL communications effective [Hatzipanagos, 2006]. Also, the use of other complex interactions and input information could cause problems related to the *Flow and Rhythm* of the conversation. For instance, the convert of text-to speech or speech-to-text in real time is complex depending on the velocity of writing of the emitter, which is especially important for screen reader users. Besides, if one of the emitters is not able to write quickly because he has cognitive or learning disabilities or is a foreigner, they could not follow the conversation easily [AccessIT, 2012] [Guenaga et al., 2004]. Maybe, because of this, foreign students prefer asynchronous tools because they can read and think about the answer in the language that they are studying [Noll et al., 2010] and they can have problems to communicate because of the use of cultural terms [Nguyen and Fussell, 2012].

Other people, who could have problems with the *Flow and Rhythm* of the conversation, are learners with dyslexia. They could feel embarrassed or shamed when they communicate using mobile devices. For instance, when they are writing a long sentence other users could write more sentences and as a result, they could feel outside of the conversation because they need more time to re-read the sentences and understand them; they can have problems with the spelling and transposition-letters which can be a handicap to understand the conversation thus their interventions could lose credibility for other students[Woodfine et al., 2008]. In

general, people who have problems with the use of some advanced functionalities or with the use of the keyboard cannot use chats efficiently [Resta and Laferrière, 2007].

Technology used

With regard to the technical problems, some web-based chats present accessibility problems because the code implementation inside the Web browser might not accessible [Webaim, 2004]. Moreover, there are other accessibility problems related to the code. For instance, developers might: not use CSS appropriately; or chat applications could be created using Flash [Bühler et al., 2007] [Webaim, 2004].

Besides, there are some problems related to the use of HTML tags improperly. For instance, developers might not use hierarchy navigation [Schoeberlein and Wang, 2009]. Furthermore, if the updated content is not tagged properly, people who use a screen readers can experience accessibility problems [Thiessen and Chen, 2007].

Specific for mobile devices

The accessibility problems of chats in mobile devices are similar to the problems they cause in a desktop computers as it was discussed in previous Section 2.3.2 . However, there are other problems which could be caused due to the mobile limitations. Firstly, it is important to remark that people without disabilities could experience the same accessibility problems when they use a mobile as the problems that people with disabilities face when they use a desktop computer [Yesilada, 2013][Newell and Gregor, 1999][Australia, 1992][Tiresias, 2009]. For instance, some people have problems to recognize colors; as a result, when they might not perceive colours when they use a computer. These accessibility problems are similar to the problems that a person without disabilities can experience when they are using a mobile with a screen which does not support all colours. Another example is related to sounds, users with hearing impairments might not hear sounds in desktop software, this problem is similar to the problems that nondisabled people have when they turn off the sound in public places. Moreover, people with mobility impairments have problems with the use of the keyboard or mouse in a desktop computer; these accessibility problems are similar to the problems that people without disabilities experience when they use a tactile keyboard or a keyboard with small buttons.

2.4.2. Related work: Previous Chat Solutions

There are some previous chat applications which have addressed some previous accessibility issues - see Chats: Accessibility Problems section. For instance, Ichat [16] application is centered in solving the accessibility problems related to technological aspects. This chat identifies the status of each user with colours and icons; thus, the idle or connected users can be identified easily. Moreover, some researchers have tried to solve the accessibility problems related to auto-updated content and have created accessible chat applications as Reef Chat which includes Rich Internet Application (RIA) and Ajax live regions as well as Web Content Accessibility Guidelines (WCAG) 2.0 [Thiessen and Chen, 2007]. Furthermore, the study [Chen and Raman, 2008] have added WAI-ARIA standard for the Google Talk IM and provides a feature which translates the content generated in Chinese to English. Another chat example is the Clap chat which is developed according to WCAG 2.0 guidelines, the user can personalise it and screen reader users can use it because it includes the use of Ajax in an accessible way through WAI-ARIA technology [Espinosa and Morales, 2012]. Moreover, BIRC prototype [Hampel et al., 1999] tries to improve the experience of users who use Braille-display

[16] Apple. iChat. http://www.apple.com/es/macosx/apps/all.html

and speech synthesiser. It provides shortcuts and allows exporting the conversations. However, it is important to specify that this prototype relies on the AT exclusively that they consider is more efficient.

Focusing on the interface, the study provided by Prior [Prior et al., 2008] proposes an adaptation of the chat's interface for being used by older adults. This adaptation includes a user representation using more lifelike characters. In addition, an Instant Messaging (IM) application, Messenger Visual, supports pictogram-based communications for people with cognitive disabilities, [Tuset et al., 2011]. [Melnyk, 2014] focuses on web chats' interfaces for screen reader users. The system notifies when new messages have been received, but screen reader users can specify if the messages are read or not by the screen reader using shortkeys.

With regards to the use of chats in learning environments, previous Learning Content Management Systems (LCMS)s have implemented more accessible chats in their tools. For instance, Moodle 2.3 has created an interface which is more accessible because it does not use frames and Javascript technology. Moreover, people can specify the period of time to auto refresh and show incoming messages [Moodle, 2012]. Besides, ATutor has developed a chat, Achat[17] , to solve some technological aspects for users who use assistive technologies and provides functionalities such as: specify the auto refreshing time, refresh messages manually, message's order, show last messages and provides a mechanism to upload the last conversations. Besides, Blackboard improved the accessibility of its chat creating an Accessible Chat alternative, using the Java Accessibility API which allows adding shortcuts and better support to screen readers [AccessIT, 2002]. However, it specifies that this does not provide "equal access" to all users [Blackboard, 2012] although some accessibility guidelines as Section 508 Act or WCAG are accomplished by the tool. Another accessible example is the chat provided by eCollege[18] which accomplishes the Section 508 Act too and provides a Java applet and an HTML-based chat option which are usable with assistive technologies [AccessIT, 2002]

Considering chats in mobile devices, AssistiveChat [19] provides new features for people with speech disabilities. For instance, the chat suggests words to the user, there are some sentences predefined and it converts the text-to-speech. Furthermore, [Kadirire, 2007] IM prototype specifies the features that a chat for mobile devices should have such as: presence awareness, asynchronous chat or multi-user chat. However, it does not specify anything related to accessibility. Moreover, Sánchez and Aguayo [Sánchez and Aguayo, 2007] developed a chat specific for blind users. It introduces some features to improve their way of writing and allow them to communicate in an asynchronous way. Besides, screen reader users can use it and they should not encounter problems. The PictoChat [Royle et al., 2010] uses a chat in a learning environment using a Nintendo DS console. This chat allows users to write or draw on the screen and communicate with their classmates, but it does not consider accessibility in its implementation. Another example of accessible chat application for mobile devices have been implemented by the CESyA group and UC3M [CESYA, 2016]. This chat helps people with sensory problems to communicate. It includes different accessibility improvements such as: Zoom, Text-to-speech, Speech-to-text, High contrast and Personalisation.

From the point of view of accessibility in mobile devices for learning environments, AMobile is an online accessible m-CSCL chat [Arrigo et al., 2008] [Arrigo and Ciprì, 2010]. Specially, it provides specific features for visually impaired students to allow them to use this tool. Another example of chat for learning is TouchChat HD-AAC . This chat does not accomplish any

[17]Achat. http://atutor.ca/achat/
[18]Ecollege. http://www.ecollege.com/
[19]Assistive Chat. http://www.assistiveapps.com

accessibility standard or guideline. However, it adds some features to improve the chat such as: large letters, clean display and messages are spoken with a built-in voice synthesizer or by playing recorded message. This chat is recommended for people with problems with speech (E.g.: Autism, Down Syndrome, ALS, Apraxia or stroke).

Next, Tables 2.5, 2.6 and 2.7 summarize the main characteristics of the chats mentioned previously. They specify for each chat if it is used in learning environments or not and if it has been designed for mobile devices or not. Moreover, the table indicates the environment for which the chat is designed; web or native. Furthermore, the accessibility problems that the chat pretends to solve, the disability in which the chat is focused and the standards and guidelines that accomplish.

Chat	Learn.	Mobile	Env.	Accessibility problems				Specific Disabilities	Stand. & Guid.
				Assistive Technology	**Flow and Rhythm**	**Technology used**	**Mobile Devices**		
iChat	✗	✗	W	?	?	?	?	?	?
Reef Chat	✗	✗	W	Live regions	✗	Text highlighting, contrast and font scaling.	✗	Visual	WAI ARIA/ WCAG 2.0
Google Talk	✗	✗	W	Live regions	✗	✗	✗	Visual	WAI ARIA
Moodle's Chat	✓	✓*	W	No frames, No Javascript	Specify the time to refresh	No Javascript	?	✗	✗
Atutor's Chat	✓	✗	W	Better support screen readers	Time to refresh, message sorting, chose only new messages, Short cuts	✗	?	✗	WCAG 2.0
Blackboards Chat	✓	✓	W	Better support screen readers	Short cuts	Java accessibility API	?	✗	WCAG 2.0
eCollege	✓	?	W	Better support assistive technology	✗	Java applet and html-based	✗	✗	Section 508

Table 2.5: Previous Accessible Chats I

Chat	Learn.	Mobile	Env.	Accessibility problems				Specific Disabilities	Stand. & Guid.
				Assistive Technology	Flow and Rhythm	Technology used	Mobile Devices		
Clap	✗	✗	W	✗	✗	✗	✗	Visual	WCAG 2.0
Alt. Met.Int.	✗	✗	W	✗	✗	✗	✗	Older Users	✗
Messenger Visual	✓	✗	D	✗	Use pictograms	✗	✗	Cognitive	✗
AMobile	✓	✓	W	Support screen readers	✗	✗	?	Visual	WCAG 1.0
AssistiveChat	✗	✓	D	✗	Suggest words and sentences ; text to speech	✗	✗	Speech	✗
PictoChat	✓	✓	D	✗	Write or draw	✗	✗	Literacy and language development children	✗
IM prototype	✓	✓	W	✗	✗	✗	✗	✗	✗
BIRC	✗	✗	D	Braille Displays and speech synthesizer	✗	✗	✗	Visual	✗

Table 2.6: Previous Accessible Chats II

Chat	Learn.	Mobile	Env.	Accessibility problems				Specific Disabilities	Stand. & Guid.
				Assistive Technology	**Flow and Rhythm**	**Technology used**	**Mobile Devices**		
TouchChat HD AAC	✓	✓	D	Word, Phrases and Messages are spoken with a built-in voice synthesizer or by playing recorded message	✗	✗	Clear the display, large letters	Speech problems (E.g: Autism, Down Syndrome, ALS, Apraxia or stroke)	✗
Messenger for blind	✗	✓	D	Compatibility with the screen reader	✗	✗	Improve the keyboard to write quickly. Asynchronous way.	Blind	✗
Parachat	✗	✓	W	Custom words, custom fonts	✗	Accessible Java	?	✗	?
Accessible Chat Interface	✗	✗	W	Custom shortcuts to control messages to read	✓	WAI-ARIA, HTML	✗	Blind	✗
Blappy	✗	✓	D	Text-to-Voice and Voice-to-Text	✓	?	Text-to-Voice, Voice-to-text, Personalization, High contrast, Zoom	Visual and Hearing	✗

Table 2.7: Previous Accessible Chats III

Basing on the literature review, it can be concluded that most of the chats studied try to solve five different types of accessibility problems.

- **Technical barriers:** Solve accessibility problems related to technical barriers that users who use AT usually face [Thiessen and Chen, 2007] [Chen and Raman, 2008]
- **Refresh messages:** Provide mechanisms to control when messages are updated and shown. For example, chats like the provided by Moodle or Atutor, allow refreshing the messages or managing the way in which the messages are shown.
- **Technical problems:** Accessibility problems related to the technology are solved by chats like Reef Chat [Thiessen and Chen, 2007] or eCollege.
- **Problems of specific users:** Some of them try to help users with visual impairments [Thiessen and Chen, 2007], with speech and literacy problems [Royle et al., 2010] or for specific population - e.g. elderly people [Prior et al., 2008].
- **Comply with accessibility standards and guidelines:** Some of them pretend to comply with some standards and guidelines related to accessibility as WCAG 2.0 or Section 508.

Although some of them try to improve the user experience, e.g. Moodle or Atutor, they do not fully achieve it and most of them do not comply with accessibility standards and guidelines. Furthermore, they do not try to solve the accessibility problems that chats in mobile devices present. Considering all these gaps in previous chat applications, the main objective of this thesis is to improve the users' interaction of chats for m-learning environments and to provide the requirements that accessible chats should include in order to avoid accessibility problems that users face.

2.5. Chapter 2 Conclusions: Problem Description

Chats are commonly used in CSCL environments were students and teachers communicate with each other. Previous researchers made improvements in the accessibility of chats but there is not any chat which complies with all the standards and guidelines and which solves the accessibility problems of interaction.

Previous studies have tried to identify the accessibility problems that people face when they use chats. Besides, most of the previous researches are focused on chats for desktop computers, and they do not consider the problems that users could face in mobile devices. To the authors knowledge, there is not any study which is focused on the analysis of the accessibility problems that people with disabilities, elderly people or even people without any disability can experience in desktop and mobile chats. Thus, one of the goals of this thesis is to obtain the main accessibility problems that these groups of people can face in order to solve their main and common accessibility problems.

> **First goal: Identify Chat's accessibility barriers.** Elicit the main accessibility problems that people experience when using chat applications.

Different laws around the world protect students' rights in learning environments and ICTs - see Section . Moreover, there are specific laws which regulate that chat applications should be accessible. For example, the American CVAA law spcecifies that chats should be accessible for everybody. After reviewing the standards and guidelines related to accessibility, software and learning, it has been detected that there are many guidelines which specify developers

how to create software in an accessible way. Specifically, the GDALA guidelines specify how chats for CSCL should be created to be accessible. However, these guidelines are really general and are specific for desktop computers. There is not any guideline which specifies the main features that a chat for m-learning should have to be accessible. This thesis aims to provide the main accessibility and learning requirements that chats should include for accessible learning environments because there is a lack of support for designers and developers. To achieve it, standards and guidelines related to accessibility, mobile devices and learning are considered and taken into account to elicit the accessibility requirements that chat applications should include in m-learning environments. Besides, the necessities identified by real users were considered to elicit these requirements.

> **Second goal: Elicit requirements needed to create an accessible chat.** Specify the requirements that designers and developers need to consider to create accessible chat applications.

As it has been explained, there are previous examples of chats that consider accessibility. However, these solutions try to solve technological problems. For example, these chat applications focus on how to solve technical problems e.g. which HTML tags need to be used to show new messages for screen reader users. These previous solutions are not focused on improving the chats interaction. In the state of art research, it has been detected that one of the most common problems that people face is related to follow the *Flow and Rhythm* of the conversation which could affect people who are not able to write quickly or are not able to read the messages quickly. In addition, in this thesis, this problem is confirmed as a current problem for people with and without disabilities when using chat applications. This thesis aims to improve the interaction of m-learning chat applications and make them more accessible. Specifically, this thesis will focus on solving the *Flow and Rhythm* problem.

> **Third goal:Proposal to improve the chat interaction.** Design a solution to solve the *Flow and Rhythm* problem that people face when they interact with chat applications

To recapitulate, the thesis goals can be summarised in three main goals: (1) obtain the main accessibility problems that people face when they use chat applications in m-learning environments; (2) elicit requirements needed to create accessible chats for m-learning environments; (3) and provide a solution to solve the main accessibility problem that people face when using chat applications, the *Flow and rhythm* problem.

Chapter 3

Involving Users to Elicit Accessibility Barriers in Chat Applications

Previous researchers detected that many people face accessibility barriers when they use chat applications. Some of these problems are related to the devices people use. Others are specific to the technology used. However, there are still some open questions related to the main problems that people face when they interact with chat applications and the main groups of people who are affected by these problems.

In this chapter, Human Computer Interaction (HCI) and Software Engineering (SE) methods are combined to answer these questions and to obtain the main accessibility barriers that people face when they use chat applications in desktop computers and mobile devices.

The chapter is divided into different sections to summarise how the studies were conducted. Firstly, previous studies related to this project are analysed. Considering previous studies, the research questions for this chapter are formulated. Then, the studies conducted to obtain the main accessibility problems that people face are described. These studies include: an expert review to obtain the main accessibility problems that current chat applications have; identification of the main accessibility problems that people with disabilities, elderly people and young adults face when they use chat applications; and analysis and comparison of the obtained problems.

3.1. Influences from previous work

Due to advance in technology during the last decade, chat applications have been improved from the point of view of their designs, features and social acceptance. However, despite of these advances, chat applications still present serious accessibility barriers for many users.

With regard to the problem following the *Flow and Rhythm* of the conversation, some people could face barriers if they have problems writing quickly or if they have cognitive or learning disabilities [Madge et al., 2009]. Furthermore, people who have problems using keyboards are not able to use chat applications efficiently [Seffah et al., 2005]. Students with dyslexia might have communication problems when using chat applications because they could feel embarrassed or ashamed as they have some problems writing long sentences, reading sentences and writing without spelling errors and transposition-letters [Woodfine et al., 2008].

The use of chat applications in mobile devices could cause problems for people with disabilities as well as people without disabilities due to mobile device limitations [Yesilada et al., 2011]. For example, people with visual impairments might have problems reading text when the colour contrast ratio between background and foreground colours is not enough. People without visual impairments might experience the same problems when they are reading the text on their mobile device in a sunny environment [Calvo et al., 2014d].

Another problem is related to the use of assistive technologies. For instance, screen reader tools could restart announcing the full page when new content is shown, instead of reading only the new content [Hargis and Wilcox, 2008]. Furthermore, there are problems related to the technology used. For example, developers do not use CSS appropriately or they use Flash, Java or Javascript without following standards [Bere, 2012][Disabilities and Technology, 2012]. In addition, the use of AJAX technology in live regions could cause problems when the tool is not tagged properly [Kadirire, 2007].

Table 3.1 shows a summary of previous studies which main aim were to analyse the accessibility problems that people face when using chat applications in different environments.

Study	Learning	Mobile	Chat	Groups studied
[Madge et al., 2009]	Yes	No	Yes	People with learning and cognitive disabilities
[Woodfine et al., 2008]	Yes	No	Yes	People with dyslexia
[Yesilada et al., 2011]	No	Yes	No	People with and without disabilities
[Hargis and Wilcox, 2008] [Kadirire, 2007] [Bere, 2012] [Disabilities and Technology, 2012]	No	Yes	No	People with and without disabilities
Ph.D. Contributions. Barriers	Yes	Yes	Yes	People with and without disabilities. Elderly people

Table 3.1: Previous Studies Related to Accessibility in Chat Applications for m-learning Environments

Previous studies have demonstrated that chat applications include accessibility barriers or have identified the accessibility barriers that mobile devices provoke. None of the previous studies have analysed the learning characteristics that chat applications should include to support and improve learning and to solve the limitations that these tools have for learning environments. In addition, previous researches have evaluated the accessibility of LCMSs tools for desktop environments and have identified accessibility barriers [Calvo et al., 2014b] [Carter et al., 2013]. Others have focused on the accessibility evaluation of non-learning chat applications for mobile devices [Calvo et al., 2014a]. However, none of them have evaluated the accessibility of m-learning chat applications or have analysed the learning characteristics which are useful for m-learning environments. Besides, previous studies have focused on specific disabilities but have not considered different disabilities and group populations.

3.2. Research goals

Basing on previous studies and influences, the main aim of this research is to answer the following research questions formulated in this chapter.

- RQ1: Which are the main learning features that m-learning chat applications include?
- RQ2: Which are the main accessibility problems that current m-learning chat applications have according to expert reviews?
- RQ3: Which are the main groups of people affected by the accessibility barriers and the problems they face?
- RQ4: Which are the main problems that people with disabilities face?
- RQ5: Which are the main problems that elderly people face?
- RQ6: Which are the main problems that young adults face?

To answer these research questions, previous competitors have been analysed in order to identify the accessibility barriers they present. Besides, fictitious personas have been created and finally, real users with and without disabilities as well as elderly people have participated in this research - see Figure 3.1.

Figure 3.1: Elicit Accessibility Barriers

Different HCI and SE methods were combined. There are some methods which are specific to one discipline (HCI or SE), others are used in both disciplines, and sometimes although they are used in both disciplines, they are used in different ways [Seffah et al., 2005]. Previous studies have demonstrated that SE and HCI must be combined in all phases of the project because there is a lack of coordination between SE and HCI specialists [Mayhew, 1999]. In this research work, different studies combined HCI [Maguire, 2001] and SE [Escalona and Koch, 2004] methods. This research combined these methods to obtain the main accessibility barriers that a chat in m-learning could have. Table 3.2 summarises the methods used during the research work. Next, the studies carried out during the research work are detailed and Annexe A details and justifies why these SE and HCI methods have been used for the study.

Method	HCI	SE
Context of use	Yes	No
Identify Stakeholders	Yes	No
Stakeholder Analysis	Yes	No
Existing systems/ competitors analysis	Yes	No
Standards and Guidelines	Yes	Yes
Personas	Yes	No
Scenarios	Yes	Yes
Personal and group Interviews	Yes	Yes
Survey / Questionnaires	Yes	Yes
Observation	Yes	No

Table 3.2: Summary of SE and HCI Methods Used in the Research

3.3. Expert accessibility evaluation: Study of accessibility and learning barriers in m-learning chat applications

In order to understand the problems that people face when they use chat applications in m-learning environments, an expert review was conducted. This provided us a general idea of the main problems that people could face.

3.3.1. Research questions

This research aims to answer two of the questions formulated in this chapter:

- RQ1: Which are the main learning features that m-learning chat applications include?
- RQ2: Which are the main accessibility problems that existing m-learning chat applications have according to expert reviews?

To achieve it, the context and stakeholders of this research are established. Then, the most used mobile chat applications were selected in order to obtain the main problems that people could face according to existing standards and guidelines and to obtain the main learning features which are included in these m-learning tools. The method used in this research was explained in detail in the following section.

3.3.2. Method

The method used to carry out this research is explained in this section. Next subsections specify the participants, apparatus, design, procedure, data collected and data analysis for the study.

Participants A total of two accessibility evaluators carried out these evaluations. These experts have conducted previous accessibility reviews following WCAG 2.0 guidelines [Calvo et al., 2014b] and learning reviews following UDL guidelines [Calvo et al., 2014a].

Apparatus The selection of the most used non-commercial LCMSs was based on the study provided by Capterra [Capterra, 2014]. The three free LCMSs which had the greatest number of users were: Moodle, Edmodo and Instructure.

All of these LCMSs include a chat application to allow communication between students and teachers through the learning environment. Also, these LCMSs were selected because

they were web based and because they could be used in mobile devices. It is remarkable that these LCMSs provide mobile native versions of their chat application, but this study is focused only on the web version of the chat application. The selected chat applications were analysed in their last available versions in September of 2014: Moodle [1] 2.7, Backchannel [2] chat application of Edmodo [3] and Canvas chat application of Instructure. These tools were evaluated in different devices: tablet and smartphone. The operating systems of these devices were Android v 4.4.2 and 4.1.2, and the website was displayed in Chrome v. 38.0.2125.111 and Firefox 32.0.3 browsers on both devices.

In addition, two different guidelines were used in this research. These guidelines were: UDL guidelines [CAST, 2011] and the WCAG 2.0 [W3C, 2008b] guidelines.

Design The Domain and the Stakeholders who will participate in this research are established in order to mark the limits for the Ph.D.

After that, the accessibility and learning comparison of the selected chat applications was analysed by the experts. In this research, every participant conducted the evaluation of every chat application interface from two perspectives: learning (based on UDL guidelines [CAST, 2011]) and accessibility (based on WCAG 2.0 [W3C, 2008b]).

In an attempt to integrate these two perspectives, the present study follows the evaluation method detailed in the following sub-section.

Procedure The participants need to establish the domain of the research. In this case, the devices, environment and limits of the study needed to be determined. In addition, the stakeholders who participate in this research are defined. See Figure 3.2 for more information about how the study was divided.

Figure 3.2: Procedure - Study Framework and Competitors Analysis

Learning features basing on UDL guidelines The main objective of the research study was to obtain the features and functionalities that chat applications for m-learning environments include from the point of view of UDL guidelines. It is a heuristic evaluation where the evaluators considered which features were included in these learning chat applications.

Firstly, UDL guidelines were studied in order to identify which guidelines might be applied for chat applications or not. Each expert made notes about which guidelines might be applicable. After that, experts pooled their opinions and compared their results. In case one guideline was selected as applicable by one expert and non-applicable by another expert, they had to make a common decision and decide if the guideline might be applicable or not. The non-applicable guidelines are described in Table 3.3 which specifies why the guideline is not applicable for chat applications.

[1] Moodle. https://moodle.org/
[2] Backchannel chat in Edmodo. http://backchannelchat.com/pages/Edmodo
[3] Canvas chat of Instructure. https://canvas.instructure.com/login

Guid. Num.	Guideline	Justification for making the guideline as non-applicable
4.2	Optimize access to tools and assistive technologies.	This will be evaluated in detail in the accessibility evaluation.
5.1	Use multiple media for communication.	Chat applications are communicative tools by itself.
6.1	Guide appropriate goal setting.	Chat applications are not used for this purpose.
8.2	Vary demands and resources to optimise challenge.	The degree of difficulty in the conversation will be similar to all participants.
8.3	Foster collaboration and community.	Chat tools help users to communicate.
8.4	Increase mastery-oriented feedback.	Users will not get learning feedback while they are learning using chat applications.
9.1, 9.2, 9.3	Provide options for self-regulation.	The chat application will not make students develop self-assessment or development.

Table 3.3: Non-applicable UDL Guidelines

After selecting the guidelines, every expert picked the features which could make a benefit for learning basing on the UDL guidelines.

Accessibility evaluation basing on WCAG 2.0 guidelines The accessibility evaluation consisted of evaluating the accessibility of the chat application interface from the point of view of WCAG 2.0. These guidelines have been chosen because they are a standard [ISO, 2012] and because they can be applied even for non-web technologies [W3C, 2013b].

In order to perform these two types of evaluations, preliminary steps described by the W3C evaluation methodology [W3C, 2014b] and other studies [Abou-Zahra, 2008] were taken:

- **Selection of tasks to be evaluated:** The tasks selected for this study were those whose execution was identified as necessary for the creation and maintenance of a chat application conversation between students and teachers as well as the learning features that the evaluators identified in the previous phase.
- **Selection of priority level:** WCAG 2.0 guidelines are divided into four different parts: Perceivable, Operable, Understandable and Robust. Additionally, each part of WCAG 2.0 is further classified into layers of guidance, that is, principles, guidelines and Success Criteria (SC). A principle is divided into guidelines providing basic aims to follow in the development of accessible tools. The guidelines are then divided into SC which are testable and can be catalogued by conformance levels A, AA or AAA, where AAA is the highest and A the lowest. In this research, the priority level established was the AA priority level because it is the minimum level of accessibility that chat applications should comply according to the Spanish Law [Spain, 2013].
- **Selection of automatic and semiautomatic tools for the evaluation:** Any expert evaluation may be conducted automatically, semi-automatically or manually [W3C, 2012]. Currently, there are many tools to evaluate the accessibility of the websites; however, for this study it was necessary to select some of them which could help participants

in the evaluation. For this evaluation, Wave [4], Juicy Studio [5], Web developer Mozilla [6] were used.

Data collected The potential stakeholders and the domain was defined by each expert before it was agreed by both of them.

After each expert evaluation was conducted, a list of learning features and accessibility barriers was provided. These lists were analysed and agreed by the experts in order to make a consensus.

Data analysis The environments and devices where the Ph.D could be applied were analysed in order to provide a limit. Considering the environments and devices as well as the stakeholders suggested by the participants, a decision was agreed between both experts.

With regard to the learning guidelines, the list of UDL guidelines was analysed by each expert and each expert selected the guidelines applicable or not and the results were compared with the rest of the participants. After selecting the guidelines that can be applicable or not, every expert picked the features which could make a benefit for the learning basing on the UDL guidelines. Then, experts compared these features in order to agree if these features were beneficial for learning environments. If there was any difference in their opinions, they made a common decision.

Each participant conducted an expert review as it was specified previously. After the review was conducted, experts compared their results and in case any difference in their results was found, a consensus was taken. Finally, the list of accessibility problems found in the review was analysed and confirmed.

3.3.3. Results

Domain and Stakeholders There are different tools used by teachers and administrators to manage and create learning environments. One of these tools is named Learning Management System (LMS). According to [Avgeriou et al., 2003], a LMS is defined as:

> [...] a collection of eLearning tools available through a shared administrative interface. A learning management system can be thought of as the platform in which online courses or online components of courses are assembled and used from.[...]

LMSs are divided into different modules which are needed to support a course. Specifically in mobile LMSs, there is a study provided by [Jin, 2009] which specifies the main modules that a mobile LMS should have. This dissertation was based on the Jin's framework which specifies different modules for a mobile LMS. A collaborative module is added to this framework [Calvo et al., 2011], which is considered an important module in learning environments nowadays. The collaborative module supports the communication and collaboration between students and teachers.

Moreover, there are different authors who specify the main components of a CSCL module [Kantel et al., 2010] [Martínez, 2005] [IMS, 2007] and a summary of the main CSCL tools are classified into asynchronous and synchronous tools in Table 2.2. Moreover, it is important to emphasise that these are some of the most used, synchronous tools that exist nowadays, but

[4]Wave. http://wave.webaim.org/
[5]Jucy studio. http://juicystudio.com/services.php
[6]Web developer Add-on Mozilla https://addons.mozilla.org/es/firefox/addon/web-developer/

other tools will be created in the future. Furthermore, this study is based on the IMS [IMS, 2007] specification which specifies how to create CSCL tools to be accessible. Moreover, this specification shows synchronous tools should be: chat, audio-conferencing, video-conferencing, whiteboard and multiuser domain object oriented environments. Figure 3.3 shows the framework which is considered in this study. This framework is an improvement of the Jins business logic layer of a mobile LMS which includes a collaborative module with the synchronous tools specified by IMS.

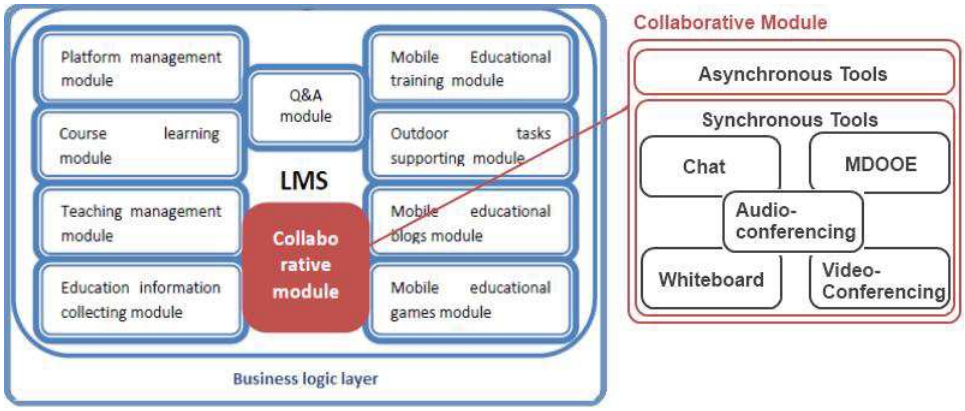

Figure 3.3: Chat's Framework: Based on Jin's Framework and IMS Synchronous Tools

This dissertation is focused on one of the synchronous tools specified in the collaborative module of the m-learning system: the chat application. Considering the classification of the CSCL tools shown on Table 2.2, this thesis is centred on the first generation and synchronous tool, chat application.

There are many definitions of chat applications; however, there are not many definitions which include accessibility on it. The research work [AccessIT, 2004] defines a chat and the accessibility problems that it usually presents.

> [...] chat is a synchronous tool, which allows several users to communicate via typed text in real time. [...] There are two basic issues related to accessibility of chat applications: fast-paced conversation and the need to track multiple simultaneous threads present problems for users with difficulties reading, composing, or typing under time constraints; and, confusing interfaces and inconsistent navigation can be difficult and frustrating for users with cognitive or mobility disabilities.[...]

These barriers are mainly interaction problems that people have to face when they interact with a chat in desktop computers. However, mobile devices could increase these problems because of the device restrictions and the situations where these devices are used [Yesilada, 2013].

On the other hand, although chat applications were created to send synchronous information, it is important to underline that a chat application can be used also as an asynchronous tool. It means that students can write messages to their contacts when they are not connected but they will read the messages later. Thus, emitter and receptor do not need to be connected at the same time. In order to establish a domain for this research, this research work is focused on studying the synchronous dimensions of chat applications because this way of communication could have more accessibility problems due to the real time restrictions [AccessIT, 2004].

Furthermore, the chat application is enshrined in the two types of interaction: learner and instructor and learner and learner - see Figure 3.4. Thus, the student can interact with

other students or teachers and they could execute the same functionalities. All of them are the stakeholders of the application and teachers are not conducting the way of learning; they are as other learners because they can learn from the students. If teachers conducted the conversation in order to improve the way of learning, another study should be carried out to cover additional functionalities which could improve learning.

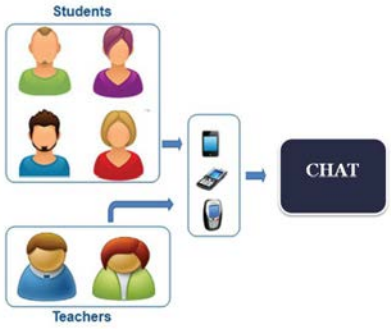

Figure 3.4: m-learning Chat Applications' Stakeholders

To summarise, the development of the accessible chat application is enshrined in an LMS environment and inside a CSCL module which can be used in different mobile devices. Furthermore, students and teachers can interact with each other and can exchange their experiences and resources with their classmates and their teachers in the same way synchronously. Thus, there are not differences in the functionalities that both groups of people could execute. Figure 3.5 shows this context.

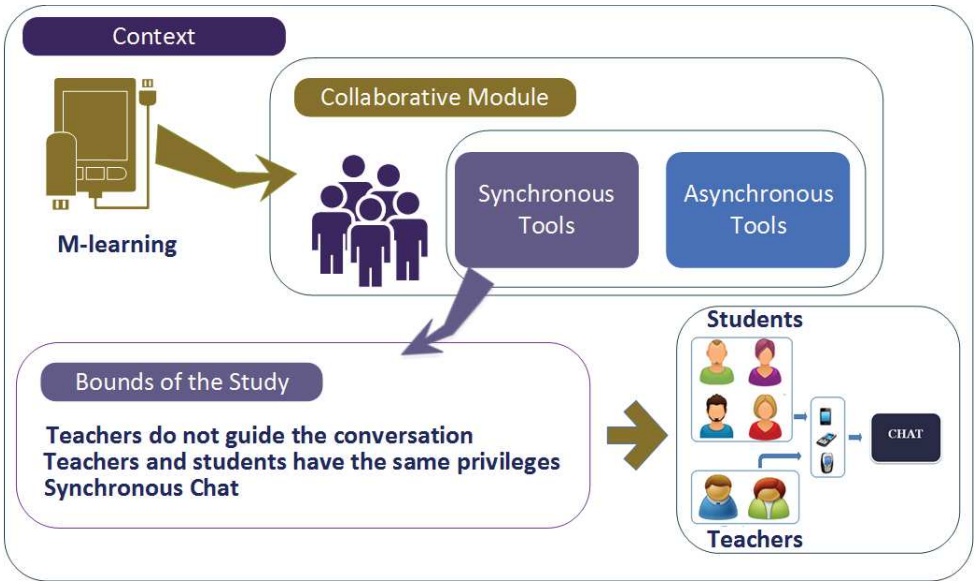

Figure 3.5: Summary of Chat Context

Learning Features The results of this sub-section were obtained from the manual expert evaluation of Moodles Chat Application, Edmodos Chat Application (Backchannel) and Instructures Chat Application (Canvas) with respect to UDL guidelines. The findings - Table 3.4 - show that analysed chat applications have more and different built-in features than non-m-learning chat applications.

Group	Functionality	Description
Interface	Banner image (UDL 1.1)	Add banner images to customise the interface.
Users	Roles (UDL 2.1)	Teachers and students are identified with different symbols.
Users	Number of students (UDL 7.1)	Invite new users to the conversation.
Users	Change usernames (UDL 1.1)	The name of the user could be changed.
Messages	New messages notification (UDL 1.3/1.2)	Show a sound when new messages are received.
Messages	Number of messages (UDL 4.1 /6.2)	The system shows only the new messages.
Messages	Show new messages (UDL 4.1 /6.2)	The website is refreshed to show the last messages.
Messages	Away auto response (UDL 4.1)	Automatically send auto response message when you are away.
Learning	Rate messages (UDL 3.2/3.3 / 8.1)	Allow users vote which messages are more important.
Learning	Pin messages (UDL 3.2/3.3 / 8.1)	Detail important messages.
Learning	Transcripts (UDL 3.4 / 6.3)	Download the conversation to a text file.
Learning	Send files (UDL 6.5)	Send files between students and teachers.
Learning	Hide students name (UDL 7.2)	Teachers could show or hide students name.
Learning	Moderate messages (UDL 2.2 / 7.3)	Teachers can check every message before showing them to the rest of participants.
Learning	Deleted messages (UDL 6.3)	Keep deleted messages to look up them in the future.
Learning	Read only (UDL 7.1)	Students can watch the messages but cannot participate.
Learning	Previous conversations (UDL 6.3)	Save previous conversations for the future.
Learning	Statistics (UDL 6.4)	Show the number of messages sent per participant.
Learning	Profanity filter (UDL 7.3)	Allow removing nasty words.

Table 3.4: Learning Features Basing on UDL

Chat Application Accessibility Problems After performing the accessibility evaluation, different accessibility barriers were discovered in the analysed chat applications.

This accessibility evaluation was performed through the chat application interface of the website exclusively. Thus, it is necessary to remark that there could be additional problems in the LCMS interface which could be a handicap for users.

In this section those obtained results are detailed and are grouped through the WCAG principles: Perceivable, Operable, Understandable and Robust. The results obtained in this evaluation are presented as the number of errors per Success Criteria (SC) and chat. Every

section includes a Figure which shows the number of times each SC was not fulfilled.

Perceivable With respect to perceivable principle WCAG 2.0 specifying that information and user interface components must be presentable to users in ways they can perceive. Evaluation results demonstrate that chat applications usually does not satisfy 1.1.1, 1.3.3, 1.4.1 and 1.4.3 WCAG - see Figure 3.6. However, it is important to emphasise that most of the SC related to the perceivable principle are related to video and audio features - WCAG Guideline 1.2 - and they are considered out of the scope due to chat applications do not include videos or audios.

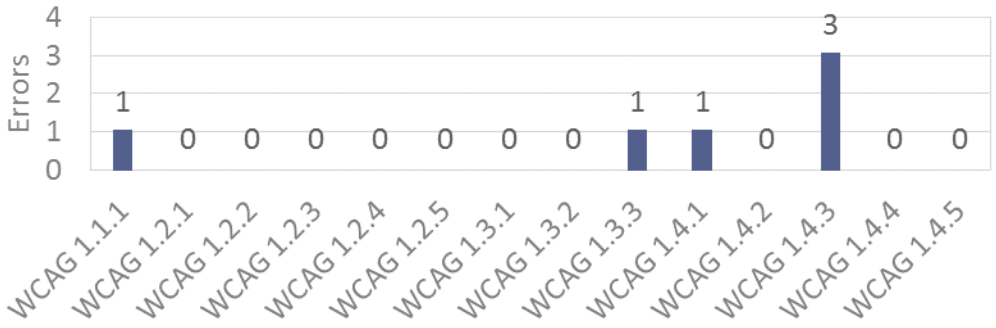

Figure 3.6: Accessibility Evaluation. WCAG 2.0. Perceivable Errors

The first guideline 1.1 of WCAG 2.0, specifies that text alternatives must be provided. This guideline is divided into one SC, WCAG 1.1.1, which details text alternative must be provided for every non-text content. Canvas does not include alternative text descriptions to some images. This constitutes, of course, an error of great importance.

According to WCAG 1.3 Guideline, content can be presented in different ways. This principle is divided into three SCs. However, this guideline was not fulfilled by the analysed chat applications either, since the tools did not nest headings correctly with HTML tags, as specified by the WCAG 1.3.1 SC. Screen reader users might have problems to participate in the chat conversation as they use headings to navigate the page. For instance, Moodle included an empty heading in the website which might confuse people.

Besides, there are input text fields which did not have the HTML label associated programatically. For example, Canvas did not have associated any label to the message input text element. As a result, screen reader users might not use these elements.

The use of sensory characteristics e.g. use of images to convey information - without the use of textual elements could affect people with visual impairments or knowledge disabilities because they might not understand some information (WCAG 1.3.3 SC). For instance, Edmodo used an image to represent students and another image to represent teachers. This is really useful from the point of view of learning because students will differentiate quickly each participant. However, this image did not include a HTML attribute with its alternative text and screen reader users will not be able to differentiate teachers and students.

Regarding guideline 1.4, the content must be distinguishable. However, Edmodo identified teachers using green colour and students using red colour (WCAG 1.4.1 SC). Besides, analysed chat applications did not have enough colour contrast ratio between background and foreground (WCAG 1.4.3 SC).

Operable Operable principle specifies that user interface components and navigation must be operable. This principle was also not fulfilled by any of the analysed chat applications. Next Figure 3.7 shows a summary of the number of SCs not satisfied.

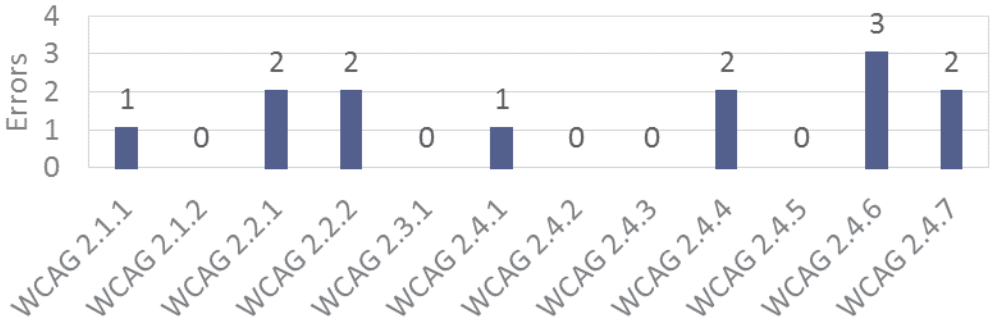

Figure 3.7: Accessibility Evaluation. WCAG 2.0. Operable Errors

With regard to the guideline 2.1, Moodle and Canvas chat applications are accessible using the keyboard. In contrast, Edmodo chat is not fully operable using the keyboard because some components e.g. Buttons cannot be pressed using the keyboard (WCAG 2.1.1 SC). Considering guideline 2.2, users must have enough time to read and use the content. The WCAG 2.2.1 SC indicates any time must be adjustable by the user and the SC WCAG 2.2.2 specifies any moving, blinking, scrolling or auto-updating information must be controllable by the user.

Usually, chats show new messages automatically every specific time established. As a result, the guidelines WCAG 2.2.1 and 2.2.2 are not fulfilled in the majority of commercial chat applications. In m-learning, Edmodo and Canvas do not allow students and teachers to control the period of time to show new messages or control reception of new messages. In contrast, Moodle does not show new messages, if the user does not press a button to refresh messages. Thus, Moodle fulfils the WCAG 2.2.1 and 2.2.2 SCs.

Concerning guideline 2.4 of WCAG 2.0 guidelines states that web tools should provide ways to help users to navigate, find content, and determine where they are. Nevertheless, this help is not completely provided in Edmodo. Since Moodle and Canvas allow students to by-pass blocks of content, Edmodo does not include any bypass link (WCAG 2.4.1 SC). Moreover, the purpose of links is not clear in Edmodo or Canvas which do not follow the SC 2.4.4. For instance, Canvas includes two links with the same text but different purpose.

Finally, the SC 2.4.7 is not fulfilled by Edmodo and Canvas because the focus is not always visible around all the interactive elements.

Understandable Concerning Understandable WCAG 2.0 principle related to the creation of Understandable content, as the following paragraphs will show, there are certain SCs not satisfied by the analysed chat applications. Figure 3.8 represents the number of SCs not fulfilled by the chat applications.

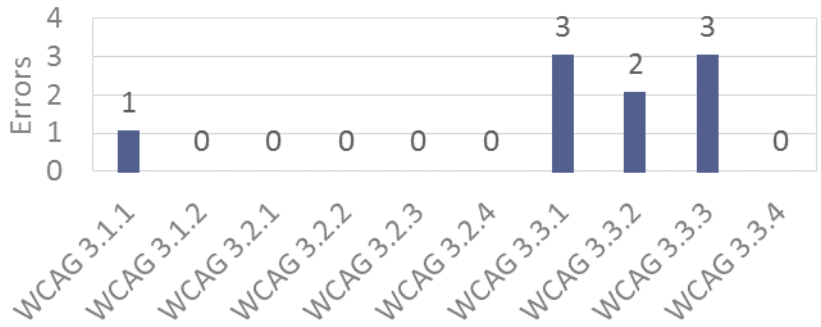

Figure 3.8: Accessibility Evaluation. WCAG 2.0. Understandable Errors

According to SC 3.1.1 of WCAG 2.0 states that content should be readable and understandable. Nevertheless, Edmodo does not detail the language of the website.

Regarding guideline 3.3 indicating that web pages must help users avoid and correct mistakes, none of the chats fulfil this guideline. For instance, users can press the Send button and the system avoids sending blank messages. However, chat applications do not show any message which informs an error occurred (WCAG 2.0 3.3.1 and 3.3.3 SCs). Edmodo changes the colour around the input text field but this does not fulfil the WCAG 1.4.1 SC because it uses colour to convey information. Moreover, WCAG 2.0 3.3.2 SC specifies that labels and instructions should be included when content requires user input. Edmodo does not provide any title when users hover the hand with the thumb finger up.

Robust Finally, the last principle, Robust, details content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies. The chat applications do not follow the SCs from guideline 4.1 - see Figure 3.9.

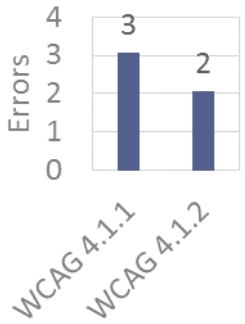

Figure 3.9: Accessibility Evaluation. WCAG 2.0. Robust Errors

Chat applications do not follow completely HTML and CSS specifications. These tools were analysed using the official W3C check validator and there were some code errors which could provoke problems for user agents (WCAG 2.0 4.1.1 SC). Furthermore, although Canvas and Moodle include roles in the website to help users identify the content of the website, these tools do not associate a HTML label or use WAI-ARIA to identify the label of their input text fields (WCAG 2.0 4.1.2 SC).

3.3.4. Discussion

The study was enshrined in a chat application which is included in a mobile LCMS. Students and teachers could communicate using this application in order to discuss information which is not clear in the class.

Learning features: The first research question addressed in this study was:

- RQ1: Which are the main learning features that m-learning chat applications include?

This chat application should include specific learning features which will be useful for students and teachers to improve learning. Basing on the learning features that the previous analysed chat applications include from the point of view of UDL guidelines, this section details which learning problems explained previously will be solved using these learning features.

Feedback is important for students in order to engage them in the conversation. Two learning features: *Rate messages feature* and *Pin messages feature* could solve this issue because students would get feedback about the messages. Some messages will be more important than others; thus, students and teacher could rate messages and could pin important messages to be shown at the top. Furthermore, some teachers might not be available in specific moments and teacher would like to receive feedback from students which explains their current situation. As a result, features to specify users statuses might be important *Away auto-response feature*. In addition, teacher messages might be more important than student messages and as a result, students might pay more attention to teachers messages [Bonk et al., 2002]. Distinguish students messages from teachers messages *Roles feature* is important for students in order to improve their learning.

The information sent in these learning conversations might affect students. If too many messages are sent at the same time, students could feel overwhelmed and they could prefer asynchronous communication tools [Noll et al., 2010]. Mechanisms to control this reception of messages could be included to improve learning. For example, users could receive notifications about new messages, control the number of messages shown on the screen in order to not have too much information on the screen, or allow users control when new messages are shown *New messages notification feature*, *Number of messages feature* and *Show new messages feature*. When the conversation has finished, these logs could be used for learning and students might use them as class notes [Mak and Chui, 2015]. As a result, it is important to provide features for students to get this information. For instance, users could download transcripts, access to previous conversations or have access to delete messages *Transcript feature* , *Deleted messages feature* and *Previous conversations feature*.

According to previous researches, the number of students who participate in collaborative environments might affect students participation and interaction [AbuSeileek, 2012]. Teachers should control the number of participants per conversation *Number of students feature* - and the participation will not be affected. Shy students might not participate in the conversation because they might not feel comfortable [Xie, 2008]. As a result, students might get a benefit of features to control users names or to hide their names *Hide students name feature* and *Change users name feature*. Furthermore, teachers sometimes do not need interruptions while they are explaining something using chat applications [Ene et al., 2005]. To support it, a feature could help teachers to control students participation *Read only feature*. As a result, students will not be allowed to send messages while the teacher activates this feature.

Apart from previous cited features which might solve previous problems detected by other researches, there are other features that will help users in learning environments. Teachers could evaluate the participation that students have when they interacted in a conversation. Thus, it will be useful and quick for teachers to access student's participation statistics *Statistics feature*. Furthermore, in order to engage students in the conversation, the application interface might be improved. For instance, banner images might be added *Banner image feature*. In addition, textual information might be complemented using additional information as files which explain better the information exchanged through the messages *Send files feature*.

Accessibility features: Considering the second research question to be addressed in this study - RQ2: Which are the main accessibility problems that existing m-learning chat applications have according to experts reviews? - a list of accessibility problems that people could face is obtained.

Chat applications should be accessible. As a result, students could use them without facing accessibility barriers. The following recommendations aim to remove previous barriers.

The interface must be adapted to different viewports. Nowadays, students use many devices to access learning environments. As a result, the interface must be responsive. To fulfil it, web standards should be followed. Besides, interfaces must not rely on one way of interaction. Users could interact with mobile systems using their fingers, a tactile pen, a wireless keyboard or their own voice. Consequently, the interface must be controllable using all possible ways of interaction.

Students and teachers might commit errors when they interact with chat applications. Thus, it is important to control all possible errors that they could commit. For example, before deleting messages, users should be asked to confirm it. Some chat applications might use shapes and colours to improve the interface. However, the use of these shapes and colours should not be used to convey information. These methods must be combined with other cues to not discriminate users with visual impairments - e.g. colour blindness.

Every interactive element must describe properly their purpose for assistive technology users. Besides, links must provide a description of their purpose and must be unique in the website.

Finally, different ways of navigation must be included in the chat interface in order to help users access to the main content quickly.

3.4. Groups Affected

Experts and users must be taken into account to obtain accessibility barriers because expert reviews could not be enough to obtain the problems that people face [Henry, 2007]. People can experience other problems; so, it is necessary to involve users in the research. In this study, fictitious people - or *Personas* - are used to understand the problems that real people face when they use these chat applications.

3.4.1. Research Questions

This study aims to obtain the main groups of people who could be affected by accessibility problems in m-learning chat applications. Thus, the research question is:

- RQ3: Which are the main groups of people affected by the accessibility barriers and the problems they face?

This study aims to get a general idea of the problems that people face when they use chat applications in m-learning environments. Next section explains the method followed in this study to address this research question.

3.4.2. Method

This second study aims to use HCI methods (*Personas* and Scenarios) to obtain the groups of people who could have more accessibility problems when they are using chat applications in m-learning environments.

Participants Three experts have collaborated to design the *Personas* and scenarios and obtain the main accessibility problems that people could face when they interact with these chat applications in mobile learning environments.

Apparatus Previous studies which specify the main characteristics of users as well as the previous study described in the previous section, are considered to specify the scenarios and *Personas* taken into account in this study.

Design The study is divided into different steps to identify the main problems that people face when they use chat applications in mobile devices.

The *Personas* method is used in HCI discipline to understand group users‘ behaviours in a specific environment. *Personas* are not real people, but they represent groups of real people who share behaviours and motivations when using a particular product [Cooper et al., 2012]. The characteristics that *Personas* should have are identified as well as the values and ranges for each characteristic.

Considering these characteristics and values, some *Personas* are defined. These *Personas* reflect how users of chat applications could be. In order to understand user's behaviours and problems, a list of scenarios was designed. These scenarios include the most common tasks that people can execute when they interact with chat applications in mobile learning environments.

Procedure This study combines *Personas* and *Scenarios* methods in order to obtain the list of problems that people face when they use these applications. Figure 3.10 specifies the procedure followed in this study.

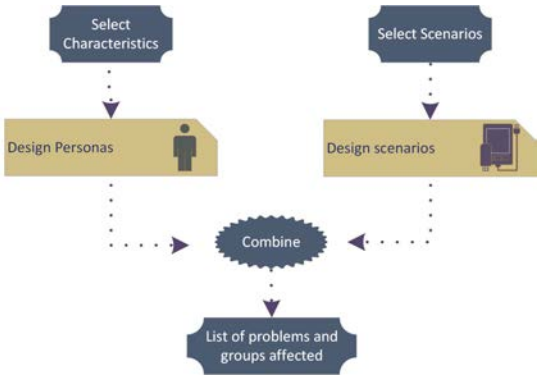

Figure 3.10: HCI Methods Used: Personas and Scenarios

Each user has its own characteristics and each user executes each task depending on his abilities or disabilities, experience, age, etc. [Henry, 2007]. Extrapolating this study to a mobile chat application, people who use a chat application in a mobile device can have the following characteristics: Kind of mobile device, Browser, Physical disabilities, Visual disabilities, Auditory disabilities, Cognitive and neurological disabilities, Environment, Mobile and Web expertise, Assistive SW and chat expertise, Age, Sex, Job, Native Speaker, Speech Disability, Frequency of use, Task Knowledge, Culture and Place of birth.

Some of these characteristics can be grouped in user profiles in order to structure the study. Dealing with SW accessibility, the **age characteristic** can be related to visual or sensory disabilities as well as IT expertise (Mobile, Web or Chat expertise) because some researchers have demonstrated that older people have declined their perceptual capabilities as the years gone by [Richardson et al., 2011]. Moreover, older people are not used to use new technologies. Sometimes they are worried about breaking or deleting something or they feel confused when an error message is showed [Hanson, 2009] [Arch et al., 2009]. Furthermore, the **nationality** can influence in the use of m-learning chat applications. For example, if a person were born abroad, the native language and culture could be different. Then, this person could have problems to understand tasks or conversations or could not understand some icons [Pappachan and Ziefle, 2008]. Furthermore, the **educational level** can be a handicap to execute a task because the person could not be able to comprehend the main tasks. This person could have the same problems as a person with learning disabilities or a person with another native language.

The **environment characteristic** can be similar to some disabilities. Depending on the place where the user is using the chat application, the user could have more or fewer problems and can have a "situational disability" [Hannukainen and Holtta-Otto, 2006]. For instance, if the user is sending a message while he is driving (Hands-free environment), the user could have the same problems as a person with visual impairments [Schildbach and Rukzio, 2010] [Hoggan et al., 2008] or mobility problems [Vogel and Baudisch, 2007]. Besides, people, who are in noisy environments, can have the same problems as people with auditory impairments because people could not listen audio because of the noise [Hannukainen and Holtta-Otto, 2006].

Depending on the **job** of the person, they can have more or less problems to complete a task. If the person is an ICTs professional or works with computers every day, this person could have fewer difficulties to understand some tasks because he is familiar with ICTs. On the other hand, if a person does not use computers or any ICTs environment in his job, this person could have more problems completing the tasks because of his expertise level using chat applications.

The **kind of mobile device** can difficult the execution of a task because of the mobile limitations. For instance, if a person uses a mobile with tactile buttons, they could face the *thumb size problem* because of the small keys. Besides, if the screen of the mobile is not big enough, the user could have the same problems as if tehy had motor or visual impairments[Yesilada, 2013].

Basing on these similarities, each *Persona* has to be created considering the following characteristics: speech disability, visual disabilities, physical disability, hearing disability, cognitive and neural disability, mobile expertise, web expertise, assistive software expertise, chat expertise, age, sex, native speaker and place of birth. Table 3.5 shows the main characteristics considered in the creation of *Personas*.

Characteristic	Values
Speech disability	Yes or No
Visual disability	Blindness (B), Low vision (LV), Color Blindness (CB)
Physical disability	Motor disabilities (MD)
Hearing disability	Deafness (D), Hard of hearing (HH)
Cognitive and neural disability	No, Dyslexia and dyscalculia (DD), Attention deficit disorder (ADD), Intellectual disabilities (ID), Memory impairments (MI), Mental health disabilities (MHD), Seizure disorders (SD)
Mobile expertise	Low (L), Medium (M), High (H)
Web expertise	Low (L), Medium (M), High (H)
Assistive software expertise	Low (L), Medium (M), High (H)
Chat expertise	Low (L), Medium (M), High (H)
Age	Young Adulthood [19-49]; Middle Adulthood[40-65]; Maturity[65-end]
Sex	Female (F), Male (M)
Native speaker	Spanish(Yes), No
Place of birth	Name of the country

Table 3.5: User Profiles Considering Common Characteristics and Values

Considering these values and characteristics, some *Personas* are created to capture the accessibility barriers of chats and the groups of people who face more accessibility barriers. These *Personas* are abstractions of the users that are using the tool and cover the characteristics that people who use chats for m-learning can have. A total of five *Personas* were created and combine the characteristics specified previously. It is important to emphasise that other *Personas* could be created if the characteristics were combined in a different way. However, due to limit the costs of the study, five *Personas* were created. Basing on previous studies, this number of *Personas* is enough to obtain the accessibility barriers that the target population could face [Blomkvist, 2002].

These *Personas* are detailed with all their characteristics and are explained with a background and a description. The background consists of all the *Personas*'s characteristics including: working environment, frustrations, relationships with others, skill levels and some demographics characteristics [Calabria, 2004]. On the other hand a description consists of how their experience is when this *Persona* uses a chat application. One of these *Personas* is detailed in Figure 3.11 and Appendix B shows all the *Personas* created in the study.

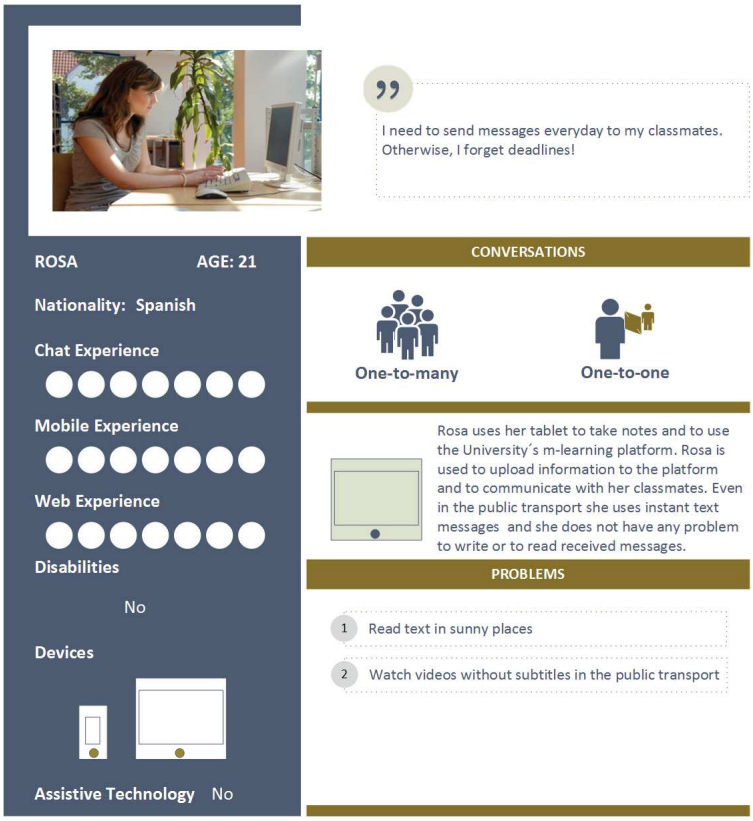

Figure 3.11: Example of Persona

Next, a summary of the characteristics' of each persona is detailed in Table 3.6. This table represents the disabilities of the *Persona*, the mobile, web, assistive technology and chat expertise, their age, sex, language and place of birth. Moreover, each value is based on the values showed in Table 3.5

	Speech disabilities	Visual disabilities	Physical disabilities	Hearing disabilities	C. and N. disabilities	Mobile expertise	Web expertise	AT expertise	Chat expertise	Age	Sex	Native Speaker	Place of birth
Rosa	No	No	No	No	No	H	H	No	H	21	F	Yes	Spain
Shannon	No	LV	No	No	No	L	L	No	L	22	F	No	USA
Felipe	No	No	No	HH	No	H	H	H	H	19	M	Yes	Spain
David	Yes	No	No	No	MI	L	L	No	L	41	M	Yes	Spain
Antonio	No	LV	MD	No	No	M	M	No	M	67	M	Yes	Spain

Table 3.6: Characteristics of Created *Personas*

HCI discipline combines the *Personas* method with the *Scenarios* method in order to obtain the behaviour of some people in a specific environment [Sears and Jacko, 2007]. This thesis combines both disciplines to obtain the user's problems when they use chat applications in m-learning environments as well as to obtain the main people who could face accessibility barriers.

A *Scenario* is a narrative description of what people do and experience when they use the application [Rosson and Carroll, 2009]. The *Scenarios* method is used to obtain information related to how the *Personas* created previously execute each scenario. Then, it could be obtained the main accessibility problems that people face when they execute these scenarios. The scenarios selected are the main tasks that users can execute in a chat application. These scenarios are: create a conversation, create a chat sentence, send a file, add interlocutor, previous conversation, and select written language. Next, an example of a scenario is shown in Table 3.7 and Annexe C details all the scenarios as well as the *Personas* who have interacted in each scenario, the problems detected and the people who could face these problems too.

Scenario:	Send chat sentences
Settings:	Rosa and Antonio are chatting in different places. As Rosa is really good at new technologies, she is able to write really fast. However, Antonio is not able to write really fast because of his temblor.
Task Description:	Rosa and Antonio are chatting with the MD. Rosa sends a message to Antonio. Antonio starts to reply it. Rosa replies the sentences really fast but Antonio is not able to answer quickly. As a result, Antonio is not able to follow *FLow and Rhythm* of the conversation and feels really uncomfortable because of this. Rosa replies even if Antonio even when Antonio has not replied previous messages. Then, Antonio receives more than one sentence at the same time. Antonio feels uncomfortable and leaves the chat.

Table 3.7: Example of Scenario

Combining these *Personas* and scenarios methods, some of the problems that real people could face when they interact with chat applications in mobile devices are identified.

Data Collected This study creates scenarios and *Personas* and provides a list of problems that real people could face when they interact with chat applications in m-learning environments.

Data Analysis Considering the scenarios and *Personas* created as well as the problems found during this study, the problems found are categorised basing on the related scenarios.

3.4.3. Results

Each *Persona* has been used to execute each scenario and to obtain the main accessibility problems that the fictitious *Persona* could have. The results showed that chat applications have some features which are difficult for some users.

Some of the problems detected are related to: impossibility to identify colours, impossibility to answer the conversation when they want, etc. Some people with visual impairments could have problems identifying some colours of the application. For example, if the users connected in the application are identified with a colour exclusively, people with visual impairments or people, who are executing the mobile device in a sunny place, could have problems identifying the status of each user. Moreover, people with motor disabilities, people with fewer mobile, web and chat expertise, people with learning problems and foreign people could face problems following the *Flow and Rhythm* of the conversation. In addition, elderly people could suffer these problems too because they usually experience problems related to motor dexterity and sighted problems. It means that these groups of people could face problems reading or answering the conversation and as a result these people could be overwhelmed because they cannot

follow the conversation.

Next, Table 3.8 shows a summary of the main problems that the *Personas* could face. This table shows the scenario, the *Persona* who could experience problems, the accessibility barriers faced, a description of the problem and other *Personas* who could be affected by this problem depending on the context of use and the mobile device. Furthermore, Annexe C shows all the scenarios, the *Personas* who have interacted in each scenario and the problems detected in the process.

Scenario	**Persona**	**Problem**	**People Affected**
Create Conversation	Antonio	Antonio is not able to distinguish if Rosa is connected or not because it is used the color green to show if she is connected or not	People with visual impairments. Interact with the MD in sunny places.
Create sentences and Add File	Rosa	Rosa is not able to see the image because she cannot download it; she has reached the limit connection.	People with visual impairments. Interact with small screens of MDs. Elderly people.
Chat sentences	Antonio	Antonio is not able to follow the rhythm of the conversation and feels really uncomfortable because of this.	People with motor disabilities. People with few mobile, web and chat expertise. People with learning problems. Foreign people. Elderly people.
Add interlocutor	Antonio	Unable to distinguish which users are connected or not. The user is not able to follow the rhythm of the conversation.	People with visual impairments. People who interact with the MD in sunny places. People with motor disabilities. People with few mobile, web and chat expertise. People with learning problems. Foreign people. Elderly people.
Previous conversations	Rosa	N/A	N/A
Written language	Rosa	N/A	N/A

Table 3.8: Accessibility Problems Detected After the use of Scenario and *Persona* Methods

3.4.4. Discussion

The combination of *Scenarios* and *Personas* methods showed that users can experience accessibility problems when they use chat applications in m-learning environments. As a result, the addressed research questions were:

- RQ3: Which are the main groups of people affected by the accessibility barriers and the problems they face?

The people who could experience more problems are detected as well as the problems that each *Persona* could face. People who could experience more problems when use chats are: people who have disabilities; elderly people; and people without disabilities who are using the chat application in specific situations or because of their ICTs expertise level.

These people can face problems when they create conversations, when they send a messages or attach a file as well as when they want to add an interlocutor to the conversation or when they want to read previous conversations. Some of these problems will affect people with disabilities but people without disabilities and elderly people could be affected too.

As it has been explained before, the *Personas* created do not cover all the characteristics that people could have. In case of covering all combinations of characteristics, the number of *Personas* could be infinite. Besides, the use of *Personas* does not find all problems that real people could suffer. As a result, it is important to involve real people in the experiment because it will help us to obtain the main problems that real people could face as well as to confirm problems identified by people in previous studies. Next section aims to obtain the accessibility problems that real people with disabilities, elderly people and people without disabilities have.

3.5. Accessibility Problems: People with disabilities

In the previous study, one of the groups of people, who experience accessibility problems when interacting with chat applications in m-learning environments, is people with disabilities. Previous studies have detected some of the problems that they could face but these studies do not involve real users. As a result, some problems could have not been detected and real users could help us to understand and identify these problems.

3.5.1. Research questions

This study aims to obtain the main problems that people with disabilities face when they interact with chat applications. The research question to address is:

- RQ4: Which are the main problems that people with disabilities face?

Next sections specify how the studies have been designed and how people have been involved in the research studies.

3.5.2. Method

The study explained in this section aims to obtain the accessibility problems that people with disabilities face when they interact with chat applications in m-learning environments. To achieve it, the study was divided into two phases: *Interviews* and *Questionnaires*. The following sections specify how these methods were combined.

Participants

Interview A total of eleven users participated in the user interviews. Five users were blind users, two users had partial vision, two had motor impairments, one had a cognitive disability, one had a hearing impairment. It is important to remark that the disabilities considered are the disabilities that could affect to users who use ICTs basing in the W3C specification [Abou-Zahra, 2013]. However, the disabilities related to neurological or speech disabilities were not considered in the study.

Although the selection of the participants were carried out randomly, the participants who offered to participate in the study had to comply with some requirements which are: previous expertise using chat applications in mobile devices or desktop computers; and have any disability. Next the characteristics of each user are detailed:

- **User1:** is a blind man and 55-64 years old. He rarely uses chats in desktop or mobile devices. The chats that he uses are: Whatsapp [7] and Messenger
- **User2:** is a blind man and 35-44 years old. He uses chats every day in desktop or mobile devices. He uses chats such as: Whatsapp, Line [8] , Messenger, Skype or Spotbros [9].
- **User3:** is a blind man and 35-44 years old. He uses chats in desktop computers but not in mobile devices. The chats that he uses are: Messenger and Chats of some LMSs (E.g.: Moodle).
- **User4:** is a male with motor impairments and 18-24 years old. He uses chats in mobile devices everyday but he does not use chats in desktop computers. The chats that he uses are: Messenger, Whatsapp, Social Network's chats (E.g.: Facebook [10] or Tuenti [11]).
- **User5:** is a male with partial vision and 35-44 years old. He uses chats in desktop computers but he does not like to use chats in mobile devices. The chats that he uses are: Social Network's chats (E.g.: Facebook or Tuenti) and Chats of some LMSs (E.g.: Moodle)
- **User6:** is a female with cognitive disabilities and 18-24 years old. She uses Whatsapp in mobile devices everyday and she uses chats in desktop computers (Skype) one or two times per week to chat with her friends.
- **User7:** is a blind man and 45-54 years old. He uses chats in mobile devices almost everyday but he does not use chats in desktop computers every day, just once a week. The chats that he has used are: Messenger, Whatsapp and Skype and he uses them to communicate with his friends.
- **User8:** is a blind woman and 45-54 years old. She uses chats every day to communicate with her friends in her mobile and laptop. Whatsapp, Skype and Twitter are the chats that she has used previously.
- **User9:** is a male with motor disabilities and is 35-44 years old. He is a computer engineering student and he uses ICTs everyday. He uses chats in desktop and mobile devices everyday and he uses chats as Whatsapp.

[7] Whatsapp: http://www.whatsapp.com/
[8] Line: http://line.me/en/
[9] Spotbros: http://www.spotbros.com
[10] Facebook: https://www.facebook.com/
[11] Tuenti https://www.tuenti.com

- **User10:** is a female user with visual impairments, who need to increase the size of the websites continually, and is 25-34 years old. She uses computers everyday to work and she uses mobile devices every day. She has used chats in desktop computers and mobile devices and she has used chats such as: Whatsapp, Skype, Messenger or Facebook.
- **User11:** is a female user who has hearing impairments and is 18-24 years old. She uses mobile devices everyday in order to communicate with her classmates and so on. Moreover, she uses chats in mobile devices as well as in desktop computers almost everyday.

Next Table 3.9 summarises the characteristics of the people who participated in this study:

User	**Age**	**Gender**	**Disability**	**Exp. Chat Mobile**	**Exp. Chat Desktop**	**e-learning**
User1	55-64	Male	Blind	Low	Low	No
User2	35-44	Male	Blind	High	High	No
User3	35-44	Male	Blind	Low	High	Yes
User4	18-24	Male	Motor	High	Medium	Yes
User5	35-44	Male	Partial vision	Low	High	Yes
User6	18-24	Female	Cognitive	High	Medium	No
User7	45-54	Male	Blind	High	Medium	Yes
User8	45-54	Female	Blind	High	High	Yes
User9	35-44	Male	Motor	High	High	Yes
User10	25-34	Female	Partial vision	High	High	Yes
User11	18-24	Female	Hearing impairments	High	High	No

Table 3.9: Users Interviewed Characteristics

Questionnaire A total of 53 users with disabilities participated in this survey. However, eight of them were not taken into account because they did not complete properly the questionnaire or they were not part of the target population (People with at least one of the next disabilities: auditory, cognitive, physical or visual). As a result, the selected questionnaires were 45.

The questionnaires were completed by 24 males and 21 females. All of them have a disability such as: visual, hearing, motor or learning and cognitive disabilities which are included in the category of other. However, three people have more than one disability (One person has partial vision, audio and learning problems; another person has audio and motor problems; and the last one combines motor and psychological problems). Next, Figure 3.12 shows a relation between the age of users and the disabilities.

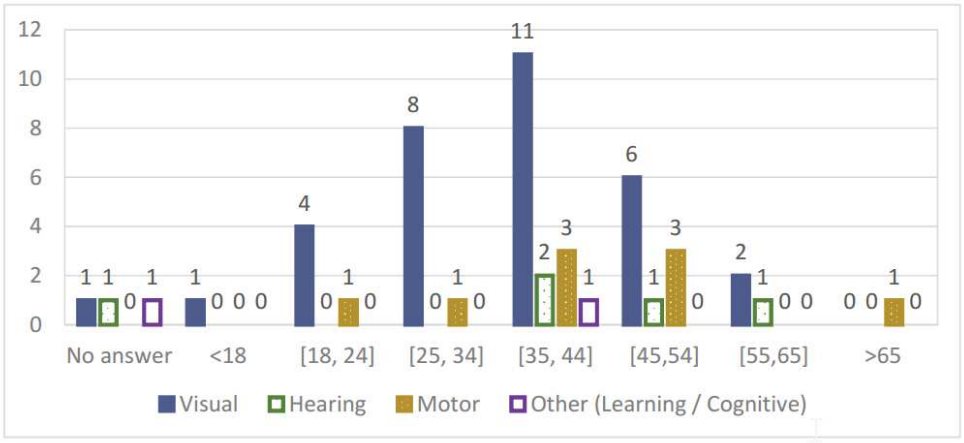

Figure 3.12: User's Age and Disability Characteristics

With regard to their expertise level using chat applications in mobile devices and desktop computers, 53.33% of users use chat applications every day on their desktop computers and 48.89% of users in mobile devices. In contrast, 2.22% of users are not used to use chats in desktop and 20% in mobile devices. Figure 3.13 shows the percentage of use of chats in desktop and mobile devices by respondents.

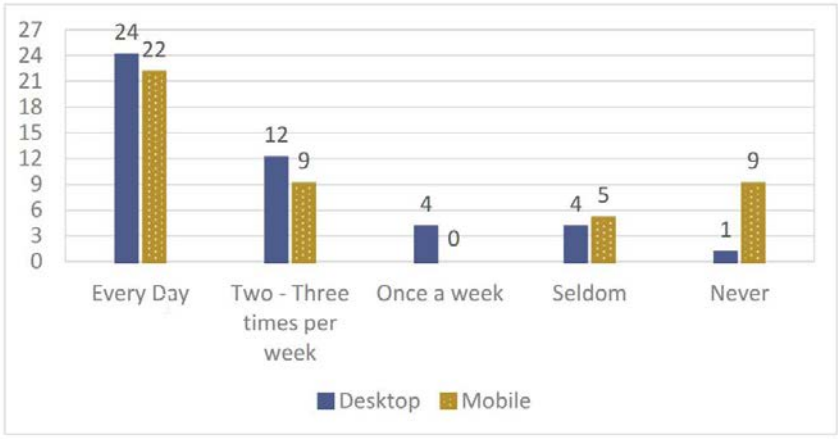

Figure 3.13: Chat Use in Desktop and Mobile Devices

Moreover, users should specify which are the chat applications that are used to use. Figure 3.14 shows that the most used chats are those chats of social networks like Facebook and Whatsapp chat.

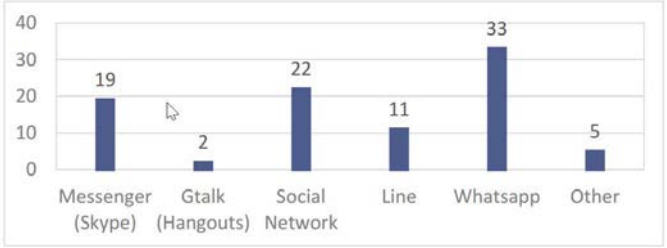

Figure 3.14: Most Used Chats

Apparatus

This section details the apparatus used when both interviews and questionnaires were conducted.

Interview A script was created for each interview. This script included how the interview should be conducted in order to avoid differences between the interviews.

Questionnaire A list of questions were created. These questions were grouped in a file and was posted in different forums, blogs, mail lists, etc. In addition, different formats were provided to allow users select the best format which adapted to their necessities.

Design

The methods used were questionnaires and interviews. This section describes how these methods were carried out and which groups of people were involved.

Interview The interview method was carried out with people with disabilities because they could face more accessibility barriers according to previous research - see section 3.4. These interviews were carried out because qualitative research is really useful to obtain user‘s opinion at a deep level. Answers were open answers because users could explain their answers[Patton, 1990].

The interviews carried out in the research were semi-structured interviews which follow some questions created previously to guide the interviews [Rogers et al., 2011] [Pfleeger and Kitchenham, 2001] [Kitchenham and Pfleeger, 2002a] [Kitchenham and Pfleeger, 2002b] [Kitchenham and Pfleeger, 2002c] [Kitchenham and Pfleeger, 2002d] [Kitchenham and Pfleeger, 2003].

Moreover, apart from using this method to identify user's problems, the interviews were used to design the questionnaire used in the following phase of the research.

Questionnaire This method was helpful to obtain users' problems quickly and to obtain quantitative information which could be catalogued and compared later [Vredenburg et al., 2002].

Questionnaires used in the study were elaborated considering the guidelines provided by Kitchenham and Pfleeger[Pfleeger and Kitchenham, 2001, Kitchenham and Pfleeger, 2002a, Kitchenham and Pfleeger, 2002b, Kitchenham and Pfleeger, 2002c, Kitchenham and Pfleeger, 2002d, Kitchenham and Pfleeger, 2003]. A questionnaire for people with disabilities is shown on Annexe E.

Procedure

As it was explained previously interviews and questionnaires methods were used to obtain the main problems that people with disabilities could face. The following Figure 3.15 shows how these methods were combined.

Interview The personal interviews were conducted through a telephone call, audio-conference or face-to-face interviews which were recorded to be analysed later. All interviewed people could answer each question according to their own opinion following turns.

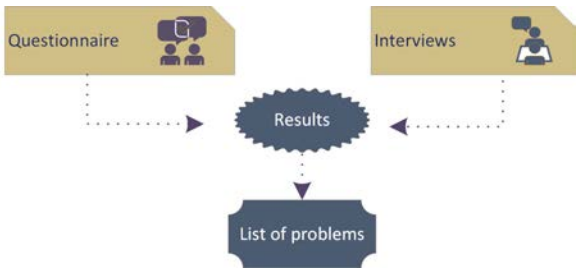

Figure 3.15: Procedure - People with Disabilities

The interviewer asked some questions during one ro two hours. All interviews were divided into four parts: the purpose of the research; warm-up questions; personal questions; and questions related to the specific study. Firstly, the interviewer explained the interviewee the main goal of the experiment and an introduction about her. Next, some relaxed questions were asked previously to warm-up the interview. Later, users were asked personal questions including questions related to their previous experience using chat application; and finally, users had to answer specific questions of the study. It was important to follow this structure because users could understand the purpose of the experiment and were able to familiarise with the person who was carrying out the interview. In addition, questions were framed in different environments: kind of conversations (E.g.: Formal or informal) and the purpose of the conversation (E.g.: With Friends, At Work; or With Relatives). It is important to emphasise that these questions were useful to obtain the way that interviewers use chat applications and the problems that they could face.

All asked questions were opened questions and users could explain their experience when they use the chat applications in different environments such as: desktop or mobile device environments, formal or informal conversations or learning environments. To conclude the interview, the interviewer asked users if they had any suggestion to improve the chat interaction. Next section specifies the users who participated in the study. Annexe D shows all the questions followed in the interviews.

Questionnaire The questionnaire research is an experiment with a theoretical design and is a concurrent control study where participants were not randomly assigned to groups. Furthermore, the questionnaires were unsupervised questionnaires; respondents filled the questionnaire by their own and there was not any person who supervised the questionnaire. This research followed a non-probabilistic sampling method where people were invited to participate in the survey. Specifically, it is followed a convenience sampling method because the users, who participate in the surveys, were willing to take part in the survey without obtaining any compensation.

The questions of the questionnaires were created basing on the questions of the previous interviews which were improved basing on the feedback obtained in the interviews. The Annexe E shows the questionnaire spread out through the Internet to obtain the users‘ barriers. Each questionnaire was divided into two parts: demographic questions and questions related to the use of chat applications in mobile devices. Each questionnaire is composed of a total of sixteen questions. Fourteen of them were rating scale and two of them were open-ended questions. In addition, it is important to emphasise that six of the rating scale questions were also open-ended questions. The questionnaire included questions related to their mobile device and assistive technology, frequency of use of chats and types of chats, accessibility problems that they faced.

In order to provide different formats and allow users choose the best format for them , a unique questionnaire was created in three different formats: plain text (.txt), accessible Microsoft Word (.doc) and accessible online form. Then, each user could decide which format adapted better to their necessities. The data collection process was open for more than one month and users spent around fifteen minutes to complete each questionnaire.

Data collected

Both studies provided quantitative and qualitative data which was recorded and stored in different formats in order to analyse it later.

Interview Each interview was recorded and stored in a server. In addition, each interview was heard once in order to obtain the highlights of the interview.

Questionnaire Users sent their questionnaires to the person who collected the questionnaires and they were stored in an Excel spreadsheet in order to analyse the information later.

Data analysis

After the information related to both methods was collected, the data was analysed considering that most of the information obtained in the interviews was qualitative data and the information collected from the questionnaire was quantitative data.

Interview Most of the information obtained in these interviews was qualitative data and qualitative methods were applied. Each highlight obtained in the interviews was analysed and grouped in order to obtain patterns of user's behaviours.

Questionnaire The data of each questionnaire was analysed to check if the data was robust enough or not. Thus, it was checked if the questionnaires were whole-completed and fulfilled properly. The uncompleted questionnaires with more than one question were not taken into account for the survey and uncompleted questionnaires with one question were filled with the most common answer to this question. Finally, statistics of each question and answers were obtained in order to understand user's problems.

3.5.3. Results

This section specifies the results obtained from conducted interviews and questionnaires.

Results - Interview

After carrying out the interviews, some of the accessibility problems that people with disabilities experience were identified.

The first user considers that the use of chat applications is a lost of time because he spent much time on writing messages. He explained that:

User1: "Chats are not useful for me. I am wasting my time when I chat."

Moreover, if he is in a conversation, he is not able to write as quickly as the other person and he becomes stressed because he receives many messages at the same time.

With regard to the second user, he considers that chats are really useful for him and uses them 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 said:

> User2: "Line has some image-buttons without alternative text and I cannot know the purpose of the button. Moreover, when I receive a new message notification in Whatsapp, it opens the last conversation that I have opened and it does not open the last message received. It is a problem because the screen reader does not notify it and I know that once I wrote to another person. Thus, I press the top of the screen always to auto-refresh the screen"

Besides, he considers that the use of the chat of Facebook is easier in mobile devices than in desktop computers because the navigation is easier. And he considers that Spotbros is completely inaccessible for him because it is not prepared to be used by screen readers.

The third user considers that communication using chat applications is useful for him. However, he experiences some difficulties when people use emoticons in the sentences.

> User3: "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 response sentences. If he is speaking with many people, he sometimes cannot follow the conversation because he answers previous messages.

> User3: "If I am writing previous messages, the other people write messages and my messages become obsoletes."

In addition, it is important to emphasise that this person has used the chat in LMSs and the chat does not update continually. Thus, if he wanted to know the last sentences he had to refresh the page manually. It could be annoying for him and sometimes he was not able to know the conversation.

The fourth user uses chat applications every day with his classmates and colleges and he uses it in different ways depending on the people who is in that chat. The language is different and the way of speaking too. Besides, he uses it to share their notes and ask questions to his colleges. With regard to the difficulties that he has experienced, he specified that he does not experience difficulties. 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.

> User4: "No, I have not experienced any difficulty when I chat with someone. The opposite, I have chatted with some people who write more slowly than me and I have to wait them."

Furthermore, he specified that the other students in general follow the conversation and do not change the topic until a doubt has been solved.

The fifth user is a student too and uses the chat in LMS with his colleges and teachers in a desktop computer. He uses it as a way of learning to solve doubts and to exchange knowledge through URLs and videos. The Moodle's chat is good for him because he can maximise the screen and he can use the magnifier to increase the letter's size. Other chats do not allow him to do it and he cannot read the conversation with the magnifier. Besides, he does not like the chats which have many columns. For example, if there is a column on the right which shows all the people who are connected to the chat, the middle column shows the conversation and

the right column shows a banner advert. Then, he needs much time to read the conversation.

Some teachers copy and paste the information constantly in chats because they prepare the classes before and they paste all the information. Then, he specified that he is not able to read all the information because he increases the letter's size and the screen shows fewer lines.

> User5: "Imagine that the teacher writes one hundred lines and you can see it on your screen without any problem. However, if I increase the letter's size, I cannot see all the text, I can see only fifty lines and I have to use the scrollbar to read the whole message."

Another problem is related to the information showed per 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 much time reading the messages information until he reads the text's message.

> User5: "Imagine that the chat shows me all of this information (Image, Nickname, Date, Message). If I have to read all the information I have to spend much reading it."

Considering it, the user prefers that the only information showed close to the message is the Image of the person because he spends less time reading it. He recognises the image instantly and he knows who is writing. Then, he considers that all people must upload an image when creating an account.

> User5: "If I see the image, I can associate the message with the image and I can recognise it instantly. For me, it is even better an image than a short nickname."

Chats in mobile devices are not good for him because he has to move the mobile device closer to his eyes and it is really uncomfortable for him. Besides, if the keyboard is a tactile keyboard is not good for him because he spends a lot of time reading what he types and watching the keyboard.

> User5: "The tactile keyboards of the mobile devices do not show any reference to specify which letter I am pressing. Then, I have to read the message and watch the keyboard constantly. What I do? I do not use the chats in mobile devices because of this. "

The chat's language is not really good neither, if the other person uses contraction words, the screen reader could have problems recognising the text because it only reads the letters not a word.

Another problem is related to the colours of the text shown. He specifies that sometimes there are some clear blue texts which cannot be read by him.

The User6 has experienced some difficulties when she chats with her colleagues. Most of times she is able to communicate with her colleagues without problems; however, sometimes she can experience some difficulties because she wants to say something at a precise moment and she is not able to write what she wants quickly.

> User6: "Sometimes, if there are a lot of people at the conversation, they start to write quickly and to say many things and when I answer something; they are not talking about it anymore."

However, she specified that she was able to understand all the emoticons and to press the tactile buttons without problems.

The user 7 experiences some problems because of the screen reader. Sometimes he is not able to read the conversation because the messages are in the queue and he has to move to the queue and later to the textbox and insert text. It takes him much time and he has to move the finger from the top to the bottom many times. Besides, he experienced more problems when there are many people in the conversation. Then, sometimes he switches to 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.

> User7: "If I am in a group conversation, sometimes I select the "plane mode" of my mobile phone to not receive more messages and read the conversation carefully."

Due to the limitations of mobile devices, the tactile keyboard of the mobile can make him write slower because he is not able to distinguish the letters and he has to identify one letter and then, move to another letter. Moreover, the mobile device corrects the words that he has written and sometimes it changes the word completely.

He has used the chat in informal learning. For example, he has used it to learn how to use NVDA [12] and JAWS [13] better. The teacher explained to them how to use it through Skype[14] . In these virtual classes, students waited until a student finished with his doubts and they established turns to follow a correct class. He considers that it is a good way to learn and to communicate with teachers to solve doubts.

The User8 experiences some difficulties due to the inaccessibility of chat applications. For example, the Skype version for desktop is not accessible for her because she is not able to access to the window where the messages are shown. Moreover, she is not able to download the sent files because the steps that she has to follow are very complex. Another problem related to Skype is that it uses many visual things that are not accessible for her. Due to these things, she uses the mobile version of some websites including web chats because they are clearer and there are not many things to read.

With regard to emoticons, she does not experience any problem. Moreover, she likes to use them in their conversations because she considers that they are really funny.

In group conversations, she has experienced some problems because maybe she chats slower. Sometimes, I want to say something in a specific moment and I cannot say it because of this.

She has used chat applications to learn in some courses too. She communicates with her colleagues and teachers through the chat and they take a turn to speak. However, if there is a student who does not respect it, the teacher could decide to chase them out. In these courses, they exchange knowledge through links and sometimes, they use files.

The user, User9, experiences some problems when he writes on his mobile device. Although he considers that his writing velocity is a normal velocity. Due to his motor impairments, he is not able to write quickly with his mobile device and he needs to connect a Bluetooth keyboard to write quicker. Thus, sometimes he would like to say something in a specific moment and

[12]NVDA: http://www.nvaccess.org/
[13]JAWS: http://www.freedomscientific.com/products/fs/jaws-product-page.asp
[14]Skype: http://www.skype.com/es/

he could not say it at that moment.

He has used chat applications in learning environments to communicate with his teachers. However, he has not used chats to communicate with his colleges or classmates because he considers that it is really difficult to find colleges in his University as it is a distance University. Moreover, some teachers wanted to use the chat in the classes but the students did not participate in the classes.

> User9: "Students do not usually participate in the chats. Maybe because they could be ashamed to ask "stupid" questions."

The User10 has experienced problems mainly with the font size because some chats do not allow her to increase the size of the messages in the input text element or the message's size. Besides, she likes to change the contrast colour because she could see the messages better and to personalise the background colour. However, some chats do not allow her to do it. Some of the chats, mainly chats which are based on websites, do not adapt to the screen size and she cannot see it well. Moreover, the tactile keyboard could be a problem for her too. It took her many time to change her mobile phone to a smart-phone because she was worried about the tactile keyboard. She did not know if she was going to be able to adapt to the new generation of mobile phones. In contrast, as she bought a mobile device with a huge screen and with a huge tactile keyboard she is able to identify the letters better. Furthermore, she likes that the keyboard shows a vibration when she presses a button because she is able to detect if she had pressed the button or not. Another functionality which is really important for her is the automatic correction of words.

From the point of view of the use of chat applications in e-learning, she had used it with her colleges in the University to solve doubts with each other or to ask questions to her teacher. It was a good idea for her because it was another resource to exchange messages. Moreover, she would like to save the conversation for later. For her, the use of chats or online materials is really useful because in traditional classes sometimes she experienced some difficulties. Some teachers wrote tiny sentences in the blackboard and sometimes she was not able to take notes even if she sat down in the first row.

Finally, the User11 specified that she does not experience any problem to use chats in mobiles or in desktop computers. For her is a free good way of communication with her friends and she does not have problems reading, writing, communicating, etc. This way of communication is really good for her. She has not used chat applications in learning environments, but she considers that it is a good way of communication between students and teachers; specifically, for people with hearing impairments who could be able to communicate with all of them easily.

Table 3.10 summarises the main problems that the interviewed people have experienced and if they consider chats useful or not for them.

User	Use Chats	Problem
User1	No useful	Write quickly
User2	Really useful	Untagged buttons Screen reader does not specify the name of the screen Differences between the same chat in MD and desktop
User3	Useful	Untagged emoticons Unrefreshed chats Many messages at the same time
User4	Useful in MD	None
User5	Useful in desktop No useful in MDs	Chats with many columns Large messages Too many information of each message (Time, date, nickname and photo) Contraction word Text color
User6	Useful	Sometimes cannot say something in a specific moment
User7	Useful	Screen reader problems (messages on the queue, move the focus to the last message) Tactile keyboard Spelling
User8	Useful	Unable to access to the Window where the messages are shown Download files Write quickly sometimes
User9	Useful	Cannot write quickly Sometimes have problems to follow the conversation
User10	Useful	Color Contrast Small keyboards Small font size
User11	Useful	None

Table 3.10: Interviews. Summary of the Problems for People with Disabilities

Results - Questionnaire

With regard to the accessibility problems of chats, users were asked to answer which of these problems have been faced by them. Thus, they could select barriers from the list provided in the questionnaire. Furthermore, they were able to specify other accessibility barriers found. The list provided was:

1. A1: I cannot identify the colours and shapes
2. A2: There are icons which I do not understand.
3. A3: I cannot follow the *Flow and Rhythm* of the conversation.
4. A4: The icons are really small.
5. A5: I cannot write quickly.
6. A6: There are images without alternative text.
7. A7: None

8. A8: Other

The answers to these questions are showed in Figure 3.16. It can be observed that people with visual impairments experience more problems when they use chats. These causes are related to the *Flow and Rhythm* problem identified previously because they cannot write quickly as they need sometimes because of the use assistive technologies like speech recognition software or braille keyboards (A5). Thus, they cannot follow the conversation (A3). The use of images, icons or buttons without alternative text is a handicap for them. In contrast, people who experience fewer problems using chat applications are people with hearing impairments. They are really used to use chats and text messages to communicate with other people.

Moreover, the most common problems that people experience are typical problems of synchronous tools because they are related to the 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 last one could be a consequence of the first one because while they are answering the last message the other person can write more messages and as a result, he can feel lost and overwhelmed in the conversation because he does not have the opportunity to answer previous messages.

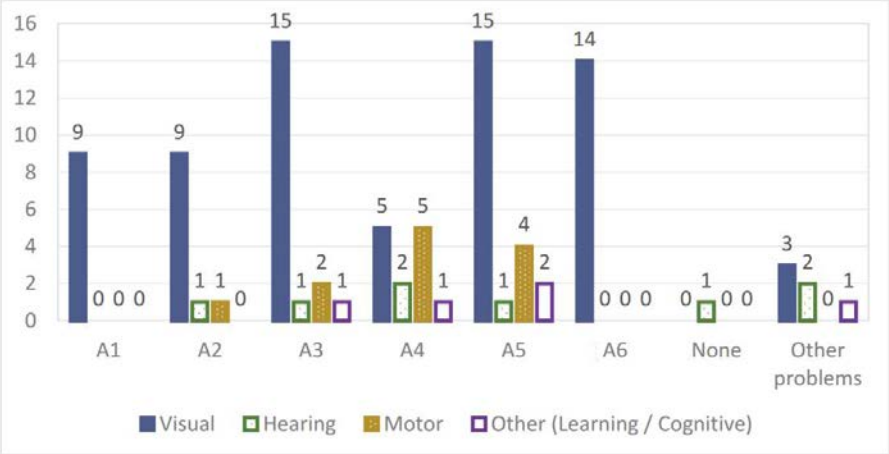

Figure 3.16: Chat Accessibility Problems per Disability

Apart from the accessibility barriers provided by the questionnaire, users gave us information related to other accessibility barriers according to their experience. However, it is important to emphasise that these problems were experienced by only one user (A7) such as: they cannot read the messages, the tabulation is not used properly and the user cannot navigate through the chat using the keyboard, they cannot access to all functionalities using the keyboard, they cannot hear the sounds and they feel insecure.

3.5.4. Discussion

The main aim of this research was to obtain the main problems that people with disabilities face when they use chat applications:

- RQ4: Which are the main problems that people with disabilities face?

Most of the participants specified chat applications are very useful for them specially in learning environments because they can: share notes or collaborate with their colleagues. In

addition, they adapt their behaviour to learning environments. For example, they follow teachers recommendations or they adapt their language to learning environments.

However, there are many accessibility problems that people with disabilities experience when they use chat applications. Some of these barriers are classical problems that people usually face when they use software which has not been developed according to accessibility standards and guidelines. For instance, there are icons which cannot be understood by users; the chat application does not provide alternative content for the non-textual content [Thiessen and Chen, 2007]; some functionality is not keyboard accessible[Resta and Laferrière, 2007]; and the user cannot hear some sounds. Besides, there are some accessibility barriers which are specific of synchronous environments - e.g. chat applications. These problems are related to the interaction with the conversation. For example, users cannot follow the *Flow and Rhythm* of the conversation and they cannot write quickly [AccessIT, 2012] [Guenaga et al., 2004] [Noll et al., 2010][Nguyen and Fussell, 2012][Resta and Laferrière, 2007]. With regard to the accessibility problems per disability, the results underline next accessibility problems:

1. **Visual impairments**. Problems related to: shapes; text sizes and colours; and icons; follow the *Flow and Rhythm* of the conversation; and have difficulties writing quickly.
2. **Motor impairments**. Problems to interact using keyboard only navigation; use of small icons and have difficulties writing quickly.
3. **Hearing impairments**. Impossibility of hearing sounds and notifications.
4. **Other impairments**. Have difficulties writing quickly.

Considering these results, almost all user categories regardless of their disabilities had interaction problems and these problems were related to the *Flow and Rhythm* because they cannot write or read quickly.

These are the most common problems that people with disabilities face when they interact with chat applications. However, other groups of people - e.g. elderly people - face accessibility problems when they interact with the system. Next section aims to obtain the main problems that elderly people face when they interact with chat applications.

3.6. Accessibility Problems: Elderly People

Another group of people, who could face barriers when they use chat applications, is Elderly people. The study aims to obtain the main problems that elderly people have when they use chat applications in desktop and mobile environments. To achieve it, this study has been divided into different phases. The same users participated in Group Interviews, Observations and Questionnaires in order to identify the problems they face daily.

3.6.1. Research questions

This study aims to obtain the main problems that elderly people face when they interact with chat applications. The research question to address is:

- RQ5: Which are the main problems that elderly people face?

Next sections specify how the study was conducted to address the previous question.

3.6.2. Method

This study is divided into three different phases: Group interviews, Observations and Questionnaires and all participants participated in all these phases. The following sections detail how these studies were conducted.

Participants

The same participants participated in the three sessions in order to obtain accurate results. A total of sixteen students, who study ICTs in the Leganés City Council Centre, participated in this study. These students were divided into two classes composed of nine students (Range age between 64 and 72 years old) and seven students (Range age between 65 and 70 years old) respectively. Next a summary of the ages and genres of both classes is detailed - see Figure 3.17 and 3.18.

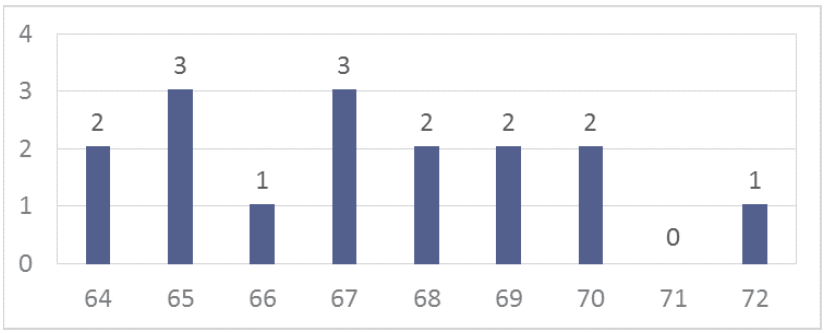

Figure 3.17: Demographics - Age of Participants

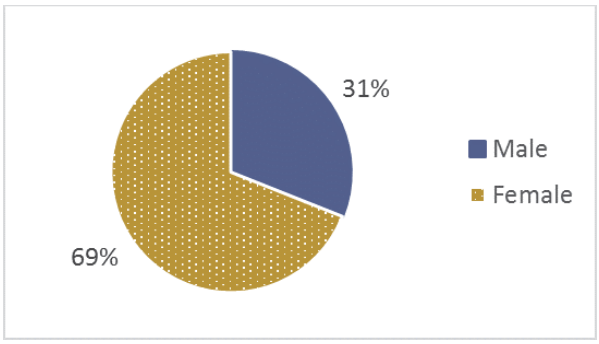

Figure 3.18: Demographics - Gender of Participants

Moreover, they were asked they expertise level using chat applications in mobile and desktop environments. As the diagram shows, there are a huge percentage of people (50%) who did not use chat applications previously in desktop or mobile environments - see Figure 3.19.

From the point of view of users who has used chat applications previously, it is important to mention that almost all of these users who have used chat applications previously have used Whatsapp (87,5 %) - see Figure 3.20.

Apparatus

The research studies were conducted in the same room where students learn with their colleagues. The same environment was used in order to avoid possible bias due to the environment

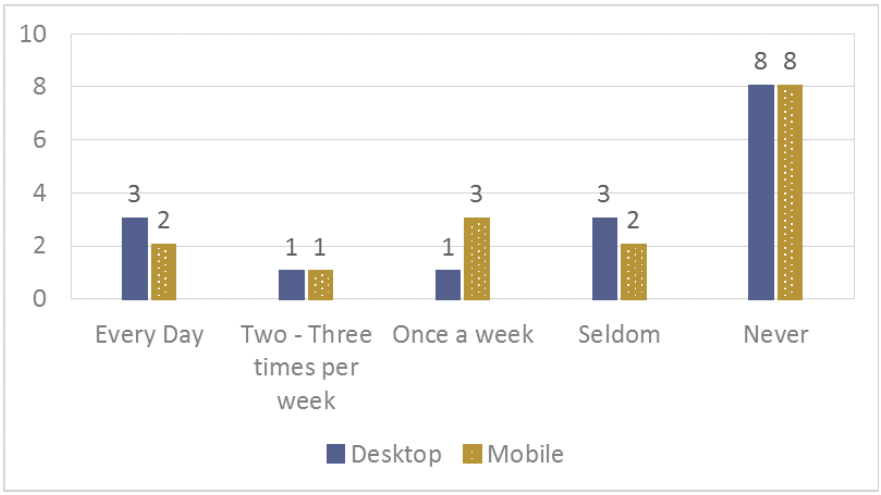

Figure 3.19: Chats' Use by Elderly People

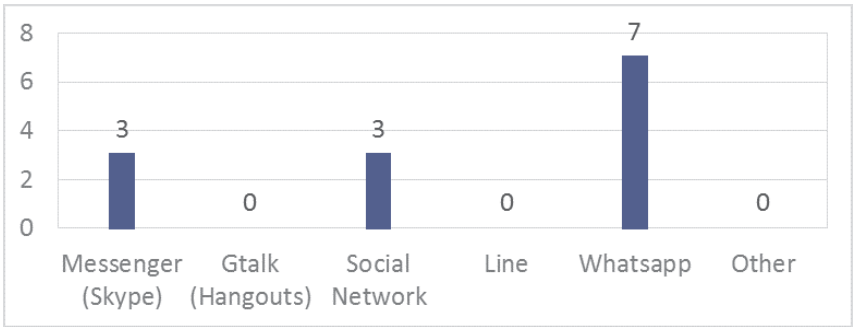

Figure 3.20: Most Common Used Chats by Elderly People

and they could feel more relaxed in this environment.

Group interview Users were introduced to the moderator and they were asked questions regarding to their previous experience using chat applications. The moderator specified they had to detail the environment where they faced these problems and how they managed to avoid this problem.

Observation This phase consisted on structured observations. Users used Skype desktop chat application in their desktop computer. The selected Skype version was the 6.9.59.106 because it was the most up-to-date version. Users had to execute specific tasks using this Skype version and the moderator was mentioning what they had to do everytime.

Questionnaire A paper questionnaire was handed out to each student. In this case, a paper questionnaire was selected because it was quicker for participants to complete this questionnaire using pen and paper instead of computers.

Design

Each study was designed carefully to obtain as many problems as possible and to assure these problems are not specific to only one user.

Group interview Group interviews were conducted in two sessions with different participants. These interviews were semi-structured interviews and users could explain their issues and difficulties openly.

Observation These observations were carried out in two sessions as well. Users were asked to chat using Skype with other students in groups and in pairs in order to obtain the problems they face when they sent messages using Skype. Meanwhile, a moderator was observing the problems and frustrations that users found during this experiment.

Questionnaire A questionnaire which included questions about their previous experience using chat applications as well as demographic questions were distributed to each participant.

Procedure

The studies were conducted in three classes (1 hour each) and in two groups of elderly people who assisted to ICTs classes tough by volunteers of the Leganés City Council (Madrid, Spain). Semi-structured group interviews, structured observations and questionnaires methods were combined in order to obtain the main barriers that elderly users experience when they use chat applications.

These three main phases used the following methods: group interviews to know their previous experience with the use of chat applications in mobile devices and desktop computers; structured observations to obtain the problems that they experienced with Skype (desktop version); and questionnaires which obtained the problems students face when they use chat applications - see Figure 3.21.

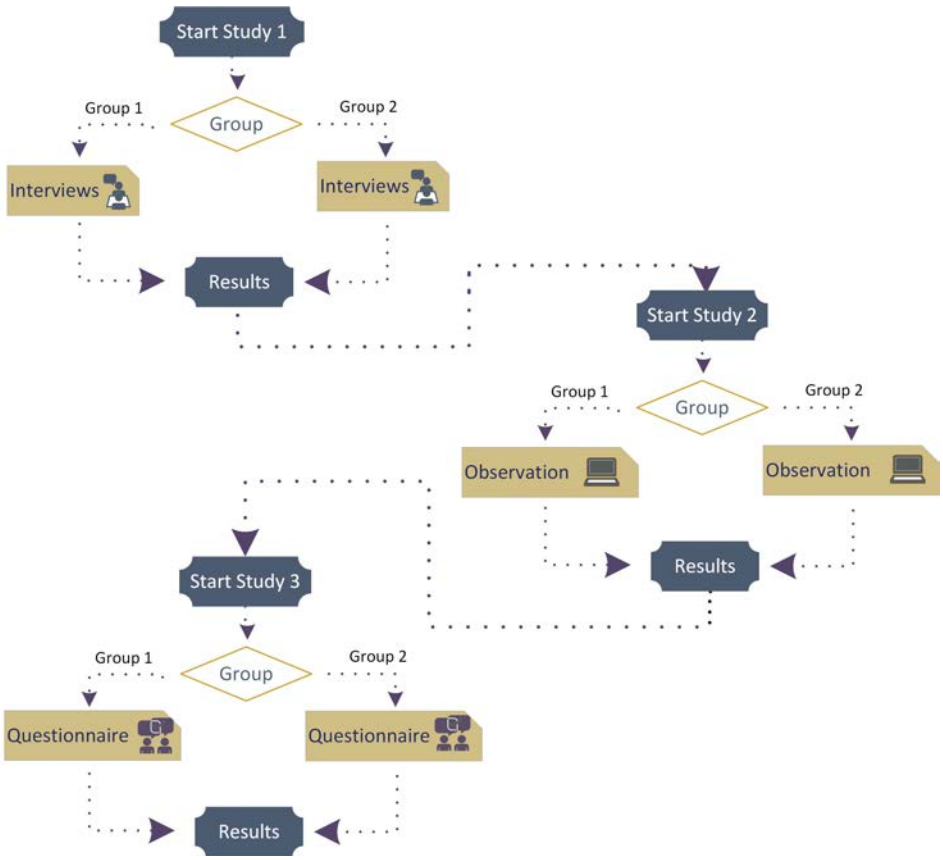

Figure 3.21: Studies' Procedure - Elderly People

Group interview The main aim of this phase is to detect the previous problems that elderly students had faced when they used a chat as well as their previous experiences using chat applications. Moreover, this phase allows researchers to identify users' expertise level when they used ICTs.

Two semi-structured group interviews were carried out with all the students in each group. Each interview took one hour including the explanations given by the moderator about the differences between social networks, chat applicatitons and other new technologies. Meanwhile, the moderator was writing the most important quotes of the students in a notebook to analyse them later. The moderator asked different questions to guide the conversation between the students. These questions were:

- Who has used a chat?
- Who knows what is it?
- Which problems have you faced?
- Do you have problems when you write or answer messages?
- Do you have any problem related to the colours or images used?
- Do you have any problem related to the mobile device?

It is important to remark that each participant answered the questions individually because the main goal of the research was to allow them interacting and arguing with each other about these problems.

Observation This phase consisted of structured observations of the participants' use of a chat application in desktop computer with the use of Skype - see Figure 3.22. Firstly, students were explained how to use Skype and how to chat with their classmates through Skype because in the previous phase it was detected that the level of expertise using chat applications was not high.

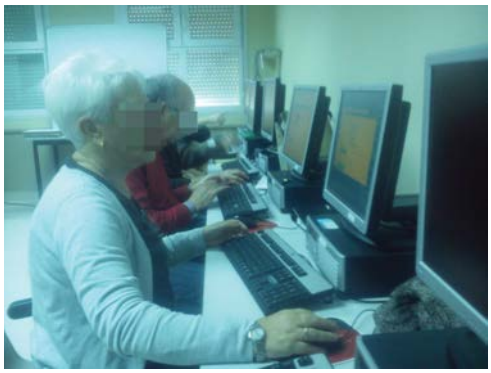

Figure 3.22: Users in the Structured Observations

This study was carried on in a desktop computer because some of the students did not have a smartphone. Thus, it was decided to use the desktop version of Skype. The decision of selecting Skype was because of many reasons such as: the structure is simple as it is not integrated into a social network or email; and it was not necessary to install it in their machines, so users could install it in a pen drive and they could practice at home.

Two researchers taught students how to execute the most common and necessary tasks to allow them chatting using Skype because the experiment would be more quicker. Moreover, the sent messages during the experiment were saved to analyse them later. This phase was carried out in two classes of one hour in both groups and the explained features in the classes were:

1. Execute the application
2. Create an account (Just in case they did not have an account)
3. Log into the application
4. Add contacts
5. Chat with one student (one-to-one) or with more than one students (one-to-many)

After explaining participants how to execute each task, they had to send messages to the classmate, who was behind them. This message should refer to the topic they preferred. Finally, a chat with all the classmates was created and one of the researchers was asking them questions related to a topic.

Questionnaire After carrying out previous phases of the study, students fulfilled a questionnaire - Annexe F - about their chat's experiences and thoughts. These questionnaires were similar to the questionnaires that people without disabilities fulfilled.

Data collected

The data collected in these studies was qualitative data except for the questionnaires were the data was quantitative and qualitative.

Group interview Group interviews were not recorded because it was not possible to install microphones in these rooms. As a result, one observer was taking notes about the problems and ideas that people were mentioning in the interviews. These notes included "Quotes" of the participants as well as notes to the user's behaviours.

Observation A moderator was asking participants to execute tasks and the observer was taking notes about the comments and questions that participants asked. The messages sent in the group conversations were stored and analysed later in order to obtain additional problems that were not found during the session.

Questionnaire The questionnaires were collected by the moderator and observer at the end of the session. These paper questionnaires were transcribed to an Excel Spreadsheet and the information was analysed later.

Data analysis

After the data was collected, the data was analysed to obtain patterns and common behaviours. As the data was in different formats different approaches were followed.

Group interview The data obtained in the group interview was qualitative data and it was grouped in order to obtain pattern behaviours.

Observation In the observations study, the data collected was qualitative data and the data analysis was the same as in group interviews.

Questionnaire The data of each questionnaire was analysed to assure the data was robust enough. The data obtained from these questionnaires was qualitative and quantitative data. The quantitative data was analysed from a statistical point of view. As a result, graphics and percentages were calculated as well as correlations between the obtained data. However, no correlations were found. On the other hand, the qualitative information was analysed in order to obtain patterns and categories.

3.6.3. Results

After carrying on these three studies, the problems that elderly people face when they use chat applications in desktop and mobile environments are specified. Next, the results obtained in each phase are specified.

Group interview The students were asked different questions to obtain the main problems they face when they use chat applications in desktop and mobile environments.

The first question was: "Who has used a chat? For example: Skype, Messenger, Whatsapp or Hangout [15] ". Some participants said they had used some of them and they said other applications they had heard before such as: Facebook, Twitter [16], Tuenti or LinkedIn [17]. They did not know the difference between social networks, chat applications or other technology. Then, it was necessary to explain them which were the differences between them.

After explaining these differences, the next question was "Which problems have you faced previously when you are chatting with your friends and classmates?". Then, students who had used the chat applications previously asked all these questions but the students who did not have any experience using chat applications specified their feelings regarding chat applications and why they do not use it. Next, these problems can be grouped into different categories:

1. **Number of Messages and language:** the students had problems related to the number of messages that they receive at the same time and understanding contracted language that other participants used.

   > S.I : "I am sending 'Whatsapps' to my son and he writes really quickly. I am not able to follow his rhythm. And the language! He uses a weird language that I do not understand"

2. **Keyboard size:** some participants have problems with the keyboard of their mobile devices because it is too small for them. Sometimes, they want to press a key and they press another one. As a result, they cannot maintain a quick conversation.

3. **Few contacts:** they prefer use chat applications with close friends. Besides, they do not want to chat in groups because they have to write quickly and/or they are not able to read it quickly.

   > M.F.: "I do not have many contacts in Skype because I do not want to have 150 contacts. Why? For wasting more time on it" [..] "I do not want to chat with more than one person because they write quickly and I get lost! "

[15] Hangout http://www.google.com/+/learnmore/hangouts/
[16] Twitter https://twitter.com/
[17] LinkedIn https://www.linkedin.com/

4. **Unknown technology:** they can feel out of place because sometimes they are not able to contact with their grandsons or granddaughters using new technology - e.g. chat applications. They would like to use it but they do not know how to use it.

5. **Do not use it because:** they do not use it because of many reasons. For example, they are sometimes scared or prefer to use other ways of communication with their classmates and friends. A student said that she does not send messages during the whole day because she considers that she could waste her time. Other student specified she did not use a chat application because she does not know how to use it.

   > A.M: "I do not know how to use it and I want to learn it because I like it. However, I consider that ICT makes close far people and far close people."

   Other person considers that it is a vice because when you start doing it you cannot stop and you will not be able to leave it.

   > S.I.: "You can get hooked when you use it too much."

   Some participants were confused because they could not assure the identity of a other person. As they cannot see the face of the other person they can feel uncomfortable because they are not sure if the other person is lying or not.

   > H.W.: "I do not chat because I do not know the person who I am chatting with"

   As they are advised regularly about the importance of preserving their personal information, if an application asks them for their mobile phone number or their address, they do not want to provide it.

   > C.P.: "I do not want to use it because they ask me for my mobile phone number. I am scared about it. Maybe they are cheating me"

Observation After conducting the second phase, some of the problems that elderly face when using a chat application in desktop computers were obtained. Moreover, it is important to emphasise that some of these errors are not specific of Skype or chat applications; these are general problems that elderly experience when using ICTs. Thus, as the study is focused on the problems that elderly experience when they use chat applications, these problems are not detailed here.

With regard to the chats' accessibility barriers, these problems could not usually occur in other ICTs. Moreover, these problems can occur in chat applications with only one user (One-to-one), with more than one user (one-to-many) or in both cases. Next, these problems are summarised and specified if they have been detected in one-to-one or one-to-many conversations:

1. **Many messages showed in a specific moment:** when they receive many messages at the same time they spend more time reading them and sometimes some of them write something. (One-to-one and one-to-many)

2. **Privacy:** they did not know if they could write to other people or not and if they could chat with everybody. It could be related to the confusion of chat applications and social networks. For example, some of them considered that they could send messages to one specific person and other people, who are not involved in the conversation, could read what he has written.(One-to-one and one-to-many conversations)

P.: "I have written to xx. Then, does my granddaughter see it?"

3. **Messages' size** some of the students did not send small and quick messages. It can be because they do not write quickly or because they prefer to send a long message only. (One-to-one and one-to-many)

4. **Offline vs. Online:** they had problems knowing which users where online and offline because the icon was not intuitive. Furthermore, they asked if they could send messages to other people who were not connected at that moment. (One-to-one)

   E.M.: "Can I write a message to a person who is not connected to say him/her that I want to chat with her at seven?"

5. **Persistence**: they wanted to reread the conversations that they had had at home and they wanted to know if they could use the same user when they were chatting at home with other classmates. Moreover, they would like to know if they could copy the software and carry out to other computers. (One-to-one and one-to-many)

6. **Emoticons:** sometimes they do not know how to use these emoticons and they do not know the meaning of the emoticons. Other students knew how to use them and they used them in each sentence.(One-to-one and one-to-many)

   A. M. "Oh! What is this face with big tooth???! "

7. **Contact with other people:** they mix things related to search on Google or in a personal electronic agenda. A participant considered that he could send a message to a specific person just saying the name and the city where she lives. (One-to-one and one-to-many)

   P.: "I have searched a contact on the list of contacts. The name is Margarita. There are many people with this name. Then, if I say Alicante, will the contact appear instantly?"

8. **Reception:** the reception of the messages is really important for participants because they need to know if the message has been sent or received. Sometimes they asked to their classmates if they had received the message because they needed a confirmation. (One-to-one and one-to-many)

9. **Answer previous messages** if some of the emitters wrote messages quicker than the other participant, they could be waiting until the other person wrote a message or can get nervous. (One-to-one)

10. **Participation:** some of them preferred reading instead of writing and it was more common in students who did not use the chat previously. (One-to-many)

    A.M.: "I prefer to read the messages instead of writing. It is funnier! "

11. **Orthography:** they were worried about the grammatical errors they could commit and they asked how they could correct them and avoid them using the system. They had used Word before and they were comparing the chat application with Word. When the moderator explained them there was not any way to check the orthography, they said they would like to have a similar functionality. (One-to-one and one-to-many)

    P.: "When I write something in Word, Word underlines the words which are written badly and later I select the best one. How can I do it here? "

Questionnaire After previous studies were completed, users fulfilled a questionnaire. They specified the main problems they experienced when they used the chat application in the classroom or previously. They had to select one or more options from the following possibilities:

- A1: I cannot identify the colours and shapes
- A2: There are icons which I do not understand.
- A3: I cannot follow the *Flow and Rhythm* of the conversation.
- A4: The icons are really small.
- A5: I cannot write quickly.
- A6: There are images without alternative text.
- A7: None
- A8: Other

The answers specified by the users were analysed and the obtained results are shown on Figure 3.23.

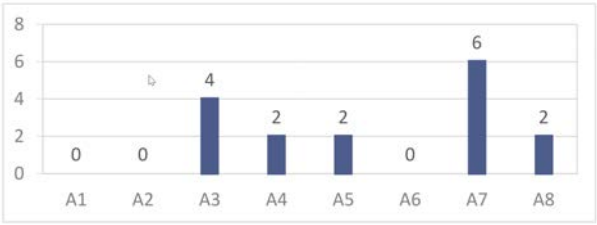

Figure 3.23: Elderly People. Accessibility Barriers

Almost half of the students specified that they did not experience any problem when they used chat applications (6 out of 16 people). However, other students (10 out of 16) experienced problems when using chat applications. The most common problem (four out of 16) is related to follow the *Flow and Rhythm* of the conversation. Another related problem is a problem to write quickly because some considered that buttons are really small (two out of 16) or participants were not able to write quickly (two out of 16).

3.6.4. Discussion

The main aim of this research was to address the main problems that elderly people face when they use chat applications.

- RQ5: Which are the main problems that elderly people face?

Previous researches have been focused on obtaining problems that people with disabilities face [Hampel et al., 1999] [Resta and Laferrière, 2007] [Noll et al., 2010][Nguyen and Fussell, 2012]. However, they have not been focused on the problems that elderly people face. Although, some problems detected previously could be extrapolated to elderly people because impairments are being increased as we age [Arch et al., 2009], some of them are specific to elderly people.

All phases detected problems that elderly people face when they interact with a chat application in mobile or desktop environments (**RQ5**). Some of these problems were detected in one of the phases and others were detected in all phases. Next, Table 3.11 shows the main detected barriers and in which phase/s were detected.

Interviews	**Observations**	**Questionnaires**
Number of messages and language	Many messages	Flow and Rhythm
Keyboard size	Messages size	Connection
Not many contacts	Privacy	Small icons
Unknown technology	Difference between offline vs online	Write quickly
Do not use it because: it is a waste of time, it is a vice, do not know the identity of other people	Persistence of the messages	
Privacy	Emoticons	
	Search for contacts	
	Situation of the messages	
	Answer previous messages	
	Participation	
	Spelling	

Table 3.11: Summary of the Problems that Elderly People Experienced

Some participants could be confused when the topic of the conversation changed and they were worried because they had answered a previous message instead of the last message. Another related problem is the reception of many messages in one go, they can be overwhelmed and sometimes they cannot follow the *Flow and Rhythm* of the conversation because they did not have time to read the whole message or they were not able to write quickly.

The action to write and send messages is easy and intuitive for them but they can have problems with other tasks such as: Add a Contact or Login because they have to remember the steps to configure the chat and it could be difficult for them.

To conclude, the use of chat applications by elderly students is useful for them to communicate with their classmates and relatives. However, the chat application should be simpler and more intuitive; otherwise, participants could experience many difficulties and they could avoid communicating using this chat application.

In the last two sections, the problems that people with disabilities and elderly people face when using chat applications have been identified. In a previous study - see Section 3.4 - it was obtained that people without disabilities could face problems when they interact with chat applications. However, all problems that people can face were not identified. The following research aims to obtain the main problems that people without disabilities could face when they interact with chat applications.

3.7. Accessibility Problems: People without Disabilities

People without disabilities could experience accessibility barriers due to the mobile limitations[Newell and Gregor, 1999] [Yesilada, 2013] [Tiresias, 2009]. This study considers users without disabilities' opinions in order to know their experiences and problems when they use chats in mobile devices and desktop computers. Next sections specify how this study was conducted.

3.7.1. Research questions

The main aim of this research is to obtain the main problems that people without disabilities could find when they use chat applications in mobile devices. The research question which aimed to be answered in this research is:

- RQ6: Which are the main problems that people without disabilities face?

The following section details the method used to address this question.

3.7.2. Method

Questionnaire method was used to obtain the main problems that people without disabilities could face. This section explains how this method was conducted.

Participants

A total of 117 people participated in the study. However, the number of selected questionnaires were 113 questionnaires because the others were not completed correctly. The participants were 56 males and 57 females who had any experience with the use of chats. Moreover, it is important to emphasise that the elderly students of the previous study, Chapter 3.6, who used the chat previously (nine users) are taken into account in this study because they are considered as people without disabilities too. Next, Figure 3.24 shows the participant's ages.

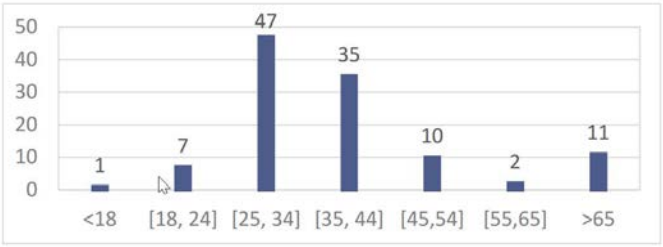

Figure 3.24: Users Without Disabilities: Participant's Age

Considering their expertise in the use of chat applications in mobiles and desktop computers, a total of 38% users use chats in desktop computers every day and 77.9% of users use chats in mobiles every day. However, 13.25% of users do not use chats in desktop computers never and only 2.7% of users do not use chats in mobiles never. Figure 3.25 shows the level of chat's expertise that users have.

From the point of view of the chat applications used, the most common chat used by users is Whatsapp, 103 out of 113 used it, followed by the chats's of social networks such as: Facebook or Tuenti, 51 out of 113 used it. Figure 3.26 shows the most common chats used.

Apparatus

Forums, blogs and email lists related to accessibility were used to obtain information about the problems that people without disabilities could face. The questionnaires were hosted in a server and they were available from everywhere.

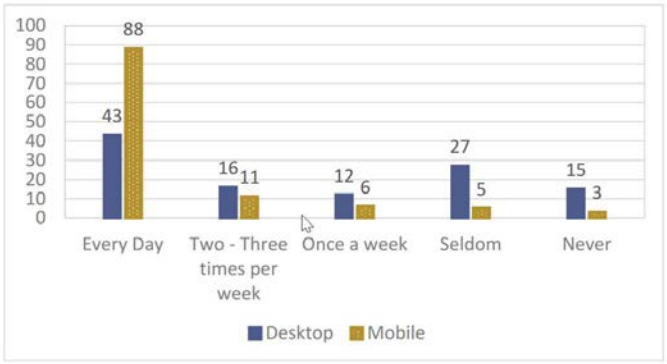

Figure 3.25: Users Without Disabilities. Chat Expertise in Desktop and Mobiles

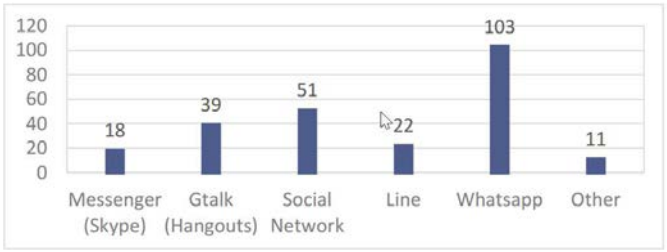

Figure 3.26: Users Without Disabilities. Chats Used

Design

The questionnaires were elaborated considering the guidelines provided by Kitchenham and Pfleeger[Pfleeger and Kitchenham, 2001] [Kitchenham and Pfleeger, 2002a] [Kitchenham and Pfleeger, 2002b] [Kitchenham and Pfleeger, 2002c] [Kitchenham and Pfleeger, 2002d] [Kitchenham and Pfleeger, 2003]. A questionnaire for people without disabilities can be found in Annexe F.

Procedure

The questionnaire was composed of ten questions (two open questions and eight closed questions) and was divided into: questions related to their mobile devices (three questions); questions related to the use of chat applications and the problems that they face (four questions); and one open question to explain new features that chat applications should include. Annexe F shows the list of questions included in these questionnaires.

This questionnaire was translated to English and Spanish in order to obtain more completed questionnaires. The questionnaire was distributed to different forums and blogs in order to obtain as many questionnaires as possible and they were completed online.

The data collection process was open for six months and the respondents were random respondents who spent twenty minutes to complete the questionnaire.

Data collected

The sent questionnaires were stored and saved in a server and those questionnaires included qualitative and quantitative data which was afterwards analysed .

Data analysis

After the questionnaires were collected, the data was analysed to check if the data was robust enough. It was checked if the questionnaires were whole-completed and fulfilled properly. The uncompleted questionnaires with more than one uncompleted question were not taken into account.

These questionnaires included qualitative and quantitative data which was analysed from two different perspectives. Qualitative data was grouped in order to obtain common opinions between users. From the point of view of quantitative data, statistics were obtained in order to confirm and provide figures to the qualitative data.

3.7.3. Results

After carrying out the questionnaires, it can be concluded that users without disabilities could experience some problems when they use chat applications in mobile devices.

Users could select one or more problems of a list of seven items. Also, users had the possibility to select they do not have any problem. In additions, users could specify if they had experienced other problems or not. Figure 3.27 shows the answers of the users who sent the questionnaire. These results are summarised in the following list:

- A1: I cannot identify the colours and shapes
- A2: There are icons which I do not understand
- A3: I cannot follow the *Flow and Rhythm* of the conversation
- A4: The icons are really small
- A5: I cannot write quickly
- A6: There are images without alternative text
- A7: None
- A8: Others

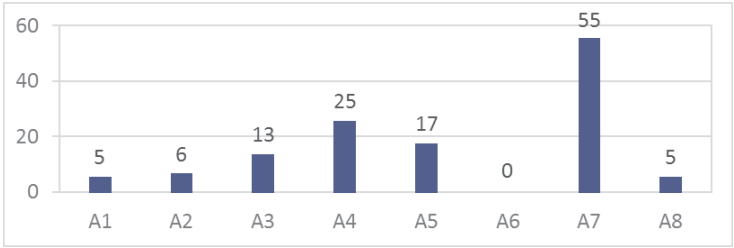

Figure 3.27: Users Without Disabilities. Accessibility Barriers

It is important to remark that almost half of the participants do not experience problems when they use chats (55 out of 113 users). However, the rest of the users experience at least one problem when they use chat applications either on desktop computers or mobile devices. The most common barrier that people face is related to the use of tiny icons or buttons which cannot be selected by the users (25 out of 58 users).

The second most common problem is related to *Flow and Rhythm* of the conversation because of two reasons: they cannot read messages quickly or they cannot write quickly. Thus, they could have problems replying messages at a specific moment or to read the conversation as quickly as they want.

Finally, users were asked about which improvements should be done in chat applications. People explained that they would like to specify which messages are important or not (two out of 113 people); other people declared they would like to have a button to inform other users when they do not want to receive messages because they were too busy (two out of 113 people); the messages could be shown not in real time - e.g. an automatic delay could be assigned (three out of 113 people); create an accessible interface and accessible buttons (three out of 113 people). Besides, there was one functionality which was specified by only one user. The user would like to have the option to transform messages from text-to-voice and voice-to-text.

3.7.4. Discussion

The main aim of this research was to identify the problems that people without disabilities could face when they use chat applications:

- RQ6: Which are the main problems that people without disabilities face?

Considering the obtained results, users without disabilities could face accessibility problems when they interact with chat applications. The main problem that people face is related to the *Flow and Rhythm*. Users can have different problems related to this. For example, they could not be able to follow the conversation because they are not able to write quickly or because they have difficulties to read the information included in the sent messages.

The study has shown that users without disabilities could face fewer accessibility problems but users could face problems when they interact with chat applications. As a result, they should be taken into account in future studies in order to provide solutions to solve these problems.

3.8. Conclusions

This chapter analyses the main problems that people could face when they interact with chat applications as well as the main learning features that learning chat applications have. The main conclusions of the studies and evaluations carried out are summarised next:

RQ1: Which are the main learning features that m-learning chat applications include? One of the main purposes of this research was to analyse the main learning features that chat applications should have to improve learning from the point of view of UDL guidelines. This research has depicted the main learning features that chat applications should have basing on an expert opinion - see Table 3.4. Some of these requirements are accessibility features too. From the point of view of learning, some features are related to: establish roles, allow users exchange files, control messages sent by participants or allow users configure their preferences. Some of these features have been found by previous researches too. Previous studies [Jin, 2009] have identified the components that a LCMS for m-learning should include but this study did not specify the learning features that chat applications should have in m-learning environments.

RQ2: Which are the main accessibility problems that existing m-learning chat applications have according to expert reviews? Expert evaluations were conducted in order to obtain the main accessibility problems that users can face when they use chat environment nowadays. The study showed that these tools are not accessible for users and they could face problems interacting with them - see Figure 3.6, Figure 3.7, Figure 3.8, Figure 3.9. Some of these problems have been found before in previous researches. In this research, it was detected that alternative text is not provided for images or non-textual content. This corroborates previous researches conducted by Thiessen which specifies content is not tagged properly for screen reader users [Thiessen and Chen, 2007]. Problems with content that is updated continually is not announced properly by screen readers either [Hampel et al., 1999]. In addition, it was mentioned before that people who use keyboards only to interact with the application could experience problems interacting with chat applications too [Resta and Laferrière, 2007]. Apart from confirming problems identified in previous studies, this research found problems that have not been identified before such as: chat applications use sensory characteristics e.g. colours - to convey information; colour contrast issues; headings and skip links are not provided to navigate between page sections.

RQ3: Which are the main groups of people affected by the accessibility barriers and the problems they face? As it has been mentioned before, previous studies and researches have detected that chat applications have accessibility problems. Previous studies have been focused on detecting the accessibility problems that people with disabilities could face but these studies have not been focused on the problems that people without disabilities could face too. In this research, it has been studied if people without disabilities could experience problems or not. This research has identified three main groups affected: people with disabilities; adults and elderly people - see Table 3.8. Each group could face accessibility problems and these problems could be related to the devices they are using [Yesilada et al., 2010] as well as the abilities that are decreased as the years go by [Arch et al., 2009].

RQ4: Which are the main problems that people with disabilities face? People with disabilities are the people who experience more accessibility problems when they interact with chat applications. This study has detected most of the problems that people with disabilities could face and it identifies that some of these problems have been detected previously by other researchers; although, others have been discovered in this research - see Table 3.10.

Some of the problems are related to: the use of poor colour contrast ratio between background and foreground; impossibility to increase text size; problems related to the assistive technology used; lack of alternative textual information [Thiessen and Chen, 2007]; and problems related to the use of the keyboard to interact with the application [Resta and Laferrière, 2007]. In addition, the most common problem is related to the *Flow and Rhythm* of the conversation because they cannot write or read messages quickly [AccessIT, 2012]. It is important to mention that to solve this problem, one of the participants specified he uses the Flight mode feature of the application to stop the reception of messages and read them when he could. This could be considered in the future as a solution to solve this problem.

As people with disabilities experience more accessibility problems, they could be more discriminated when they use chat applications in m-learning environments and their learning could be affected.

RQ5: Which are the main problems that elderly people face? Elderly people could be classified as the second group of people who could experience more problems. Most of elderly people are not used to use ICTs because they do not usually use them. Besides, they

can feel out of place because they cannot use this technology easily. Although researchers have focused their studies on people with disabilities, these studies have not been focused on the problems that elderly people could face [Hampel et al., 1999] [Resta and Laferrière, 2007] [Noll et al., 2010][Nguyen and Fussell, 2012]. Elderly people can experience similar problems to the problems that people with disabilities face [Arch et al., 2009]. They could develop disabilities as the years gone by. However, there could be other problems that can be faced by elderly people only. This study has found the problems that elderly face when they use chat applications - see Table 3.11. For example, they might not understand the behaviour of these new technologies; they are worried about spelling; they could have problems remembering tasks; they could have problems interacting with small buttons; and to follow the *Flow and Rhythm* of the conversation. As a result, they could feel frustrated if the chat is not accessible and they could have problems studying and continuing with their studies.

RQ6: Which are the main problems that people without disabilities face? This research aims to identify the problems that people with disabilities experience when they use chat applications. However, previous studies have not been focused on the accessibility problems that people without disabilities experience when they use these applications.

This study has identified that people without disabilities can face problems - see Figure 3.27. One of the problems is related to follow the conversation because they are not able to write quickly or they cannot read the messages sent by other participants on time - the follow the *Flow and Rhythm* of the conversation problem. However, if these three groups are compared (People with disabilities, Elderly people and People without disabilities), people without disabilities could face fewer barriers. Although, it does not mean that people without disabilities should not be considered when designing accessible chat applications.

After conducting these studies, every group has specified that they face accessibility problems. The problem identified by every group is the *Flow and Rhythm* problem because they experience difficulties to participate in the conversation. Students and teachers could have problems interacting and communicating with other students or teachers using chat applications because of different reasons such as: impossibility to read quickly or impossibility to write quickly. Next Table 3.12 and Table 3.13 shows a summary of the problems faced by all analysed groups and marks the most common problems.

Subgroup	Problem
Visual Impairments	**Follow the *Flow and Rhythm***
	Write quickly
	Not tagged elements
	Language used in the conversation
	Assistive technology
	Tactile Keyboard
	Colours and contrasts
	Non adaptable content to the screen
	Font size
	Lack of vibrations or audio to inform about the interaction with the keyboard or screen
	Use of colours than text information (People with Visual Impairments)
	Icons which do not understand
	Read the conversation
	Spelling and autocorrection
	Group conversations
	Queue messages
	Unimportant information
	Messages' size
	Users without identifiable images assigned
	Many messages on the screen
	Emoticons
Hearing Impairments	**Follow the *Flow and Rhythm*** * (Combined with other disabilities)
	Write quickly * (Combined with other disabilities)
	Incomprehensible icons
	Small or Tiny Icons
Motor Impairments	**Follow the *Flow and Rhythm***
	Write quickly
	Incomprehensible icons * (Combined with other disabilities)
	Small or Tiny Icons or Buttons
Other Impairments	**Follow the *Flow and Rhythm***
	Write quickly
	Unable to say something in a specific situation
	Small or Tiny Icons
	Different conversations or windows at the same time
	Many people talking at the same time
	Different formats

Table 3.12: Summary of the Common Problems I. People with Disabilities

Subgroup	Problem
Elder People	**Follow the *Flow and Rhythm***
	Write quickly
	Many messages showed in a specific instant
	Privacy
	Messages size
	Offline vs. Online
	Persistence of the messages
	Emoticons
	Contact with other people
	Reception of messages
	Answer to previous messages
	Participation
	Orthography
	Small buttons
	Memory
Adults	**Follow the *Flow and Rhythm***
	Write quickly
	Small icons or buttons

Table 3.13: Summary of the Common Problems II. People without Disabilities

Considering these results, people with disabilities, elderly people and people without disabilities face accessibility barriers when they use chat applications. As a result, it is important to create accessible chat applications to avoid people‘s discrimination and to make sure people can use chat applications regardless of their abilities and disabilities. The following chapters aim to address the main requirements that accessible chat applications should have to solve the problems identified by people in this research. In addition, solutions to the most common problem identified by people - the *Flow and Rhythm* problem - are suggested.

Chapter 4

Requirement Engineering to Elicit Accessibility Requirements for m-learning Chat Applications

Standards and guidelines are used to create accessible software. There are many standards and guidelines related to accessible software, accessible learning environments, accessible m-learning, etc. These standards or guidelines have some limitations. Firstly, each standard or guideline is focused on a specific field and sometimes they are overlapped. Secondly, none of the existing standards and guidelines is focused on accessible chat applications for m-learning environments. Thirdly, some of these standards and guidelines are difficult to understand by people who do not have previous accessibility background. Finally, these standards and guidelines do not specify all the necessities that people with disabilities could need when they use chat applications for m-learning environments.

This chapter follows a Requirement Engineering (RE) process [Kotonya and Sommerville, 1998a] to identify the requirements that accessible chat applications should have in order to reduce and minimise the accessibility barriers that people with disabilities face when using these chat applications. The chapter is divided into five sections. The first section details previous works. Then, section two specifies the research questions to answer. Different studies were conducted to answer these questions. Firstly, the list of standards and guidelines related to chat applications in m-learning environments is identified. Then, basing on the necessities that people with disabilities have, and the standards and guidelines, the requirements needed to create accessible m-learning chat applications are specified. These requirements aim to solve the accessibility barriers that people with disabilities face. The requirements are elicited and specified. Finally, the validation of these requirements is presented.

4.1. Influences from previous work

Currently, there is a huge number of standards and guidelines which should be followed by IT professionals to create accessible chat applications. These professionals need to analyse these standards and guidelines and select those related to the environment they are developing the website or application. Although currently accessibility guidelines exit to develop accessible chat applications, these guidelines have some limitations such as: they are general or they are specific to desktop computers. As a result, these standards and guidelines need to be combined in order to apply them to the environment needed. Consequently, computer science specialists have to invest time and money to decide which standards and guidelines need to use for the software or application they are creating.

There are two guidelines which are applicable for accessible chat applications. Table 4.1 compares current accessibility guidelines to specify: if the guideline is related to m-learning environments; if it is precise or general; and if the guideline suggests how to improve the *Flow and Rhythm* problem identified in Chapter 3 as the most common accessibility problem in chat applications. In addition, this table compares the purpose of this Ph.D. with previous guidelines.

Guideline	Description	Learning	Mobile	Precise or general?	Improve Flow and Rhythm
CVAA	A law which contains protections to enable people with disabilities to access broadband, digital and mobile innovations	No	No	General	No
GDALA	Guidelines for the development of synchronous communication and collaboration tools including: synchronous text chat	Yes	No	General	Yes*
Ph.D. Contribution Requirements	**Necessity to specify the requirements which make easy the creation of accessible m-learning chats without the necessity of reviewing every related standard and guideline.**	**Yes**	**Yes**	**Precise**	**Yes**
* The guidelines don't specify how the *Flow and Rhythm* should be controlled.					

Table 4.1: Previous Accessible Standards and Guidelines to Create Accessible Chats

There is not any standard or guideline which supports designers or developers in the creation of accessible chat applications for m-learning environments. Thus, there is a necessity to specify the requirements that IT specialists need to consider when designing and coding an accessible m-learning chat application. The requirements specified in this dissertation could be used by IT specialists to create accessible chat applications for m-learning environments.

4.2. Research goals

Basing on previous research studies and previous studies carried out in this thesis, which are specified in former chapters, three research questions were defined to be solved in the successive studies.

- RQ1: Which are the main standards and guidelines related to accessibility, mobile learning environments and chat applications?
- RQ2: Which requirements are necessary to create accessible chat applications for m-learning environments?
- RQ3: Are these requirements valid?

To address these questions, a requirement engineering process is followed. It means the study will: elicit and analyse the requirements; specify the requirements; and finally, validate

the requirements. Next chapters describe how these studies were conducted and the results obtained. Figure 4.1 shows a summary of how the process was carried out, and the following sections answer the research questions identified in this chapter.

Figure 4.1: Requirement Engineering Process

4.3. Requirement Elicitation and Analysis

Before specifying the chat accessibility requirements, it is necessary to select the standards and guidelines which are more related to: accessibility, m-learning and chat applications. This will help us identify and define the requirements in the future phases. Next sections describe the goals of this study, the method followed and the results and conclusions obtained.

4.3.1. Research questions

This research aims to answer one of the research questions specified in this chapter:

- RQ1: Which are the main standards and guidelines related to accessibility, mobile learning environments and chat applications?

The main aim of this research is to obtain the standards and guidelines which should be followed to create accessible m-learning chat applications (RQ1). To carry out this research, it is important to explore and analyse all the standards and guidelines which could be related to accessible m-learning chat applicationos.

4.3.2. Method

This section specifies the method used to conduct the research to be able to replicate the experiment in the future. A literature review was conducted to review and select existing standards and guidelines related to m-learning chat applications.

Participants

A total of three accessibility experts participated in the study and they have searched, analysed and selected those standards and guidelines which are related to accessible m-learning chat applications. The main researcher conducted the literature review to identify the standards and guidelines related to accessible chat applications in m-learning environments. Then, the other two researchers, as well as the first researcher, participated in the comparison and selection of the standards and guidelines which are more relevant and related to the specified environment.

Apparatus

Participants searched on the Internet a list of keywords in order to find a most representative sample of standards and guidelines related to accessibility in m-learning environments. They used the same search engine because it is known that depending on the search engine, the results might be different. In this case, all participants used Google search engine. Next, Table 4.2 shows the list of terms used to obtain the list of standards and guidelines.

Accessibility	Standards	Guidelines	m-learning	Learning
e-learning	Collaborative learning	CSCL	Mobiles	Web
Disabilities	Laws	World	Handheld	Communication
Instant Text Messaging	Inclusive	Chat	Education	Synchronous

Table 4.2: Selected Keywords to Find Standards and Guidelines

Those websites, expert groups, articles, books or papers which mentioned standards and guidelines related to the previous keywords were considered in the study, as well as the retrieved standards or guidelines found. All of them were noted in an Excel Spreadsheet in order to keep a record of the standards and guidelines found. This spreadsheet was used to compare and select the standards and guidelines to be considered in this study.

Design

The standards and guidelines literature review study was designed and divided into two main phases. Next, each phase is explained in detail and the graphic details how the study was designed:

Identification of standards and guidelines: after carried out a deep review of existing standards and guidelines, the most related standards and guidelines to accessibility in chat applications for m-learning environments are identified.

Analysis and selection of standards and guidelines: the standards and guidelines found were analysed in order to determine those which are specific to the selected environment. Then, a process for comparison, selection and agreement among the participants was carried out.

Procedure

In order to identify the standards and guidelines related to accessible m-learning chat applications, this section specifies how the research was conducted. The next subsections describe how these steps were carried out in detail and the following Figure 4.2 represents how this procedure was approached.

Figure 4.2: Procedure - Comparing Accessibility Standards and Guidelines

Select keywords Experts identified the keywords that were related to accessible m-learning chat applications - see Table 4.2. These keywords retrieved pages which referred to standards and guidelines related to accessible chat applications in m-learning environments.

Identify standards and guidelines Basing on the information retrieved in the previous phase, experts selected those search engine's entries (websites, expert groups, articles, books or papers) which were related to accessible m-learning chat standards and guidelines published in the last five years.

Store retrieved standards and guidelines For every selected standard and guideline, related information was stored. This information was: the name of the guideline or standard; the URL where the standard or guideline can be found; the year of publication; and a brief description of the guideline.

Analyse and select standards and guidelines Considering the previous list of standards and guidelines, each expert selected those standards and guidelines which were more related to the specified environment. They had to read the purpose and content of each standard/guideline and understand it in detail. Then, they had to consider if the standard/guideline was related to the specific environment and they had to consider if this standard/guideline should be considered in this study or not. These standards and guidelines were reviewed from the point of view of the following characteristics:

1. Accessibility: Are they related to accessibility?
2. Learning: Are they applied for learning environments?
3. Mobile: Are they applied for mobile devices?
4. Interface or content: Are they applied for application interfaces or content?
5. CSCL: Are they applied for any tool which could be related to CSCL systems?
6. Precise or general: Are they precise to a specific environment or are they general?

The selected standards and guidelines were those related to: accessibility, learning environments, mobile environments, content or interface and CSCL. This process identified those standards/guidelines which were not overlapped and reduced the number of selected standards/guidelines.

Compare results with other experts and agree which one should be selected Each expert could have a different opinion and they could have selected one standard/guideline but the other expert could not have selected it. Experts had a meeting to discuss the results and in case of a disagreement, experts made agreements by consensus. Thus, all experts had to agree if the selected standard/guideline should be included in the study or not when there was any discrepancy in the selection.

Data collected

In this study, qualitative data was obtained. Firstly, it was obtained a list of standards and guidelines which could be applicable in the creation of accessible chat applications for m-learning environments. After that, each expert created a list of standards and guidelines to include in the research.

Data analysis

Considering the data collected in the study, the results were analysed. Firstly, each expert analysed the list of standards/guidelines retrieved. This data was qualitative data and it was transformed into quantitative data when experts decided to select or not the standard or guideline.

4.3.3. Results

To select the standards and guidelines which could be relevant for chat applications in m-learning environments, the study of Gesa was considered [Gesa et al., 2010]. This study analysed the main accessibility guidelines and standards relevant for e-learning environments. Besides, as it has been specified in the previous sections, it was carried out an exhaustive research on the Internet and deep literature review to identify standards and guidelines related to chat applications for m-learning.

Following the steps described in the previous section, a total of **62** standards and guidelines were found during this process and all of them were reviewed by experts in order to identify those standards and guidelines relevant to the creation of accessible chat applications for m-learning environments.

Once all potential standards and guidelines were selected, each standard/guideline was analysed and was marked as applicable or not, depending on different parameters that experts had to value before marking the standard/guideline as applicable or not.

- Is this standard/guideline related to accessibility, learning, mobile, interface or content, or CSCL?
- Is this standard/guideline similar to another standard/guideline?
- Is this standard/guideline general and not described in detail?

Next, Table 4.3, Table 4.4 and Table 4.5 summarise the standards and guidelines which were retrieved in this phase. In addition, if the standard/guideline is relevant in this study it is marked as Yes (Apply) but if the standard/guideline is not relevant, related or is covered by other standard/guideline, this is marked as No (Not apply).

Standard/Guideline	**Apply**
ADL SCORM - Learning Object Reference Model	No
CETIS LEAP2A - Portability and interoperability of e-portfolio	No
ETSI EG 202 116 V1.2.2. - Design for all guidelines for ICT products and services	No
ETSI ES 2012 746 V1.1.1 - User profile preferences and information	No
IEEE std. 1484.1-2003 - Learning Technology Systems Architecture	No
IEEE std. 1484.4-2007 - Digital Rights Expression Languages for eLearning	No
IEEE std. 1484.11.1-2004 - Data model for content to learning system communication	No
IEEE std. 1484.11.2-2003 - ECMAScript API for content to runtime services communication	No
IEEE std. 1484.11.3.2005 - XML Schema binding for content object communication	No

Table 4.3: Study: Comparing Existing Guidelines and Standards - Retrieved Standards and Guidelines

Standard/Guideline	Apply
IEEE std. 1484.12.1-2002 - Learning object metadata	No
IEEE std. 1484.12.3-2005 - XML Schema for learning object metadata	No
IEEE std. 14848.20.1-2007 - Reusable competency definitions	No
IMS AccLIP - Accessibility for LIP	No
IMS AccMD - Access for all meta-data specification	No
IMS Digital Repositories	No
IMS ePortfolio	No
IMS GDALA - Guidelines for accessible learning applications	Yes
IMS Learning Design	No
IMS Question & Test Interoperability Specification	No
ISO 9241-110 - Dialogue principles	No
ISO 9241-129 - Individualization	No
ISO 9241-151 - Web user interfaces	No
ISO 9241-171 - Software accessibility	Yes
ISO 9241-20 Accessibility guidelines for ICT	No
ISO/IEC 13066-1 Interoperability with assistive technology	No
ISO TR 22411 Ergonomics data and guidelines to address the needs of older personas and persons with disabilities	No
ISO / IEC 19780 Information technology - Learnig, education and training – Collaborative technology – Collaborative Learning communication	Yes
ISO/IEC24751-1 Framework for adaptability and accessibility in e-learning	No
ISO/IEC 24751-2 Access for all personal needs and preferences	No
ISO/IEC 24751-3 Access for all digital resource description	No
ISO/IEC 24752-1 Framework of universal remote console	No
ISO/IEC 24752-2 URC user interface socket description	No
ISO/IEC 24752-2 URC presentation template	No
ISO/IEC 24752-2 URC target description	No
ISO/IEC 24752-2 URC resource description	No
ISO/IEC 24756 Common access profile	No
ISO/IEC 24786 Accessible user interface for accessibility settings	No
ISO/IEC TR 29138-1 Accessibility: user needs summary	No
ISO/IEC TR 29138-2 Accessibility: standards inventory	No
ISO/IEC TR 29138-3 Accessibility: user needs mapping	No
ISO/IEC 40500:2012 Information technology – W3C Web Content Accessibility Guidelines (WCAG) 2.0	Yes
W3C ATAG - Authoring tool accessibility	No
W3C UAAG - User agent accessibility	No
W3C WCAG - Web content accessibility	Yes
Mobile Web Best Practices 1.0	Yes
Mobile Web Best Application Practices	Yes
USA Section 508	Yes
USA. Century Communications and Video Accessibility Act (CVAA) 2010	Yes
Android Accessibility	No
Blackberry. Understanding accessibility	No
Apple. Accessibility Programming Guide for Ios	No
Apple. Developer	No
Nokia. Nokia Accessibility	No

Table 4.4: Study: Comparing Existing Guidelines and Standards - Retrieved Standards and Guidelines (II)

Standard/Guideline	Apply
Microsoft. Designing applications for Windows mobile platforms	No
Funkanu. Guidelines for the development of accessible mobile interfaces	Yes
BBC Mobile Accessibility Guidelines v0.8	Yes
UDL Guidelines - Version 2.0	Yes
UNESCO. Policy and guidelines for mobile learning	No
Mobilelearn. Best practices for instructional design and content development for mobile learning	No
Guidelines for developing mobile learning deliverable	No
IBM Developer Guidelines	No

Table 4.5: Study: Comparing Existing Guidelines and Standards - Retrieved Standards and Guidelines (III)

After analysing and comparing these standards and guidelines, a total of 12 standards and guidelines were selected by the experts. Next sections categorise the selected standards and guidelines from the point of view of the organisation which developed it.

IMS Global Learning Consortium (IMS GLC) "The IMS Global Learning Consortium (IMS Global/IMS) is a highly effective nonprofit, member organisation that strives to enable the adoption and impact of innovative learning technology" [IMS, 2007]. They provide a list of guidelines for developing accessible learning applications (IMS GDALA). Some of these guidelines are specific for developing accessible synchronous communication and collaboration tools and they cover synchronous text chat.

International Organisation for Standardisation (ISO) ISO is an independent, non-governmental international organisation which develops and publishes international standards. There are different accessibility guidelines which help to standardise how to include accessibility in our lives. For this study three ISO standards were selected:

- ISO 9241-171- Software accessibility: "Ergonomics guidance and specifications for the design of accessible software for use at work, in the home, in education and in public places."
- ISO / IEC 19780 Information technology - Learnig, education and training – Collaborative technology – Collaborative Learning communication: "It provides a standardized way of isolating and describing textual expressions composed and communicated by collaborative group members."
- ISO/IEC 40500:2012 Information technology – W3C Web Content Accessibility Guidelines (WCAG) 2.0: "Wide range of recommendations for making Web content more accessible."

W3C. World Wide Web Consortium Three W3C guidelines have been selected for this study:

- W3C. WCAG - Web content accessibility guidelines 2.0: "covers a wide range of recommendations for making Web content more accessible." Similar to "ISO/IEC 40500:2012 Information technology – W3C Web Content Accessibility Guidelines (WCAG) 2.0".
- W3C. Mobile Web Best Practices 1.0: "Specifies Best Practices for delivering Web content to mobile devices".

- W3C. Mobile Web Best Application Practices: "Aid the development of rich and dynamic mobile Web applications".

LAWS There are laws around the world which aim to protect people's with disabilities necessities. These laws include requirements that ICTs need to comply. For this study two US laws have been selected.

- USA Section 508: "The Section 508 Standards apply to electronic and information technology procured by the federal government, including computer hardware and software, websites, multimedia such as video, phone systems, and copiers. The Section 255 Guidelines address access to telecommunications products and services, and apply to manufacturers of telecommunication equipment".
- USA. Century Communications and Video Accessibility Act (CVAA) 2010: "Makes sure that accessibility laws enacted in the 1980s and 1990s are brought up to date with 21st century technologies, including new digital, broadband, and mobile innovations".

Other organisations (Funka Nu, BBC, UDL) Other organisations aim to create and provide guidelines to create accessible ITs. This study has considered the following:

- Funka Nu. Guidelines for the development of accessible mobile interfaces: " Funkas work and services are based on the international Web Content Accessibility Guidelines 2.0 (WCAG 2.0)"[...]"Funkas guidelines for the development of accessible mobile interfaces".
- BBC. Mobile Accessibility Guidelines v0.8: "The BBC Mobile Accessibility Standards and Guidelines are a set of technology agnostic best practices for the BBC's mobile web content, hybrid and native applications".
- UDL. Guidelines - Version 2.0:" Assist anyone who plans lessons/units of study or develops curricula (goals, methods, materials, and assessments) to reduce barriers, as well as optimize levels of challenge and support, to meet the needs of all learners from the start".

All these guidelines were analysed in order to understand their context and their purpose. Table 4.6 summarises the list of standards and guidelines selected as well as if they are related to: learning; mobile; accessibility; include information about interface or content; CSCL tools; or if they include precise or general information. However, none of these standards/guidelines are specific for m-learning chat applications because of this it is very difficult for designers and developers to create accessible m-learning chat applications.

Standard/Guideline	**Learning**	**Mobile**	**Accessibility**	**Interfaces vs Content**	**CSCL**	**Precise/ General**
IMS GDALA - Guidelines for accessible learning applications	Yes	No	Yes	Both	Yes	Precise
ISO 9241-171 - Software accessibility	No	No	Yes	Both	No	Precise
ISO / IEC 19780 Information technology - Learnig, education and training – Collaborative technology – Collaborative Learning communication	Yes	No	No	Content	Yes	General
ISO/IEC 40500:2012 Information technology – W3C Web Content Accessibility Guidelines (WCAG) 2.0	No	No	Yes	Content	No	Precise
W3C WCAG - Web content accessibility	No	No	Yes	Content	No	Precise
Mobile Web Best Practices 1.0	No	Yes	Yes	Content	No	Precise
Mobile Web Best Application Practices	No	Yes	Yes	Content	No	Precise
USA Section 508	No	No	Yes	Content	No	General
USA. Century Communications and Video Accessibility Act (CVAA) 2010	No	No	Yes	Content	No	General
Funkanu. Guidelines for the development of accessible mobile interfaces	No	Yes	Yes	Interface	No	Precise
BBC Mobile Accessibility Guidelines v0.8	No	Yes	Yes	Interface	No	Precise
UDL Guidelines - Version 2.0	Yes	No	Yes	Content	No	Precise

Table 4.6: Study: Comparing Existing Guidelines and Standards - Selected Standards and Guidelines

4.3.4. Discussion

The main aim of this study was to identify the standards and guidelines which are related to accessible chat applications in m-learning environments. The research question for this study was:

- RQ1: Which are the main standards and guidelines related to accessibility, mobile learning environments and chat applications?

This question aims to identify the existing standards and guidelines which consider accessibility and/or m-learning. Currently, there are many standards and guidelines which could be applied in accessible m-learning applications. When developers and designers need to code and design accessible software they need to take into account every standard and guideline and they might be overwhelmed because of the number of related standards and guidelines.

In this study, the standards and guidelines more related to accessible m-learning chat applications were analysed. The study concluded that twelve standards and guidelines need to be considered when creating accessible chat applications. Although more standards and guidelines were identified only those that were related to accessibility, learning, mobile, interfaces or content, or CSCL were selected. In addition, if the standard/guideline was similar to other standard/guideline or if the standard/guideline was not detailed enough, this standard/guideline was not selected. Table 4.6 shows the list of standards and guidelines selected as well as a comparison between these standards/guidelines. **(RQ1)**

This list of standards and guidelines is still wide and it could take designer and developers many efforts to understand, analyse and apply them to their projects. In addition, these professionals will need previous accessibility knowledge and expertise to understand the accessibility concepts of these standards and guidelines and to include them in every stage of the software development project. Besides, these professionals might not apply the standard/guideline correctly if they have not been understood accurately. Furthermore, some of these guidelines do not include user's necessities and they do not consider all problems that users have when they use chat applications in m-learning environments. Thus, it is necessary to include their necessities and requirements in the development of any accessible chat application. This is corroborated by previous researchers who have specified the limitations of accessibility standards [Lewthwaite, 2014].

Basing on these results, designers and developers would get a benefit if these standards/guidelines were applied to a specific context and environment. In this case, these standards/guidelines should be applied to accessible chat applications for m-learning environments in order to provide designers and developers a list of requirements they need to include in the design and development of these accessible chat applications. Besides, previous problems and necessities, that people have identified in former studies, should be included in this requirements specification. Next section describes the Requirements Specification study which aims to elicit the main requirements that any accessible chat application for m-learning should satisfy.

4.4. Requirements specification

This section reports the research conducted to elicit the main requirements that accessible chat applications should have in m-learning environments.

In the following subsections, the methodological approach is described. It is outlined the participants, apparatus, design, procedure and data collected and analysis. After this overview, the main findings (requirements) are presented and grouped into categories. Finally, a discussion of the elicited requirements concluded this analysis.

4.4.1. Research questions

This study aims to answer the third question raised in this study:

- RQ2: Which requirements are necessary to create accessible chat applications for m-learning environments?

Basing on the previous selected standards and guidelines as well as the necessities and problems that people face when they use chat applications, a list of requirements are specified in order to provide support for designers and developers in the design and development of accessible chat applications for m-learning environments.

4.4.2. Method

This section describes the method followed in this study to solve the research question. Next sections describe the participants who carried out the study, the apparatus used in the study, the design and procedure followed in the study and the data collected as well as how this data was analysed.

Participants

A total of three accessibility experts participated in this study in order to identify and elicit the requirements that accessible chat applications should include. One of these experts was in charge of the analysis and definition of the requirements. The other two experts reviewed these requirements to confirm they were defined correctly.

All participants were accessibility experts that have more than ten years of experience in the design, analysis and development of accessible applications for mobile devices in m-learning environments.

Apparatus

Every selected guideline/standard in the previous section - Section 4.3 Comparing existing guidelines and standards - was applied to m-learning environments and specifically, they were applied to chat application tools.

Design

The study was divided into different phases: (1) Analyse and extrapolate every standard/guideline to m-learning chat applications; (2) Provide solutions for peoples problems and special necessities; (3) Define requirements; (4) Categorise requirements. These phases were designed to assure requirements were specified correctly. Next each phase is explained in detail.

- **Analyse and extrapolate standard/guideline to m-learning chat applications**: Analyse and extrapolate the selected standards and guidelines identified in the previous section - Section 4.3 - to m-learning chat applications in order to specify the requirements that these applications should have when they are used in m-learning environments.

- **Provide solutions for peoples problems and special necessities**: Basing on the problems that users have specified in our previous studies (Chapter 3). It is necessary to provide solutions or recommendations which help users to use chat applications in m-learning environments. Identified necessities were analysed in Chapter 3 and requirements to solve people's problems were proposed.
- **Define requirements**: Basing on previous steps, specify and define the requirements necessary to create accessible chat applications for m-learning environments.
- **Categorise requirements**: Once these requirements were specified and described they were categorised into: (1) Login, (2) Personalisation, (3) Contacts, (4) Conversations, (5) Messages, and (6) Learning. And finally, they were assigned a code and a priority.

Procedure

The procedure followed to conduct this study is explained in detail next and it is represented in Figure 4.3.

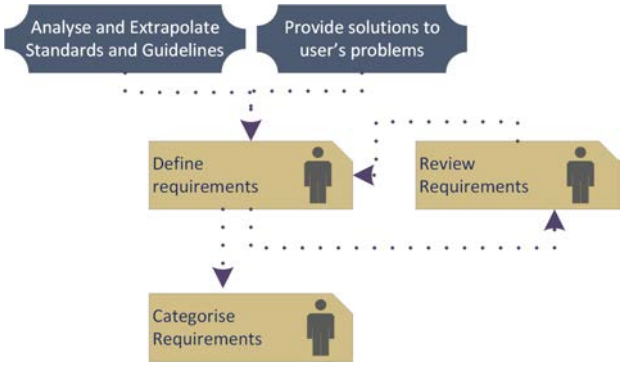

Figure 4.3: Procedure - Requirements Specification

One of the experts carried out the following four phases in order to specify the requirements necessary to create accessible chat applications for m-learning environments. Next every phase is described in detail.

Phase 1: Analyse and extrapolate standard/guideline to m-learning chat applications Most of the standards and guidelines selected are related to web pages, others are related to mobile applications, others to accessibility and others are related to chat applications but they are very general and they are not specific. Thus, it is important to analyse them and apply them to a specific environment - accessible chat applications in m-learning environments. Each guideline was analysed and studied and it was extrapolated to the selected environment. After that, all requirements specified in this phase were compared in order to find possible overlaps among the selected standards and guidelines.

Phase 2: Provide solutions for people's problems and special necessities In previous studies (Chapter), users have specified the main problems they face when they interact with chat applications. These problems could be solved if solutions were provided. In this phase, a recommendation for each users problem was provided. A summary table was created, specifying: the problem that users face, the recommendation/benefit and its description.

Phase 3: Define requirements Each requirement is specified using (1) Code; (2) Requirement; (3) Priority; (4) Classification; (5) Description (Natural Language); (6) Related

Standards and Guidelines; (7) Unified Modeling Language (UML) definition. This information is provided for each requirement in order to make it more understandable for developers and designers. As a result, it will be easier for them to involve and include accessibility requirements in the design and development phases.

1. **Code** : Each requirement is identified using a code which is created basing on the initials of the group - e.g. Login (L) - and numbered consecutively. For instance, the first requirement for the Login section is tagged as L-1.

2. **Requirement**: Title which summarises the purpose of the requirement.

3. **Priority**: A priority for each requirement is assigned. This priority could be: High - the requirement is necessary to create an accessible chat application and it will help a huge number of students; Medium - the requirement will improve accessibility barriers for students , but if the requirement is not implemented, students will be able to use the chat application; Low - these requirements will improve the users experience and it will help users to complete the task quickly.

4. **Classification**: According to the categories specified previously (Login, Personalisation, Contacts, Conversations, Messages, Exchange files), each requirement is assigned to one of these categories.

5. **Description (Natural Language)**: The requirement is specified using plain and natural language in order to be understood by everybody even if they do not have technological background.

6. **Recommendation**: The requirement is explained in detail for designers and developers to include this requirement in their designs.

7. **Related Standards and guidelines (Based on)**: This section specifies the standards and guidelines in which this requirement is based on. Each standard or guideline is named using a code pattern: Guideline initial - Version - Number of Guideline. For example, the Success Criterion 2.1.1 Keyboard included in the Web Content Accessibility Guidelines 2.0 is coded as WCAG_2.0_2.1.1

8. **UML definition**: When possible, each requirement is represented in an engineering format, UML Sequence diagram, to detail the system's interaction [OMG, 2015].

Phase 4: Categorise requirements The specified requirements are categorised and divided into the main tasks that users can complete in a chat application. This classification has been made in order to make these requirements more clear and understandable. These categories are:

- **Login**: specifications to log into the chat application easily.
- **Personalisation**: feaetures to configure the chat application.
- **Contacts**: manage how contacts are shown and identified.
- **Conversations**: create and manage groups.
- **Messages**: exchange messages between students and teachers without accessibility barriers.
- **Learning**: provide mechanisms to improve learning when using chat applications.

- **Exchange files**: allow users exchange files and manage accessibility alternatives.

Once the main expert elicited and described the requirements, the other two experts read and analysed these requirements. In this review process, they had to read each requirement carefully and answer the following questions:

- **Has the requirement been categorised properly?**: Experts reviewed if the requirement was categorised correctly in the six previous categories.
- **Has the priority's requirement been assigned correctly?**: Experts specified if the priority was specified correctly or if they would categorise it differently.
- **Is the requirement understandable?**: Experts read the requirement carefully and specified if the requirement could be rephrased as well as if new comments could be added.

Considering experts' reviews and experts' comments, the requirements were improved. In case of any discrepancy or disagreement the three experts collaborated together and agreed how to improve the requirement.

Data collected

During the study, each phase resulted in a list of qualitative data - requirements and recommendations. Next sections describe the information obtained in each phase:

- List of initial requirements (Analyse and extrapolate selected standards and guidelines): Considering every standard/guideline initial requirements were specified. This was an initial draft of the requirements.
- List of solutions/recommendations (Provide solutions or recommendations for users' problems): Considering the necessities and problems that people specified in Chapter 3, a list of requirements were identified.
- Combine requirements (Define requirements): Both lists were combined into one list because some requirements could be related or overlapped.
- Requirements (Categorised requirements): Requirements were grouped into similar categories.
- Final list of requirements (Improve requirements): A final list of requirements was defined and created.

Data analysis

Considering the collected data obtained during this study, this information was analysed in order to provide a list of requirements to create accessible chat applications for m-learning.

Firstly, the standards and guidelines were extrapolated to a specific environment - accessible chat applications in m-learning environments. This list of requirements was obtained and recorded in order to analyse them later. Secondly, recommendations were provided for the problems identified by users in previous studies. After that, both lists of recommendations and requirements were compared in order to obtain potential intersections between both lists. Then, considering this new list which combines both requirements and recommendations, the requirements were specified and categorised. This is defined as the list of requirements needed to create accessible chat applications in m-learning environments.

4.4.3. Results

After obtaining the necessities and problems that people face when using chat applications for m-learning environments (Chapter 3), a list of solutions or recommendations for the problems and necessities specified by users was created.

Solutions or recommendations for users' problems and special necessities

The following Table 4.7 and Table 4.8 indicate the recommendations provided as well as the problems that are improved.

Problem	**Benefit/ Recommendation**	**Description**
Colours and contrasts, Use of colours to identify information	Do not identify information with colours or shapes exclusively	The use of colours and shapes to identify information should be avoided.
Colours and contrasts, Font size, Small or tiny icons / text	Control font style	The font style (E.g.: colour, type, size) could be configured by users to avoid
Non adaptable content to the screen, Many messages on the screen, Many messages at a time, Messages size	Less information	Show less information on the screen in order to make clearer and easy to read the content
Write quickly, Follow the Flow and Rhythm	Reduce input text	Help users to introduce the minimum text as possible
Memory	Reduce memory	Avoid the use of memory to complete tasks
Spelling and autocorrection	Reduce, avoid and check errors	Reduce, avoid and check errors that users could commit when they use the interface.
Language used in the conversation	Identify language	Allow the configuration and identification of the language to help users in the identification of the information
Language used in the conversation	Simple language	Provide mechanisms to simplify the language exchanged in the conversation
Lack of images to support text	Avoid unnecessary images	Use images if necessary but allow users to configure if these are shown or not.
Unimportant information, Queue messages	Important information	Allow users to specify which information is more or less important
Unimportant information	Knowledge and learning	Provide ways to improve the knowledge and learning that students could obtain

Table 4.7: Benefits for the Problems found in Previous Studies (I)

Problem	Benefit/ Recommendation	Description
Group conversations	Avoid Interruptions	Interrupt users as less as possible and allow users to specify if they do not want to be disrupted
Group conversations, Reception of messages	Specify the status of the conversation and user	Students should be informed about the messages' and contacts' statuses
Icons which are not understood, Emoticons, Different formats	Textual alternative for non-alternative text	Non-text information should have associated text information to make it as much accessible as posible
No tagged elements	Understand words and accronyms	Make contractions and abbreviations as much understandable as possible
Different formats	Alternative text input and output	Provide mechanisms to transform inputs and outputs to different formats
Language used in the conversation, Different formats	Translate text	Allow automatic translation of text
Group conversations / Many messages at a time / Many windows open	Control moving elements	Provide mechanisms to control information which is updated/ refreshed automatically
Privacy	User's protection	The information of each user should be protected by each users
Unimportant information	Quick navigation / Access information easily	Allow users to navigate through the system and through the conversation as easy and quick as possible
Lack of vibrations or audio to inform about notifications	Inform users	Maintain users informed about every situation
n/a	Exchange resources	Exchange accessible resources and make them

Table 4.8: Benefits for the Problems found in Previous Studies (II)

Previous recommendations will benefit to users with disabilities and users without disabilities who use these applications in some circumstances. The following tables, Table 4.9 and Table 4.10, specify the users who will get a benefit from the previous recommendations provided to solve the problems that people could face.

		Impairments*							Other users*		
Improvement	**A**	**M**	**L**	**B**	**LV**	**CB**	**H**	**UA**	**E**	**F**	**U**
Do not identify information with colours or shapes exclusively	-	-	-	X	X	X	-	X	X	X	-
Control font style	-	-	X	-	X	X	-	-	X	-	X
Less information	-	-	X	X	X	-	X	-	X	X	X
Reduce input text	-	X	X	X	X	-	-	-	X	X	X
Reduce memory	-	-	X	-	-	-	-	-	X	X	X
Reduce, avoid and check errors	X	-	-	-	-	-	-	-	-	-	-
Identify language	-	-	X	X	-	-	X	X	X	X	-
Simple language	-	-	X	X	X	-	X	-	X	X	-
Avoid unnecessary images	-	-	-	X	-	-	-	-	-	-	-
Important information	-	X	X	X	X	-	-	-	X	-	-
Knowledge and learning	X	-	-	-	-	-	-	-	-	-	-
Avoid Interruptions	-	-	X	X	X	-	-	-	X	-	-
Specify the status of the conversation and user	-	X	X	X	X	X	X	X	X	X	X
Alternative non-text Information	-	-	-	X	-	-	X	X	X	X	X
Understand words and acronyms	X	-	-	-	-	-	-	-	-	-	-
Alternative text input and output	-	X	X	X	-	-	-	X	-	-	-
Translate text	X	-	-	-	-	-	-	-	-	-	-
Control moving elements	-	X	X	X	X	-	-	-	X	X	X
User's protection	X	-	-	-	-	-	-	-	-	-	-
Navigate easily	-	X	X	X	X	-	-	-	X	-	-
Inform users	-	-	X	X	-	-	X	X	X	X	X
Exchange resources	X	-	-	-	-	-	-	-	-	-	-
* A: All users; M: Motor impairments; L: Learning, cognitive, or reading disabilities; B: People with huge visual impairments who use screen readers; LV: Low vision impairments; CB: Colour Blindness; H: Hearing impairments; UA: User agents											

Table 4.9: Benefits Groups: People with Disabilities and Other Users

	MDs restriction*					MDs Environments*					
Improvement	**SS**	**SK**	**TK**	**UT**	**LC**	**SP**	**DC**	**WL**	**DT**	**EF**	**HF**
Do not identify information with colours or shapes exclusively	-	-	-	-	X	X	-	X	-	-	-
Control font style	-	-	-	-	X	X	-	X	-	-	-
Less information	X	-	-	-	-	-	X	-	-	X	-
Reduce input text	-	X	X	-	-	X	X	X	X	-	-
Reduce memory	-	-	-	-	-	-	X	-	-	-	-
Reduce, avoid and check errors	-	-	-	-	-	-	-	-	-	-	-
Identify language	-	-	-	-	-		X	-	-	X	-
Simple language	X	-	-	-	-	-	X	-	-	-	-
Avoid unnecessary images	-	-	-	X	-	-	-	-	-	-	-
Important information	X	-	-	-	-	-	X	-	-	-	-
Knowledge and learning	-	-	-	-	-	-	-	-	-	-	-
Avoid Interruptions	-	X	-	-	-	-	X	-	X	-	-
Specify the status of the conversation and user	-	-	-	-	-	-	-	-	-	-	-
Alternative non-text Information	-	-	-	X		-	X	X	X	X	X
Understand words and acronyms	-	-	-	-	-	-	-	-	-	-	-
Alternative text input and output	-	X	X	X	-	X	X	X	X	X	X
Translate text	-	-	-	-	-	-	-	-	-	-	-
Control moving elements	X	X	X	-	-	-	X	-	X	X	X
User's protection	-	-	-	-	-	-	-	-	-	-	-
Navigate easily	X	-	-	-	-	-	-	-	-	-	-
Inform users	-	-	-	X	-	X	X	X	X	X	-
Exchange resources	-	-	-	-	-	-	-	-	-	-	-

* E: Elderly; F: Foreign student; U: People without experience; SS: Small screen students; SK: Small keyboard; TK: Tactile keyboard; UT: Unsupported technology and switched off images; LC: Limited colour palette; SP: Sunny places; DC: Distracted conditions; WL: Weak light; DT: Environments difficult to type text; EF: Eyes free environments; HF: Hands-free environments

Table 4.10: Benefits Groups: Mobile Device Restrictions and Environments

Elicited requirements and categorisation

Considering previous solutions for people‘s problems and recommendations for people‘s necessities, a list of requirements was elicited and described. In addition, this list was completed extrapolating every selected standard/guideline in Section 4.2 to chat applications for m-learning environments.

Once the final list of requirements was created, they were categorised into groups. As it was explained in previous sections, these categories were: (1) Login; (2) Personalisation; (3) Contacts; (4) Conversations; (5) Messages; and (6) Exchange files. Next, experts reviewed the requirements in order to assure they were categorised and described correctly.

Next sections specify the requirements specified and improved using experts‘ feedback. These requirements are described and grouped by category. Every category includes: a description of the category; a table which summarises the problem identified by users, the related requirement which aims to solve this problem and the provided solutions/recommendations for this problem. Finally, Annexe H specifies each requirement in detail as well as the standard/guideline related to these requirements and the benefits of these requirements.

Login The requirements do not specify how a user could create an account in a system because it is outbound of the research. However, the requirements describe how the access to the system should be created and it is included in the *Login* requirements.

Privacy is really important nowadays and chat applications need to consider accessibility too. Chat applications need to be secure and its access should be controlled using a user name and password. Some users might consider it is very complex because they have to remember their login details. As a result, it is important to make it as simple as possible. The following table, Table 4.11 includes solutions for the users' problems obtained in previous studies and details the requirement which considers it.

Problem	**Req.**	**Solution**
Privacy	L-1	Username and password are used to log into the system.
Forget information	L-1	Provide mechanisms to reset passwords.
Write quickly	L-1	Provide mechanisms which help users typing as less information as possible when they log into the system.
User's errors	L-1	Prevent user errors as much as possible.

Table 4.11: Login: Problems Solved

Some people have problems remembering their passwords and others can have just forgotten them. Users could be allowed to save their login details on their device and to recover their password or user name. Another problem that users have is related to the password input text fields. These input text fields hide the typed information replacing letters with asterisks. Users should be allowed to hide or show their passwords when they are typing their passwords to avoid confusions. Table 4.12 shows the requirement which specifies how to help users access to the system using user name and password.

Code:	L-1
Requirement:	Login
Priority:	High
Classification:	Login
Description:	Protect the access to the system and help users to log into the system.
Recommendation:	(1) **User information:** the user can sign into the system with a password and username. (**Imp.:** *User's protection*) (2) **User errors:** Control, avoid and guide users to solve input errors. For example: sending empty fields or wrong password (***Imp.:*** *Reduce, avoid and check errors*) (3) **User name:** Save at least the last user name accessed to the system. (***Imp.:*** *Reduce memory and Reduce input text*) (4) **Forgot user name and password:** Allow users to recover their forgot passwords and user names. (***Imp.:*** *Reduce memory and Reduce, avoid and check errors*) (5)**Automatic sign in:** Provide mechanism to sign in automatically. (***Imp.:*** *Reduce memory and Reduce input text*) (6) **Hide or show passwords:** Allow hiding or showing passwords when the user does not remember it (***Imp.:*** *Reduce, avoid and check errors*)
Based on:	WCAG_2.0_2.1.1, WCAG_2.0_2.4.3, WCAG_2.0_3.3.1, WCAG_2.0_3.3.1, MWABP_6, ISO_29140_2_6.2.1

Table 4.12: Login (L-1): Login

A sequence diagram - see Figure 4.4 - represents this requirement. The behaviour of the system when the user introduces the user name and password wrongly [alt: User¡¿Ok or Password ¡¿Ok] and when the user recovers the password is shown [ForgotPassword()]. This diagram specifies the system's behaviour in these situations exclusively.

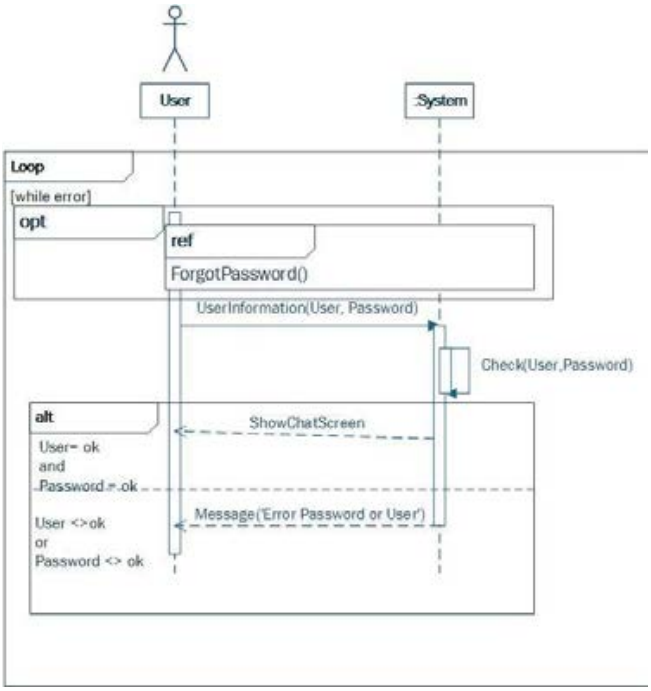

Figure 4.4: Sequence Diagram: L-1. Control Access to the System

Personalisation Users have their own necessities. Chats should allow users configuring the interface to adapt it better to their necessities. Next table, Table 4.13, shows the main solutions to the problems identified previously and the requirement which solves it.

Problem	**Req.**	**Solution**
Unknown language	P-1	Allow users to select the language used in their messages and in the system's interface.
Too much text	P-2	The information shown on the screen could be customised by users.
Modify user's name	P-2	User's name can be customised.
Awkward messages	P-3	Control messages sent by other users.

Table 4.13: Personalisation: problems solved

The Personalisation section included in Annexe H specifies each requirement in detail as well as the guidelines related to these requirements.

Contacts Students have lists of contacts that they can contact with. Some students might have problems managing their list of contacts due to different circunstances. Considering the problems obtained in previous studies, some requirements are defined to solve these problems. Table 4.14 shows the main problems that people identified and how these problems could be solved.

Problem	**Req.**	**Solution**
Search contacts	C-1	Students can search and manage their list of contacts.
Identify their contacts	C-2	Allow students to name, describe, and classify their contacts in order to identify them better.
Colours and Colour Contrast Ratio	C-3	Students can personalise colours used to identify participants and the status of each participant.
Too much text	C-2	Use images to identify students as well as text.
Incomprehensible icons and Understand statuses	C-2	Do not use just colours or shapes to identify the status of each student.
Students' protection	C-4	Allow students to control the reception of messages.

Table 4.14: Contacts: problems solved

Please see Contacts section included in Annexe H which details more information about each requirement as well as the guidelines related to these requirements.

Conversations Chat applications allow students to communicate in conversations. These conversations include two or more participants (students or teachers) which discuss a specific topic. In these conversations, students and teachers exchange their knowledge and their doubts.

Considering previous studies, students experience problems when they communicate with other students and teachers using the chat application. To solve these problems a list of requirements has been specified. The following table - Table 4.15 - shows the problem, the related requirement and the solution for this problem.

Problem	Req.	Solution
Follow the Flow and Rhythm	G-1, G-7	Provide mechanisms to help users Follow the Flow and Rhythm of the conversation.
Write quickly	G-1, G-7	Idem to "Follow the Flow and Rhythm" problem
Too much text information	G-6	Students could manage the Look and Feel of each message in order to just show the information needed.
Unaware of new messages	G-7	Students should be informed when new messages are received.
Many messages on the screen	G-5	The number of messages shown on the screen should be controlled by each user.
Many participants at the same time	G-1, G-4, G-5, G-6, G-9	Provide mechanisms to control speaker designations, control the number of participants per conversation as well as the number of messages and the chronological order of the messages.
Unable to understand conversations	G-2	Provide a list of concepts and abbreviations to help students understand and follow the conversation.
Many unimportant messages	G-10	Allow students to mark and tag important messages in order to retrieve them later easily.
Receive awkward messages	G-11	Allow students to specify when they do not want to receive more messages from a specific contact.
Asynchronous chats	G-12	Provide mechanisms to arrange tutoring dates where students and teachers could collaborate together.

Table 4.15: Conversation: problems solved

The Conversations section included in Annexe H specifies each requirement in detail as well as the guidelines related to these requirements.

Messages Students face problems when they send chat messages. These problems are related to different circumstances. For example, if messages are long, students might have problems understanding and reading them because they have to scroll up and down several times. Other students have problems following the *Flow and Rhythm* of the conversation. Besides, the use of complex language or the use of non-text information could cause problems for some students. These are some examples of problems faced by students. Table 4.16 shows the problems solved in this section and the requirements which solve these problems.

Problem	Req.	Solution
Messages were too long	M-1	Specify Messages‘ maximum text size in order to help students understand the conversation easily.
Write quickly and Follow the Flow and Rhythm	M-1, M-7	Include predefined sentences which could be selected by students and allow students to forward messages to another contact.
Untagged emoticons	M-1	Emoticons should be tagged using a descriptive text.
Language is not understood	M-2, M-3	Specify messages language and allow students to translate it.
Different formats	M-2	Allow students to change output and input formats.
Spelling and autocorrection	M-4	Provide mechanisms to check the spelling for every word.
No tagged elements	M-5	Provide a description for every acronym and abbreviation.
Reception of messages	M-6	Specify the status of each message.
Unimportant information	M-8	Provide mechanisms to skip unimportant information and to allow students navigate quickly between messages.

Table 4.16: Messages: problems solved

Messages section included in Annexe H specifies each requirement in detail as well as the guidelines related to these requirements.

Learning Chapter 3 describes a list of learning features for chat applications basing. Some of these guidelines were related to accessibility only and were included in previous subsections. In this section, learning features are included. The following table - Table 4.17 - summarises the requirements covered in this section as well as the solved problems.

Problem/Feature	Req.	Solution
Learning feature	LE-1	Provide mechanisms to arrange tutoring dates where students and teachers could exchange knowledge.
Memory problem	LE-2	Allow students and teachers to set up tutoring reminders.
Learning feature	LE-3	Files could be exchanged in the chat application between students and teachers.
Learning feature	LE-4	Teachers should be allowed to control the messages shown to the students.

Table 4.17: Learning: Problems Solved

The Learning section included in Annexe H specifies each requirement in detail as well as the guidelines related to these requirements.

4.4.4. Discussion

This study aimed to specify the list of requirements that chat applications for m-learning environments should comply. These requirements will be helpful for designers, analysts and developers when they create accessible chat applications for m-learning environments. The main purpose of this study was to answer the question:

- RQ2: Which requirements are necessary to create accessible chat applications for m-learning environments?

As it was identified in previous studies, people experience accessibility issues when they use chat applications because chat applications have accessibility design barriers and accessibility code barriers. In addition, there are many accessibility standards and guidelines that developers and designers need to follow in order to create accessible chat applications. As a result, designers, developers and analysts might have problems defining and coding accessible software because they need to take into account different resources. This study provided a list of requirements that will help non-accessibility expert designers and developers in the design and development process of accessible chat applications.

The list of requirements **(RQ2)** specified in this study was elicited basing on previous studies identified in this dissertation:

1. Previous problems faced by people with disabilities, elderly people and young adults when they used chat applications *(Chapter 3: Involving Users for Eliciting Accessibility Barriers in Chat Applications)*.

2. Selected standards and guidelines which could be related for chat applications in m-learning environments *(Section 4.3: Identify existing guidelines and standards)* .

Each requirement aimed to solve one problem found in previous studies by users when using chat applications. These requirements are divided into six categories: (1) Login; (2)Personalisation; (3) Contacts; (4) Conversations; (5) Messages; and (6) Learning. These requirements represent the main components that a chat application could have in m-learning environments. Each requirement was explained using natural language in order to make it easy to read and to understand. In addition, the related standards/guidelines which were considered to define this requirement are specified, as well as the problems that each requirement solves and the group of users who will get a benefit of it. Annexe H specifies each requirement in detail as well as the guidelines related to these requirements.

These requirements were created and classified in different functionalities by accessibility experts in order to help designers, developers and analysts to create accessible chat applications which do not have previous accessibility experience and knowledge. This list of requirements will help these professionals to create accessible chat applications for m-learning environments.

However, these requirements need to be understood by designers and developers, who do not know anything about accessibility and did not have previous experience related to accessibility. Because of this, it is important to validate these requirements and get feedback about these requirements; as well as if these requirements could be useful for designers and developers when they want to design or develop a m-learning chat application. Next section shows how these requirements have been validated by accessibility and non-accessibility experts.

4.5. Requirements validation

Software requirements specifications: should correctly define all the software requirements; should not describe any design or implementation details; and should not impose additional constraints on the software [Committee and Board, 1998]. To assure the software requirements specification defines the system and it is valid, it is necessary to validate these requirements according to IEEE Standard [Kotonya and Sommerville, 1998b]. This section specifies how the software requirements specification specified previously was validated using real people.

4.5.1. Research questions

In previous phases of the research, a requirement specification has been specified to cover the requirements that accessible chat applications for m-learning environments should have. However, these requirements have not been validated and should be validated in order to assure they are correct, unambiguous, complete, consistent, verifiable, modifiable and traceable [Committee and Board, 1998].

This research aims to specify if the software requirements specification detailed in the previous section is a good software requirement specification or not. Thus, the research question to answer in this section is:

- RQ3: Are these requirements valid?

The following sections specify how this question was addressed and the method used to conduct the research.

4.5.2. Method

Different techniques can be used individually or in conjunction to validate a software requirements specification. Some of these techniques are: Requirement Reviews; Prototyping; and Test-case generation [Kotonya and Sommerville, 1998b]. In this case, two of these techniques are combined to validate the requirements: (1) requirement reviews; and (2) prototyping.

- Requirement reviews: participants were asked questions about every requirement to point out: potential conflicts, contradictions, errors and omissions observed in the software requirements specification.
- Prototyping: participants integrated each requirement into the design in order to assure these requirements are valid. They created software or paper prototypes to represent specified requirement.

Both techniques are used in order to obtain better results and to assure participants understood correctly the requirements. In addition, both methods are really useful combined, because one provides qualitative data and the other quantitative data. The following subsections specify more in detail the method followed.

Participants

A total of thirteen participants have participated in these studies and depending on the study their background and experience was different.

Software prototype implementation: Three computer science engineering students who did not have previous accessibility knowledge developed three software prototypes.

Expert review: A total of ten accessibility experts performed this study to assure if the software requirements specification was valid. Regarding to their experience, 50% of participants had more than 3 years of experience - see Figure 4.5 - and eight of them considered they were "Extremely" or "Moderately" familiar with accessibility issues- see Figure 4.6.

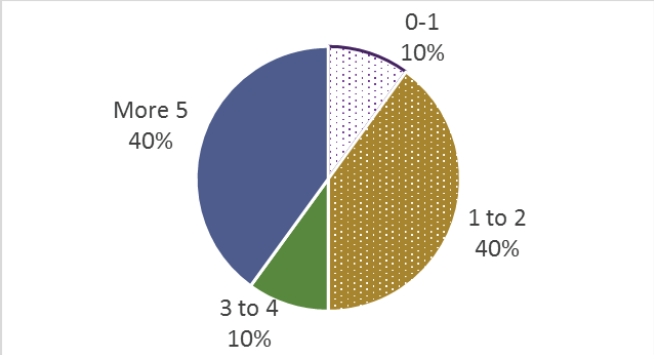

Figure 4.5: Requirements Validation: Expert‘s Experience (Number of Years)

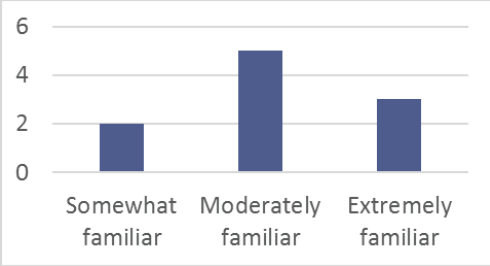

Figure 4.6: Requirements Validation: Expert‘s Accessibility Knowledge

Apparatus

Software prototype implementation: Participants received the requirements defined in the previous phase and they had to integrate them into the design of an accessible software chat prototype. After they finished the implementation of these software prototypes, they had to provide feedback about the difficulties they experienced. This feedback was provided in a paper prototype as well as in their final dissertation.

Expert review: Participants received a structured document which specifies the list of steps each participant had to follow. Each participant had to read each requirement and they had to design the interface of the application in a piece of paper they were provided as well as they had to answer a survey about each requirement.

Design

The research was divided into two main phases: software prototype implementation and expert review.

Software prototype implementation: Firstly, three participants without previous accessibility knowledge reviewed the requirements and then, designed and implemented a software prototype in order to assure if they could create an accessible software chat prototype.

Expert review: Secondly, ten participants who are accessibility experts have reviewed the requirements and designed paper prototypes to validate the software requirements specification.

Procedure

Different methods can be used in software engineering for field studies [Singer et al., 2008] [Runeson and Höst, 2009]. In this research, the conceptual modelling and questionnaires techniques are used to assure this software requirements specification is a good specification.

Software prototype implementation: The software requirements specification was provided for each participant and they had to create a software prototype using these requirements. Firstly, they designed a prototype which included all the requirements and then, they implemented the software prototype using a hybrid application using HTML and CSS or a native Android application. After they implemented the software prototype, they had to fulfil a questionnaire where they had to explain their opinion about the software requirement specification. Finally, they wrote their final dissertations where they had to test if the software was accessible as well as their feedback about the requirements specification.

Expert review: Participants received a structured document which specified the list of steps each participant had to follow. This document included: the list of requirements they had to validate; blank papers to design the requirements; and a questionnaire they had to fill out.

Considering the requirements specified in the previous phase of this study, the requirements were divided into: (1) Login, (2) Contacts, (3) Personalisation, (4) Messages, (5)Learning, (5) Group. Due to time and resource restrictions in this phase, the requirements related to Login, Contacts and Personalisation were not covered and only high priority requirements related to Learning, Messages and Group were covered. These requirements were divided into two different groups: Learning and Messages (7 requirements); and Group (7 Group). The first category Learning and Messages - included those requirements related to learning and sending messages specified in the previous section of this chapter. In contrast, the Group requirements included those requirements which are related to sending messages in a group.

Participants had one hour and thirty minutes sessions to complete the tasks and these sessions were not moderated. These participants did the experiment remotely and their results had to be sent to the organiser. Each person was assigned a group of requirements and for each requirement they had to design a Mockup prototype in a piece of paper to represent how they understand the requirement. Once each requirement was integrated in the design, participants had to fill out a questionnaire considering their opinion about the requirement.

According to IEEE Standard for software Requirements Specifications [Committee and Board, 1998], the characteristics of a good Software Requirements for Specification are: (1) correct; (2) unambiguous; (3) complete; (4) consistent; (5) ranked for important and/or stability; (6) verifiable; (7) modifiable; and (8) traceable. This questionnaire was based on the checklist specified to validate requirements [Sawyer et al., 1997] [Kotonya and Sommerville, 1998b] [Prasad and Verma, 2016]. It is important to remark that as the participants received only a group of requirements. They did not reviewed the whole list of requirements, because it was too long. These questionnaires included questions related to how the document was structured but these questions were not covered in the questionnaire. The following questions were asked for each requirement:

- **Requirements complete:** How complete is the requirement? 1 (No complete) to 5 (Complete)
- **Requirements complete:** Is there any information missing from individual requirement descriptions? ( ) Yes ( ) No ( ) I dont know

- **Requirements consistent:** How consistent is the requirement? 1 (No consistent) to . 5 (Consistent)
- **Requirements consistent:** Do the descriptions of different requirements include contradictions? ( ) Yes ( ) No ( ) I dont know
- **Requirements comprehensible:** How comprehensible is the requirement? 1 (No comprehensible) to 5 (Comprehensible)
- **Requirements comprehensible:** Can you understand the requirement? ( ) Yes ( ) No ( ) I dont know
- **Requirements ambiguous:** How ambiguous is the requirement? 1 (No ambiguous) to 5 (Ambiguous)
- **Requirements ambiguous:** Are there different possible interpretations of the requirement? ( ) Yes ( ) No ( ) I dont know
- **Requirements ambiguous:** Could readers from different backgrounds make different interpretations of the requirement? ( ) Yes ( ) No ( ) I dont know
- **Requirements unambiguously identified:** Is the requirement unambiguously identified? ( ) Yes ( ) No ( ) I dont know
- **Requirements conformance to standards:** How the requirement conforms to defined standards? 1 (No conformance) to 5 (Conformance)

Finally, once they have designed the requirements and fulfilled the questionnaires, they sent the questionnaires and the Mockup designs to the organiser who analysed the data.

Data collected

Two type of data was collected during these two phases: quantitative and qualitative data. Quantitative data was obtained from the questionnaires filled out by users during both phases. And qualitative data was obtained from the software and paper prototypes developed and designed by participants as well as further information that participants explained in the comments sections of the questionnaires and in the dissertations written by the students.

Data analysis

After the data was collected, the data was analysed in order to answer the specified research question. Statistic techniques were applied for the obtained quantitative data in order to obtain information about the participant‘s opinions. Regarding qualitative data obtained from the prototypes and from the comments explained by the participants, software prototypes were reviewed in order to assure requirements were implemented accurately. In contrast, paper prototypes were analysed to understand if the requirements were correctly interpreted by participants. Finally, participant‘s opinions were analysed to identify new improvement‘s recommendations in the proposed requirements.

4.5.3. Results

These two studies validated the requirements in two different ways: from the perspective of people who do not have previous accessibility knowledge (Software prototype implementation study) and from the perspective of people who know about accessibility (Accessibility Expert review study). The results obtained from each study are specified in detail next.

Software prototype implementation:

Three participants read the requirements specified in the previous section and they had to design and code a mobile software prototype which included these requirements. Finally, participants had to validate the software prototype created in order to assure they have created an accessible chat application.

The interfaces of each prototype are analysed to determine if the requirement has been implemented correctly or not and if the requirement has been understood by the participant.

For example, if the Login page of each prototype is analysed - see Figure 4.7, it can be identified that users have included the specifications indicated in the requirement. In this case, the requirement specifies: users should use a user name and password to access to the system; errors should be shown to users; users should be allowed to recover their password and user names; as well as users should be able to hide or show passwords.

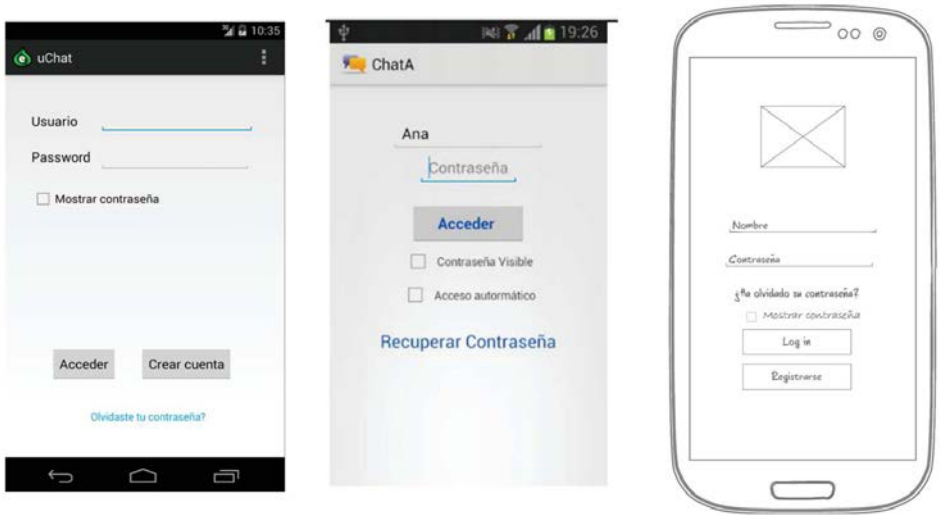

Figure 4.7: Prototype Screenshots - Login Page

Other requirements that can be compared are those related to personalise the interface of the application and adapt it to user's necessities. For instance, students should be allowed to specify the language of the messages (Requirement P-1); and students can customise their personal information (Requirement P-2). Figure 4.8 represents the designs of each participant in which the requirements were applied.

Due to time limitations and constraints, participants did not implement all requirements specified (An average of 15.67 requirements were implemented by participants $\tilde{X}$=15.67). However, participants had to explain using their own words the requirements that have not been implemented in order to assure they were understood or not.

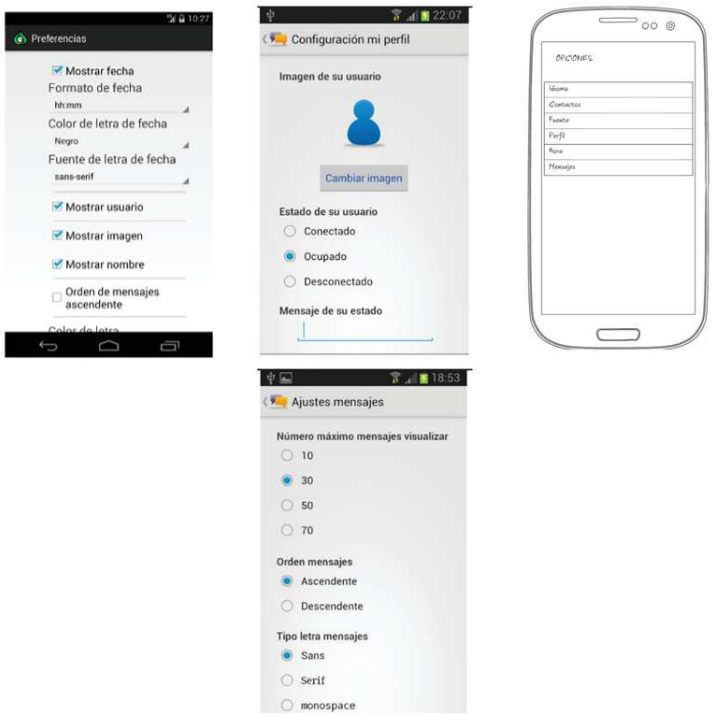

Figure 4.8: Prototype Screenshots - Personalisation Page

To summarise the number of requirements that have not been understood or implemented by the participants, the following table - see Table 4.18 - shows the total number of requirements that have been understood and implemented by the participants.

	Participant 1		**Participant 2**		**Participant 3**	
	Imp.	**Und.**	**Imp.**	**Und.**	**Imp.**	**Und.**
Total Yes	12	30	19	29	16	27
Total No	19	1	11	0	15	0
Total Partially	0	0	1	2	0	4
*** Imp. = Implemented; Und. = Understood**						

Table 4.18: Software Prototype Implementation - Comparison Results - Implementation Summary

An average of 28.67 requirements were understood by the users ($\tilde{X}$=28.67; 92.5% of requirements). Depending on the participants, they understood or implemented different requirements. The following table - Table 4.19 - shows if the requirement has been implemented, if the requirement covers the information described as well as if the requirement was understood.

Analysing those requirements that were not understood by users, the requirement that has not been understood by any user is the "G-8: Control reception of messages". This is comprehensible because this requirement is a new requirement that participants have not seen or used before. Another requirement that has not been partially understood by users is the requirement "M-5: Tag abbreviations". Participants did not know the purpose of this requirement. This might be because this is a very specific requirement which is very technical. People who do not have accessibility background will have problems understanding this requirement.

		Participant 1		Participant 2		Participant 3	
Req.	**Req. Description**	**Imp.**	**Und.**	**Imp.**	**Und.**	**Imp.**	**Und.**
L-1	Login	Yes	Yes	Yes	Yes	Yes	Yes
P-1	System and Message's language	Yes	Yes	Yes	Yes	Yes	Yes
P-2	User information	Yes	Yes	Yes	Yes	Yes	Yes
P-3	User status	Yes	Yes	Yes	Yes	Yes	Yes
C-1	Search contacts	No	Yes	No	Yes	No	Yes
C-2	Contact identification	No	Yes	Yes	Yes	No	Partially
C-3	Customise statuses	Yes	Yes	Yes	Yes	No	Yes
C-4	Block students	No	Yes	No	Yes	Yes	Yes
G-1	Group conversations	No	Yes	Yes	Yes	Yes	Yes
G-2	Add new participants	No	Yes	Yes	Yes	Yes	Yes
G-3	Glossary of terms	No	Yes	Yes	Yes	No	Yes
G-4	Message order configuration	Yes	Yes	Yes	Yes	Yes	Yes
G-5	Configure the information shown per message	Yes	Yes	Yes	Yes	No	Yes
G-6	Configure message layout	Yes	Yes	Yes	Yes	Yes	Yes
G-7	Control number of messages shown on the screen	Yes	Yes	Yes	Yes	Yes	Yes
G-8	Control reception of messages	No	No	No	Partially	No	Partially
G-9	Mute conversation alerts	No	Yes	No	Yes	No	Partially
G-10	Tag important messages	No	Yes	Yes	Yes	Yes	Yes
G-11	Manage conversations	No	Yes	No	Yes	Yes	Yes
M-1	Send messages	Yes	Yes	Yes	Yes	Yes	Yes
M-2	Language of sentences	Yes	Yes	Yes	Yes	Yes	Yes
M-3	Convert messages	No	Yes	No	Yes	No	Yes
M-4	Check spelling	No	Yes	Yes	Yes	No	Yes
M-5	Tag abbreviations	No	Yes	No	Partially	No	Partially
M-6	Message status	Yes	Yes	Yes	Yes	Yes	Yes
M-7	Forward messages	No	Yes	Yes	Yes	Yes	Yes
M-8	Skip messages	No	Yes	No	Yes	No	Yes
LE-1	Manage tutoring dates	No	Yes	No	Yes	No	Yes
LE-2	Setup reminders	No	Yes	No	Yes	No	Yes
LE-3	Exchanging files between users	No	Yes	Partially	Yes	No	Yes
LE-4	Provide mechanisms to control the messages shown to the students	No	Yes	No	Yes	No	Yes

Table 4.19: Software Prototype Implementation - Comparison Results

To summarise, participants without previous accessibility knowledge understood the requirements. Those requirements that were not understood by participants were improved and rephrased in order to make them clearer and easier to understand. However, it is important to validate these requirements by experts. Next section specifies the results obtained after the accessibility experts reviewed the requirement specification.

Expert review:

A total of ten accessibility experts participated in the analysis of the high priority requirements related to: Messages, Learning and Groups. These participants created a design - Figure 4.9 shows the design made by one of the experts - which represents the requirements assigned to each participant and then, they answered a survey for each requirement to specify if the requirement was valid or not. After analysing the designs that experts created to represent the selected requirements, it can be concluded that experts understood the requirements assigned and they were able to represent this information in their designs

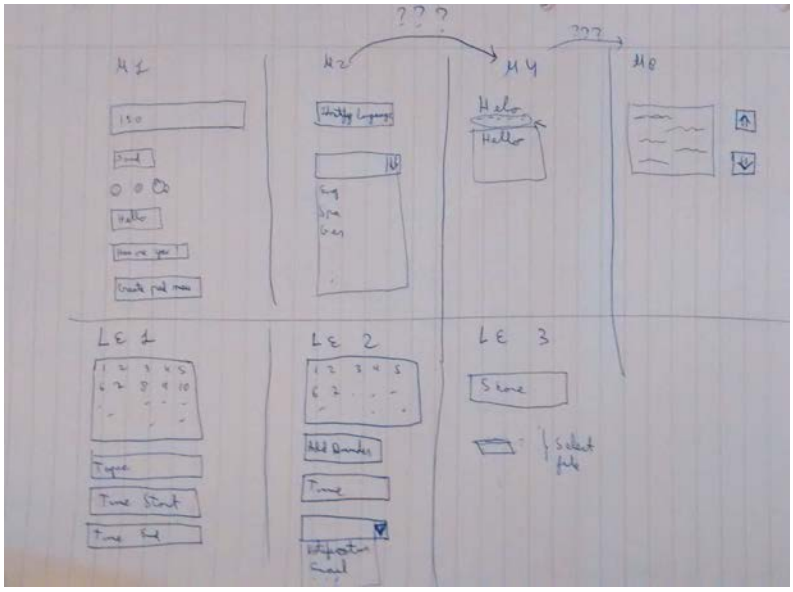

Figure 4.9: Example of Design Created by the Expert

To analyse the designs and assure the designs covered the information specified in each requirement, every design provided by the experts was analysed. It was determined if the requirement was included in the design (Yes, Partially, No); and it was analysed if the requirement was understood correctly (Yes, Partially, No). For example, if the requirement was represented in the design but the design does something different than expected, the requirement was categorised as not understood because a good representation of the requirement was not done. The following table - Table 4.20 - shows the results obtained per requirement.

Most experts understood the requirements assigned (90 % of requirements were understood by experts) because they were included correctly in their designs. The requirements which were not understood correctly by experts (2 out of 5) were the G-8 Control reception of messages, where experts had problems understanding this requirement. This means this requirement needs to be described better in order to make it clearer for them; and similar results were obtained for the LE-2: Set up reminder requirement.

	Design complete			Design understood		
	Yes	**Partially**	**No**	**Yes**	**Partially**	**No**
G-1	5	0	0	5	0	0
G-2	3	2	0	5	0	0
G-3	4	1	0	4	1	0
G-4	5	0	0	5	0	0
G-8	3	2	0	3	2	0
G-10	5	0	0	5	0	0
G-11	4	0	1	4	0	1
M-1	5	0	0	5	0	0
M-2	4	1	0	5	0	0
M-3	5	0	0	5	0	0
M-4	5	0	0	5	0	0
LE-1	4	1	0	3	2	0
LE-2	4	1	0	5	0	0
LE-3	4	0	1	4	0	1
Total	**60**	**8**	**2**	**63**	**5**	**2**

Table 4.20: Requirement Validation: Designs‘ Analysis

These results are corroborated after analysing the answers provided by the participants in the questionnaires completed after designing each requirement. Users had to rate how complete, consistent, comprehensible, ambiguous, and unambiguously identified were the requirements. In addition, participants had to identify the requirement conformance against the standards and guidelines. For each question, they had five answers they could select: Not at all (1); Slightly (2); Moderately (3); Very (4); and Extremely (5). The next table - Table 4.21 - shows the results obtained from this survey.

Analysing the results provided by the experts, it can be concluded that most of the requirements were understood by participants.

Experts had to specify how incomplete the requirements were. All requirements were rated in average as Not at all incomplete (1) or Slightly incomplete (2). The requirement that was more complete was the G-3 Configure the information shown per message requirement ($\tilde{X}$=1.2 and σ=0.4). In contrast, the more incomplete requirements were were M-2 Language of sentences requirement ($\tilde{X}$=2.0 and σ=0.7) and LE-2 Set up reminders requirement ($\tilde{X}$=2.0 and σ=1.0). Unfortunately none of the experts specified any comment about these requirements. However, if the designs are analysed, G-3 requirement was partially implemented by one of the experts and consequently, the requirement was not understood.

In addition, users had to specify how comprehensible and ambiguous the requirements were. M-3 Convert messages requirement was marked as the most comprehensible ($\tilde{X}$=4.6 and σ=0.9) and the G-3 Configure the information shown per message requirement was marked as the less ambiguous ($\tilde{X}$=1.0 and σ=0.0). This corroborates the previous results because the less incomplete requirement was the G-3 requirement. In contrast, the less comprehensible requirements were G-8 Control reception of messages requirement ($\tilde{X}$=3.4 and σ=1.3) and LE-3 Exchanging files between users requirement ($\tilde{X}$=3.4 and σ=0.9). This confirms the previous results obtained from the design study where participants confirmed G-8 requirement was not understood by users.

Finally, if the results of both groups are compared, both groups of participants under-

stood most of the requirements (Non-Experts: 92.5%; Experts: 90%). The figures are very similar and this means both groups did not experience many difficulties understanding the requirements' specification.

	Incomp.		Incons.		Compreh.		Amb.		Amb. - Back-ground		Amb. Identifi-cation		Not conf.	
	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ	$\bar{X}$	σ
G-1	1.4	0.5	1.0	0.0	4.0	0.7	1.4	0.5	1.4	0.5	1.2	0.4	1.6	0.9
G-2	2.0	1.2	1.4	0.5	4.4	0.5	1.2	0.4	1.2	0.4	1.4	0.5	1.0	0.0
G-3	1.2	0.4	1.2	0.4	4.2	0.4	1.0	0.0	1.0	0.0	1.6	0.9	1.2	0.4
G-4	1.4	0.5	1.2	0.4	4.0	0.0	1.4	0.5	1.4	0.5	1.6	0.5	1.4	0.5
G-8	1.4	0.9	1.2	0.4	3.4	1.3	1.2	0.4	1.2	0.4	1.2	0.4	1.6	1.3
G-10	1.8	1.3	1.4	0.5	4.4	0.5	2.2	1.3	2.2	1.3	1.6	0.9	1.4	0.5
G-11	1.8	0.8	1.4	0.5	4.4	0.5	1.5	1.0	1.5	1.0	1.2	0.4	1.4	0.5
M-1	1.8	0.4	1.2	0.4	4.4	0.9	1.8	0.8	1.8	0.8	1.4	0.5	1.0	0.2
M-2	2.0	0.7	1.6	0.9	4.0	0.0	1.8	0.8	1.8	0.8	2.0	1.2	1.2	0.3
M-3	1.6	0.9	1.4	0.5	4.6	0.9	1.4	0.5	1.4	0.5	1.6	0.5	1.4	0.7
M-4	1.4	0.5	1.0	0.0	4.2	0.8	2.0	0.7	2.0	0.7	2.0	0.7	1.4	0.3
LE-1	1.6	0.5	1.0	0.0	3.6	0.5	2.2	1.3	2.2	1.3	2.0	0.0	1.4	0.1
LE-2	2.0	1.0	1.0	0.0	3.8	0.8	1.8	1.3	1.8	1.3	1.8	0.8	1.2	0.1
LE-3	1.4	0.5	1.4	0.5	3.4	0.9	2.0	0.7	2.0	0.7	2.0	1.0	1.2	0.3
Incomp.= Incomplete; Incons.=Inconsistent; Compreh.=Comprehensible; Amb.=Ambiguous; Conf.=Conformance														

Table 4.21: Requirement Validation: Questionnaire Analysis

4.5.4. Discussion

The main aim of this research was to determine if the requirements specified in the previous section - Section 4.4.2 - are valid or not.

- RQ3: Are these requirements valid?

To assure this, two different research studies were conducted in order to validate these requirements **(RQ3)**. Firstly, the requirements were validated from the perspective of people who do not know anything about accessibility. Participants were computer engineer students who did not knave previous accessibility knowledge. Secondly, the requirements were validated by experts. These accessibility experts validated the requirements in order to assure the specified requirements are valid or not.

Non accessibility experts read the requirements and implemented accessible chat applications for mobile devices. They read every requirement and they designed and coded the requirement. Due to time limitations, they were not able to cover all requirements but they had to specify if they understood the requirement or not.

Analysing the results from people without previous accessibility background, people understood the majority of the specified requirements (92.5% were understood) - see Table 4.20. However, there were a small number of requirements that were not understood (2 out of 31) by the participants. The requirement that has not be understood by any user is the "G-8: Control reception of messages". This is comprehensible because this requirement is a new requirement

that participants have not used before. The requirement description was improved. Chapter 5 shows how the requirement has been specified using different HCI and SE methods to describe these requirements and make it clearer and easier to understand.

Another requirement that has been partially understood by users is the requirement "M-5: Tag abbreviations". Participants did not know the purpose of this requirement. This might be because this is a very specific requirement which is very technical. People who do not have accessibility background will have problems understanding this requirement.

The requirements were validated by people without previous accessibility knowledge but due to the number of participants that participated in this study (three participants) and their previous accessibility background, their results could not conclude the requirements were valid. Because of this, a group of accessibility experts (ten participants) validated the requirements from the perspective of experts who have previous accessibility background.

The results of the expert accessibility review show that 90% of the requirements were understood. In addition, they had difficulties understanding the G-8: Control reception of messages requirement. This means this requirement was not described correctly and needed to be improved. Otherwise, designers and developers would not be able to implement it.

Comparing the results of both groups, participants regardless of the group understood most of the requirements (Non-Experts: 92.5%; Experts: 90%) - see Table 4.21 and Table 4.20. The figures are very similar and this means both groups did not experience many difficulties to understand the requirements' specification.

Both studies have helped identifying problems regarding to: inconsistencies, ambiguities and problems of understanding. Then, the requirements have been improved and rephrased in order to make them clearer and easier to understand. In addition, these studies showed these requirements are valid and that they can be understood and used by people from different backgrounds: people with and without accessibility knowledge. This means requirements can be used by the accessibility and non-accessibility community to create accessible chat applications for m-learning environments.

4.6. Conclusions

The creation of accessible chat applications for m-learning environments is an arduous task for designers and developers if they do not know anything about accessibility. Because of this, most of the chat applications that are being used currently in m-learning environments are not accessible and people with and without disabilities could face accessibility barriers when they use these applications - see Chapter 3.

Designers and developers can use standards and guidelines in order to make their designs and code accessible. Currently, there is a huge number of standards and guidelines which are applicable and related to accessible chat applications in m-learning environments - see Section 4.3. These standards and guidelines are difficult to read and understand by developers and designers [Smith, 1986]; so, it is possible that even if these guidelines are applied in the design and development processes, inaccessible chat applications for m-learning environments could be created.

This research aimed to solve these issues and the following questions were addressed. Besides, the conclusions obtained in each study are explained in detail next.

RQ1: Which are the main standards and guidelines related to accessibility, mobile learning environments and chat applications? This study identified the standards and guidelines which are more relevant and related for accessible chat applications in m-learning environments. Researchers identified the main standards and guidelines related to this topic referenced and published in papers, conferences, journals, consortium, related groups of work, etc. A total of 62 standards/guidelines were identified and they were analysed later to specify if they could be applicable to accessible chat applications for m-learning environments. After analysing every standard/guideline, researchers selected twelve standard/guideline which were the most related and relevant to accessible m-learning chat applications. Finally, these selected standards and guidelines were compared in order to specify which of them were related to accessibility, m-learning, mobile, etc - see Table 4.6.

After analysing these selected standards and guidelines, it can be concluded that they are not fully related to accessible chat applications in m-learning environments because none of them were related to: learning environments, mobile devices, accessibility, interface and content, CSCL and were precise. For example, they can be applied to accessible learning, or m-learning but there was not any standard or guideline which was fully applicable to accessible chat applications in m-learning environments. It means designers and developers need to read every related standard or guideline, understand it and extrapolate it to m-learning chat applications. In this process, designers and developers might do mistakes or misinterpretations which can lead to create inaccessible chat applications [Smith, 1986].

Furthermore, these standards and guidelines do not usually involve people with disabilities when they were specified. This means these standards and guidelines do not include all the necessities that people with disabilities need when they use these applications in m-learning environments - see Chapter 3.

Because of these previous reasons, current previous standards and guidelines might not be enough to create accessible m-learning chat applications. Requirements are usually used by designers and developers when the are creating their designs or code [Jacobson et al., 1999]. Then, it would be useful for them to specify the requirements that accessible m-learning chat applications should have because they could use them to design and develop these applications. As a result, the second question of this research was to identify the requirements that accessible chat applications should comply in m-learning environments basing on these standards and guidelines as well as specifications indicated by users in the previous section - see Chapter 3.

RQ2: Which requirements are necessary to create accessible chat applications for m-learning environments?

In this research, it was elicited and specified the main accessibility requirements that m-learning chat applications should include in order to be accessible for people with and without disabilities.

To elicit these requirements, previous people‘s necessities obtained in former research work - see Chapter 3 - and the standards and guidelines selected in the previous section - see Section 4.3 - were used to provide solutions to the problems that people face when they use chat applications in m-learning environments.

A total of 31 requirements were elicited. These requirements were divided into six groups: (1) Login, (2) Personalisation, (3) Contacts, (4) Conversations, (5) Messages, (6) Learning.

For every requirement, the requirement was explained and defined using natural language, as well as the standards and guidelines that this requirement is based on. In addition, for each requirement, the problems solved are specified. Annexe H shows the full list of requirements that have been elicited in this research as well as their descriptions and UML diagrams which represent their interaction.

These requirements have been read and validated by three experts but they needed to be validated by real people who could use these requirements to design and develop accessible chat applications for m-learning environments. The following phase of this research aimed to validate these requirements with real people in order to assure they are valid.

RQ3: Are these requirements valid? The requirements specified previously could be useful for designers and developers but it was necessary to validate them with real people in order to assure they were valid.

Accessibility and non-accessibility experts helped in the validation of these requirements to assure these requirements are valid. Two different phases were conducted in order to validate these requirements. Firstly, three participants without previous accessibility knowledge designed and developed a software application using the requirements specified previously. And secondly, ten accessibility experts read the high priority requirements and answered a survey for each requirement as well as designed the interface of accessible chat applications using these requirements.

After conducting both phases, the results identified most experts were able to understand most of these requirements (90% of requirements) - see Table 4.20 and Table 4.21 . In addition, people who did not have previous accessibility knowledge (92.5%) were able to use these requirements to design and code accessible chat applications for m-learning environments - see Table 4.18.

Some requirements - 3 out of 31 - were difficult to understand by experts or novices - e.g. requirement related to control the reception of messages - but the feedback provided by experts and novices was used to improve the requirements and make them easier to understand and read by people.

To conclude, the elicited requirements in this chapter are understood by people and are useful to create accessible chat applications. These requirements will help designers and developers to create accessible m-learning chat applications without understanding and taking into account standards and guidelines which are related to accessibility and learning environments. The design and development processes will be easier to complete and accessibility errors will be reduced. As a result, final users will face fewer accessibility barriers when participating in learning conversations using chat applications.

Chapter 5

A New Functionality for Improving m-learning Chat Application's Interaction

After eliciting the main problems that people face when they use a chat application and specifying guidelines to create accessible chat applications, an improvement to help users communicate better using the chat application is provided. This chapter is focused on propose a new functionality to improve users interaction related to one of the most common problems they face using chat applications: the *Flow and Rhythm* problem. In the previous chapter, the list of requirements needed to create accessible m-learning chat applications was elicited. One of these requirements was related to help users to control and follow the chat's *Flow and Rhythm* easily. However, this functionality needs to be validated with real users in order to assure it is useful in real environments.

In this chapter, a User Centered Design (UCD) approach is followed to validate the functionality with the involvement of real users in order to confirm the usefulness of this new functionality. This new functionality is so called *Pause Autorefresh* and it is proposed to allow users pause the reception of new messages when they feel overwhelmed because they are receiving many messages at the same time and they cannot read or reply them.

The following sections identify influences from previous work as well as the research questions that will be answered in this study. Then, the UCD phases followed to conduct this research are explained in detail: (1) Research (Confirm this functionality could be useful for users); (2) Design (Design how the functionality could be implemented); (3) Test (Confirm with users this design and how it could be improved); (4) Adapt (Implement those modifications and finally validate the functionality with users).

5.1. Influences from previous work

The *Flow and Rhythm* problem provokes a lot of barriers for users and it has been tried to be addressed before. After reviewing former research studies and current chat applications, some applications were found which included a feature to help users *Follow the Flow and Rhythm* of the conversation. For example, Moodle creates an accessible chat application which refreshes messages when the user presses the refresh button. ATutor allows users to specify the time slot to refresh messages. Besides, Skype allows users to control their state and select *Busy*. This state allows users to not receive more messages until the user changes his or her status. Another accessible chat created by [Melnyk, 2014] allows users access to

read messages by screen reader users but this is focused on screen reader users only. However, these features do not allow users to decide when they do not want to receive messages and other participants are not informed about user's status.

The *Pause Autorefresh* functionality could help people to interact with chat applications because they will be able to control the reception of new messages. Furthermore, all participants are informed about the status of each user. As a result, all users are informed when someone has used this this new functionality. Next Table 5.1 compares previous studies with the *Pause Autorefresh* proposal of this Ph.D.

Approach	Chat	Inform other users about my status	Show myself my status	User control it	Previous Users' Opinions *
Change state to busy	Skype and Gmail	Yes	Yes	Yes	—
Refresh time	Atutor	No	No	Yes	Two of the interviewed people specified that it could be interesting to allow them control the time of autorefreshing.
Manual refresh	Moodle	No	No	No	One of the interviewed people specified that it is not easy because he had to press the button continually
Shortcuts to read messages by screen readers	Accessible Chat Interface [Melnyk, 2014]	Yes	Yes	Yes	In Melnyks research, users specified it could be helpful but it is useful for screen reader users .
Pause reception of messages	**Ph.D. Contribution**	**Yes**	**Yes**	**Yes**	**Users with and without disabilities have specified that it could be useful for them**
* Opinions based on Previous studies conducted in this Ph.D. research					

Table 5.1: Previous solutions to control the reception of messages. Comparison with the *Pause Autorefresh* functionality

This study focuses on the new functionality, *Pause Autorefresh*. To validate this proposal, the new functionality is evaluated with the involvement of real users to address the following research questions.

5.2. Research questions

Previous phases have detected that users experience accessibility barriers when they use chat applications. One of the most common problems that people face is related to the *Flow and Rhythm* problem. Every analysed group in previous phases of this thesis - Chapter 3 -

had problems following the *Flow and Rhythm* of the conversation because of different reasons such as: problems writing quickly or problems reading quickly.

This study aims to create a functionality which helps users to interact with the chat application and avoid problems related to the *Flow and Rhythm*. Next research questions will be addressed in the study.

- RQ1: Is the *Pause Autorefresh* functionality useful?
- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?
- RQ3: Could users, who do not use the *Pause Autorefresh* functionality, be bothered?

To address these questions, a UCD approach will be followed. It means the study will: research user necessities; design the prototype; adapt the prototype basing on the user's necessities; and measure if the new feature is useful for users or not. Next chapters will describe how these studies were conducted and the results obtained after each study was conducted.

Figure 5.1 shows a summary of how the study was carried out and Annexe A shows the UCD approach followed. In the next section, this feature is formalised and explained in detailed.

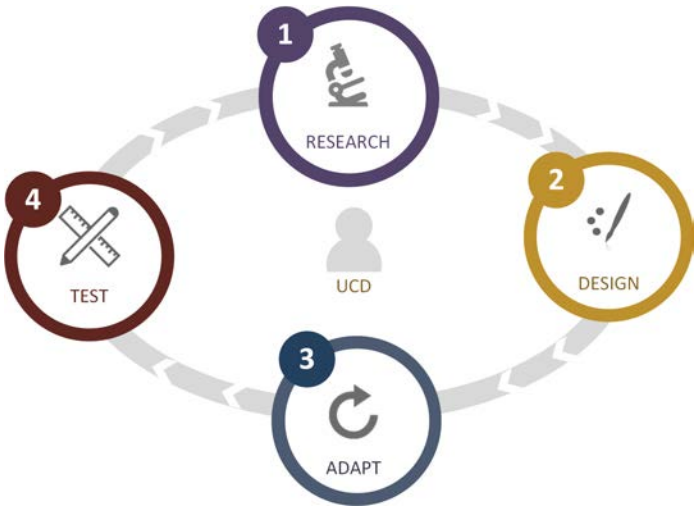

Figure 5.1: User Centered Design Approach

5.3. *Pause Autorefresh* functionality: Research phase

In previous chapters, a proposal to improve chat application interaction and help people follow the *Flow and Rhythm* of the conversation was created. The *Pause Autorefresh* functionality could help people to read and write messages quicker and easier. The main aim of this study is to obtain a user's opinion about this new functionality.

As it has been explained before, this research follows a UCD approach and it is enshrined in the first phase: Research. Next sections specify how this study was conducted and the results found.

5.3.1. Research questions

This study aims to obtain user‘s opinions about the *Pause Autorefresh* functionality before it is implemented and before they use it in a real situation. The study aims to answer the following research questions:

- RQ1: Is the *Pause Autorefresh* functionality useful?
- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?
- RQ3: Could users, who do not use the *Pause Autorefresh* functionality, be bothered?

In this case, the results will be illustrated before the feature is tested in real environments. This study helps to define the functionality and to continue or not with the study as well as modify those aspects the user thinks need to be immproved.

5.3.2. Method

Participants provided their opinions about the *Pause Autorefresh* functionality in a hypothetical situation. People with disabilities expressed their opinion when they used this new functionality. However, it is important to analyse if the new functionality is useful for users without disabilities and if users with and without disabilities could interact in the same chat application. Thus, a similar study is conducted with people without disabilities in order to know their opinion about the new functionality in a hypothetical situation.

Different methods (Questionnaires and Interviews) were used in this research to obtain people‘s opinions about this new interaction. Next sections explain the participants, apparatus, design, procedure and the kind of data collected as well as the data analysis conducted.

Participants

People with disabilities, elderly people and young adults without disabilities participated in this study.

People with disabilities People, who participated in the study described in the Chapter 3, participated in this study too. They participated in interviews (11 people) and questionnaires (45 people) to help us understand their opinion about the new functionality.

People without disabilities: Elderly people and Young adults In this study, elderly people and young adults who participated in previous studies participated in this study too. As a result, a total of 117 elderly and young adults participated in this study.

Apparatus

As it was explained before, questionnaire and interview methods were conducted in order to obtain people‘s opinions. Each method had different apparatus and they are explained next:

Questionnaires Forums, blogs and email lists related to accessibility were used to obtain retrieve surveys. This was helpful to identify the problems that people without disabilities could face. The questionnaires were hosted in a server and they were available for six months.

Before the questions were asked, a scenario was explained to the user in order to specify the context. This scenario was different for people with and without disabilities.

People with disabilities were explained the following scenario:

> *You are using a chat application. You are sending messages to another user, the other user writes many messages at a time and you could feel overwhelmed because of this. Then, you decide to pause the reception of new messages.*

People without disabilities were explained the following scenario:

> *You are using a chat application. You are sending messages to your friend, your friend feels overwhelmed because you are sending many messages at a time. Then, the user decided to pause the reception of new messages.*

Interviews An interview script was created with the semi-structured interviews and users were explained a scenario. This scenario was similar to the scenario that people with disabilities received.

Design

As it was explained before, people with and without disabilities participated in this study. However, the methods used for both groups were not the same. Some participants with disabilities participated in interviews and other people with disabilities filled questionnaires. With regard to people without disabilities, they just filled questionnaires.

Questionnaires Two questionnaires were created: one questionnaire was for people with disabilities and the other one was for people without disabilities. People with disabilities were asked questions from the perspective of a person who would use the *Pause autorefresh* functionality. In contrast, people without disabilities were asked how they would feel if someone else used the *Pause autorefresh* functionality and if they would use it.

The questionnaire used for people with disabilities can be found in Annexe E and the questionnaire used for people without disabilities can be found in Annexe F.

Interviews Semi-structured interviews were conducted following a script with a list of questions. These questions were similar to the questions used in the questionnaire section. Users were asked questions from the perspective of a user who uses the *Pause autorefresh* functionality. The questions used in the interviews are included in Annexe D.

Procedure

Depending on the method used to obtain user‘s opinions, the procedure was different - see Figure 5.2. These procedures are described next:

Questionnaires The questionnaire used to obtain the opinions of people with disabilities was composed of four questions. They were asked if this functionality could be useful for them as well as if they could feel ashamed if they used it. Finally, they were asked about the behaviour of the new functionality.

In contrast, people without disabilities were asked a total of ten questions. In these questions, they were asked if they could feel bothered when someone used this functionality as well as if they would use it. Also, they were asked about the behaviour of the new functionality.

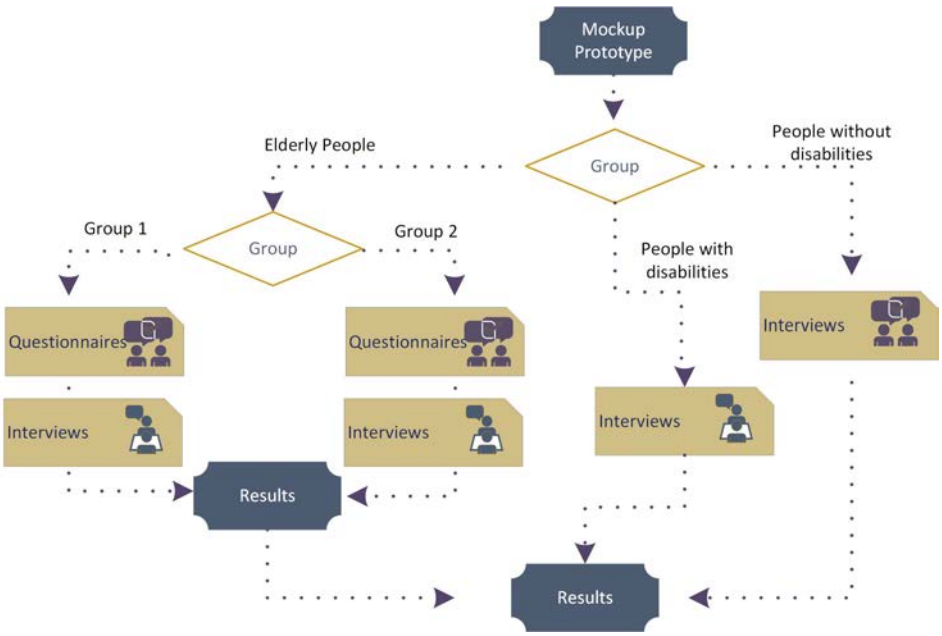

Figure 5.2: Procedure - UCD - Research Phase

The questionnaire was distributed among different forums and blogs in order to obtain as much opinions as possible. The data collection process was open for six months and the respondents were random respondents who spent twenty minutes to complete the questionnaire.

Interviews The moderator asked questions to the participant for one or two hours, this included the questions used in the previous research as well. Each interview was recorded to be analysed later. All asked questions were opened questions and users could explain their opinions in detail.

Data collected

After applying these methods, qualitative and quantitative data was obtained. Quantitative data was obtained mainly from questionnaires because users were able to select one option from a list. In contrast, qualitative data was obtained from interviews because users could explain their opinions in detail.

Data analysis

The data analysis process consisted on analysing the data obtained from the interviews and questionnaires. Depending on the method conducted, the data was analysed in a different way:

Interview Most of the information obtained in these interviews was qualitative data and qualitative methods were applied. Each highlight obtained in the interviews was analysed and grouped in order to obtain patterns of user‘s behaviours.

Questionnaire The data of each questionnaire was analysed to check if the data was enough robust or not. Thus, it was checked if the questionnaires were whole-completed and fulfilled properly. The uncompleted questionnaires with more than one question were not taken into account for the survey and uncompleted questionnaires with one question were filled with the

most common answer to this question. Finally, statistics of each question and answers were obtained in order to understand user's problems.

5.3.3. Results

This section specifies the opinions of people with disabilities and people without disabilities with regard to the *Pause Autorefresh* functionality.

People with disabilities

Users were asked about the behaviour of the chat application after they used the *Pause Autorefresh* functionality. Users were able to specify what should happen later and what the other user should do. The answers could be:

- AP1: The other user can write more messages and they will be showed together when I renew the conversation.
- AP2: The other user can write more messages and they will be showed one by one when I renew the conversation.
- AP3: The other user cannot write more messages until I decide to renew the conversation.
- AP4: The other user can write only one message more and will be showed when I renew the conversation.
- AP5: The other user can write a new message but it cannot be sent until I decide to renew the conversation.

The most selected options were (AP1, AP2 and AP4). Users prefer to not disturb other participants and they selected those options that allowed other participants write messages when the user pressed the *Pause Autorefresh* button. In addition, users prefer messages to be shown in one go (AP1) over one by one (AP2) - see Figure 5.3.

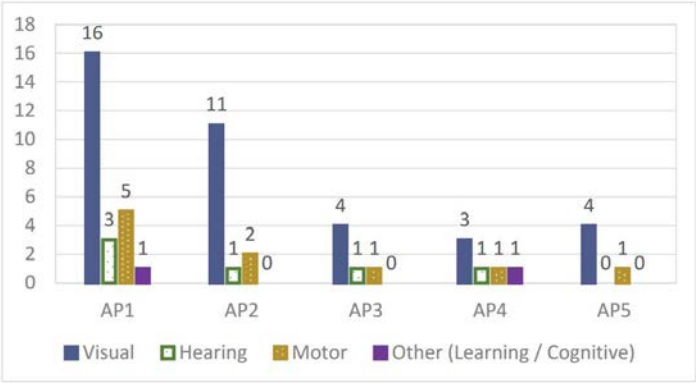

Figure 5.3: Selection after *Pause AutoRefresh* the conversation per Disability

Users were asked if the *Pause Autorefresh* functionality could be useful for them. This question uses a 5 point Likert scale (from 0 to 4; from "really no useful" to "really useful"). Most users considered the new feature was really useful or useful - see Figure 5.4. If the data is analysed from the point of view of group disabilities, twelve people with visual impairments considered the new feature is really useful for them and eleven considered it is useful. Besides,

the second group of people, who considered this feature as useful, is people with motor impairments. In contrast, people with hearing impairments considered this feature would not be useful for them. However, if this disability is combined with other disabilities - e.g. motor or visual impairments-, this feature could be useful for them too.

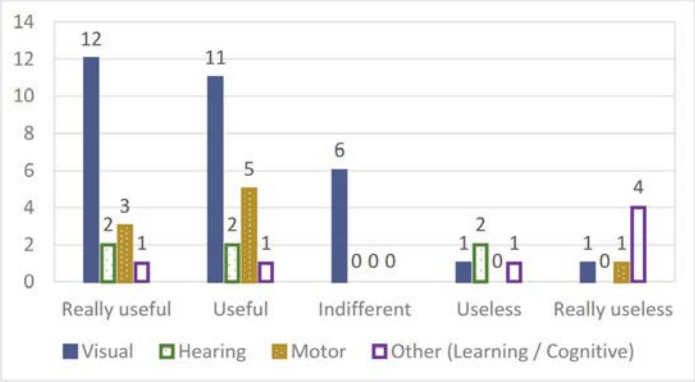

Figure 5.4: Could the *Pause Autorefresh* functionaly be useful? Results per disability

Furthermore, users were asked how they would feel when they used this application. This question used a five-point Likert scale again (from "Really not ashamed" to "Really ashamed"). Most users considered they would not be ashamed if they used this new feature - Figure 5.5 shows the feelings per disability group.

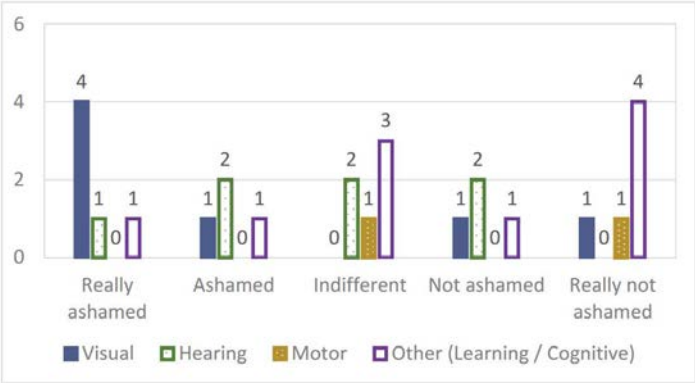

Figure 5.5: Feelings per Disability

Considering the results obtained in the interviews sessions, eight out of eleven users considered the *Pause Autorefresh* functionality could be useful for them.

> User3:"If I am not able to write quickly or to follow the conversation, it is not a problem, it only means that I need more time."
>
> User4: "Well.. I do not have problems writing quickly; but I consider that it could be useful for me in some situations where I have to re-read something because I have not understood it before."

The User7 specified that he would use this new functionality in some situations. Moreover, it is important to emphasise that the user uses already "his own *Pause Autorefresh* functionality". It means, the user changes the mobile mode to "Flight mode" to avoid the reception of new messages. As a result, he has more time to read the conversation carefully.

> User7: "Yes, sure. I consider that this new functionality could be useful because I could read the conversation easily."

Finally, users were asked if they had any other suggestion to improve chat applications. People suggested messages could be transcribed from voice-to-text and audio-to-text. Other person specified users should be allowed to decide the system's behaviour depending on the user's necessities. This is related to previous researchers' conclusions, which specify users could adapt the system to their necessities.

People without disabilities

Users without disabilities were asked about the system's behaviour after one participant paused the reception of messages. Users could select one of the following questions. Although, there was one option to suggest other behaviours.

- AP1: I could write all the messages that I would like.
- AP2: I would like to write just one more message only.
- AP3: I could not write more messages, I would like to wait.
- AP4: Others.

Most users preferred the first option (AP1). They would like to continue writing after someone used the *Pause Autorefresh* feature. The second most selected option was the AP3 option, users would like to write just one more message only. Finally, three users specified additional behaviours such as: only send important messages; include more information about the sent messages; and inform how many messages are in the queue. Next, Figure 5.6 shows the number of answers per option.

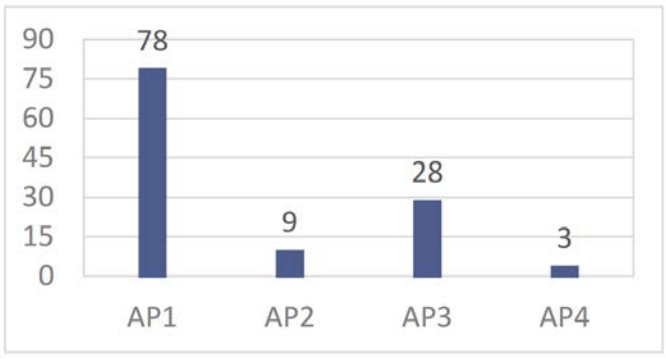

Figure 5.6: Users without Disabilities. System behaviour after a user pauses the reception of messages.

In addition, users were asked if they would like to be informed when a participant paused the reception of messages as well as if they would like to be informed when the user renewed the conversation. Users specified that they would like to be informed in both situations: when

the user pressed the button (92,04%) and when the user renewed the conversation (90,37%).

Users were asked if they would be bothered when a participant paused the conversation. Most of the users (83,19%) regardless of their IT expertise specified that they would not be bothered - see Figure 5.7.

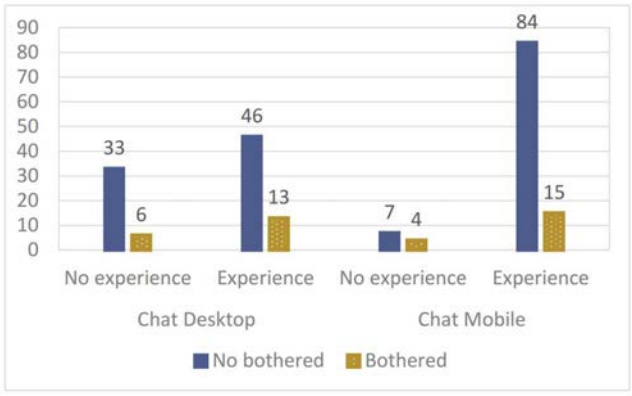

Figure 5.7: Users without Disabilities. Users' Opinion per Level of Expertise.

Users had the possibility to specify why they considered that this new functionality could bother them. A total of 19 users specified that the *Pause Autorefresh* functionality could be bothering. These opinions could be divided into five groups:

- **Urgent** (three out of 19): if the conversation was urgent and they needed to send an urgent message, this functionality could not be useful.
- **Lack of interest**(six out of 19): users could consider the participant, who paused the reception of messages, is not interested in the conversation.
- **Real time messages** (two out of 19): chat applications are synchronous conversations and users are expecting to receive answers immediately. If a person paused the reception of messages, the behaviour could be modified.
- **Unfinished conversations**(three out of 19): users could forget the purpose of the conversation.
- **Lack of information** (five out of 19): users might not know why the other participant has paused the conversation.
- **Useless in one-to-many conversations** (one out of 19): users could be bothered in one-to-many conversations if the system did not allow other participants continue writing.

Furthermore, users were asked if they would use this new functionality in all environments or in specific situations only. More than half of participants considered they would use this new functionality (55,75%) - see Figure 5.8 . Even people, who are used to chat applications, would use this functionality. However, more than half of the participants, who do not use mobile devices frequently, specified that they would not use this new functionality. This highlights the importance of testing the *Pause Autorefresh* functionality with people, who do not use mobile devices frequently.

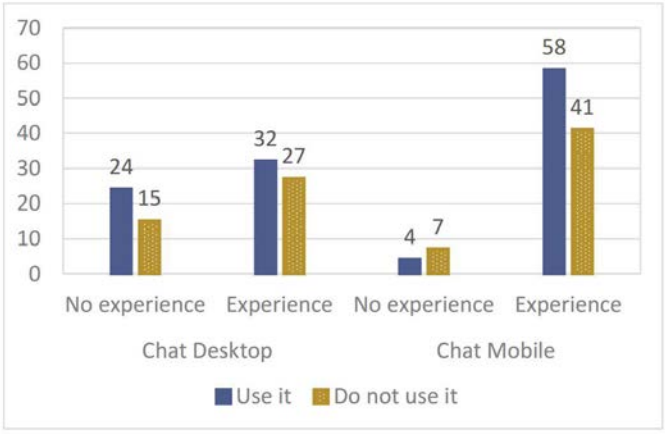

Figure 5.8: Users without Disabilities. Use of the new Functionality per Level of Expertise.

Users had the opportunity to specify when they would use this functionality. The opinions of the 63 people who would use the functionality are classified into seven groups:

- **During important situations**(19 out of 63): if users were doing another kind of activity such as: working, meeting people or watching a film, they might need to use the *Pause autorefresh* functionality.
- **Interest** (six out of 63): they would use it in important conversations because they could re-read the information.
- **One-to-many conversations**(seven out of 63): the number of messages sent in one-to-many conversations is increased and users might need more time to read messages.
- **Conversations with more experienced and quicker people** (nine out of 63): when they interact with people who write quicker, they might need more time to read the conversation.
- **Overwhelmed by the number of messages**(nine out of 63): if they receive many messages at the same time, they might not be able to read all of them.
- **Other**: other participants specified that they would use the functionality in bullying situations or when the participant considers they are bothering other participants because they write slowly.

Moreover, some participants specified some improvements for the new functionality such as: do not show messages in one go after pressing the *Pause Autorefresh* button; limit the number of messages; allow users to control the message to show - e.g. "I am busy doing ..." (three out of 113 people); activate the functionality automatically; show the number of people who have paused the reception of new messages (two out of 113 people); and allow exporting the conversation.

The averages calculated for each group [People with disabilities ($\tilde{X} = 3.61$)) and people without disabilities ($\tilde{X} = 3.78$)] showed that this new functionality is considered useful for both groups. In contrast, the standard deviation for people with disabilities ($\sigma = 1.43$) is bigger than people without disabilities ($\sigma = 0.91$). This dispersion could be explained because users with low vision and hearing impairments participated in the study. Their answers were different to the rest of people because they explained this new functionality is not useful

for them. Previous researchers have identified that users with hearing impairments are used to write quickly and text messages are commonly used by them [Pilling and Barrett, 2008]. Moreover, users with low vision could not feel comfortable with the use small screens because they have to place the mobile devices close to their face [Kane, 2009].

5.3.4. Discussion

The main aim of this study was to ask people's opinions about the *Pause Autorefresh* functionality. As this functionality was not developed yet, users were asked about a hypothetical situation. As a result, the research questions to address in this research were:

- RQ1: Is the *Pause Autorefresh* functionality useful?
- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?
- RQ3: Could users, who do not use the *Pause Autorefresh* functionality, be bothered?

People with disabilities considered the *Pause Autorefresh* functionality could be useful for them **(RQ1)**. The results obtained in the surveys show that even people, who use chat applications every day or two/three times per week, consider that it could be useful for them. In addition, people without disabilities could use the new functionality in some situations where they could feel overwhelmed - e.g. at work or while doing something important.

This new functionality could make users feel different from other people because when they access to this button, they inform other users that they cannot follow the *Flow and Rhythm* of the conversation. Thus, it was asked users how they would feel if they used this new functionality. The obtained results in the questionnaires and the interviews showed that most users would not be ashamed, if they used this functionality.

Users were asked about system's behaviour after the user used the *Pause Autorefresh* functionality **(RQ2)**, most users preferred that other user could write more messages when they had paused the reception of messages. Moreover, they preferred that the messages should be showed in one go instead of one by one when they renewed the conversation. In contrast, people preferred not to "bother" other participants; thus, the least selected options were the options in which the other user could not continue writing.

In order to create an inclusive chat application, every participant needs to feel comfortable when using the new functionality. The results showed that users without disabilities would not be bothered if users use this new functionality. In addition, they could use the new functionality in some situations where they could feel overwhelmed - e.g. at work or while doing something important. **(RQ3)**

The *Pause Autorefresh* functionality might be really useful for people with disabilities and depending on the circumstances for people without disabilities too. These results are really encouraging but they are based on a hypothetical situation. Because of this, it is necessary to validate this functionality in a real situation with real users in order to obtain more accurate results.

5.4. *Pause Autorefresh* functionality: Design

Considering the information obtained in the previous phase, the *Pause Autorefresh* functionality was designed in a prototype.

The requirement *"G8 - Control reception of new messages"*, which was specified in the previous chapter, is considered in this phase as well as previous people's feedback obtained in previous phases of the research. Basing on this obtained information, the requirement is formalised using SE and HCI methods; and finally, a mockup prototype which includes this new requirement was designed.

As a UCD approach was followed to validate the usefulness of the *Pause Autorefresh* functionality, the following sections detail how the study was conducted and designed.

5.4.1. Research questions

The main aim of this study was to formalise and design the system's behaviour when a user uses the *Pause Autorefresh* functionality:

- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?

Next section specifies in detail the method followed to address the previous research question.

5.4.2. Method

How functional requirements are documented plays an important role for ensuring that they can be read, analysed, written and validated [Nuseibeh and Easterbrook, 2000]. Moreover, the way in which the requirements are formalised could make that designers and developers do not understand the whole semantic of the functionality. Specifically, developers could use more or fewer code lines [Kantorowitz and Lyakas, 2005] to implement the same requirement. This section specifies the method used to formalise the G8 requirement.

Participants

One expert formalised the *Pause Autorefresh* functionality considering previous feedback provided by real users.

Apparatus

In order to formalise the *Pause Autorefresh* functionality the results from the previous interviews, questionnaires as well as previous researches were considered in order to specify the results.

Design

This new feature is formalised using SE and HCI methods in order to avoid possible misunderstandings related to the method used. Also, it aimed to design how the *Pause Autorefresh* requirement could be designed in a real environment.

Procedure

This study aims to formalise the *Pause Autorefresh* requirement in a way that could be understood by designers and developers properly. To achieve it the new requirement was detailed using the SE methods: Natural Language, Use Case Description and other diagrams. Besides, from the point of view of HCI methods, Scenarios, Personas and Storyboard methods are used to formalise the requirement. After the requirement was formalised in a theoretical perspective, the requirement was extrapolated to a specific environment and an interface design was created in a Mockup - see Figure 5.9.

Figure 5.9: Procedure - UCD - Design Phase

Data collection

When the requirement was formalised, the requirement could be read in different formats as it was explained before. Then, developers and designers would be able to use them. In addition, a mockup prototype will be created which will be useful for the development of the final prototype to validate in future studies.

5.4.3. Results

From the point of view of SE, requirements can be represented in different ways such as: Natural Language (text), Use Case Descriptions or Diagrams [Sutcliffe, 2003]. Moreover, as the study follows a UCD approach, HCI methods - scenarios and storyboard - are used to formalise the requirement. Next, all these methods are specified in detail.

Natural Language

Requirements need to be specified into natural language as a complement to the formal methods which sometimes are ambiguous [Escalona and Koch, 2004]. Considering the *Pause Autorefresh* functionality, the requirement could be specified as:

> The user feels overwhelmed because many messages are received. Then, the user could pause the reception of messages until the user will feel comfortable to read and send messages. The system informs other participants in the conversation about this situation. Next, the user, who has paused the conversation, could renew the conversation. Finally, when the conversation is renewed by the user, the system informs other participants about this new status.

As it has been explained before, this method is useful as a complement to formal methods. Next section specifies the formal methods used to define the *Pause Autorefresh* functionality.

Sequence UML diagram and Use Case Description

This study used sequence UML diagrams [Rumbaugh et al., 2004] and Use Cases Description to formalise the *Pause Autorefresh* requirement. The sequence UML diagram method was used to specify the how users interact with the chat application - see Figure 5.10.

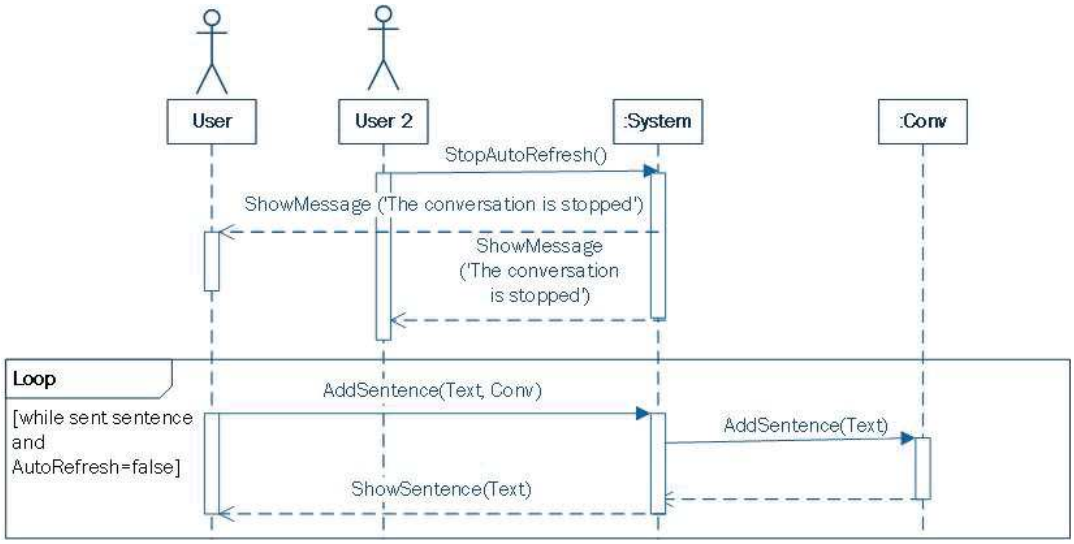

Figure 5.10: Sequence UML Diagram to Show the Interaction when a User Pauses the Conversation

This method cannot be used alone because there is some semantic which is not included in this method. The Use Case method includes more details such as: the context of use, preconditions executed before the Use Case, post conditions and etc which are really important to formalise the requirements. Then, the Use Case Description method is used to complete the information represented by the Sequence UML Diagram. This method has been used basing on the template provided by Cockburn [Cockburn, 2001] which specifies how to write use cases in an effective way. An example of the use of this method for the Use Case showed in Figure 5.10, is showed in Table 5.2. Notice that this template does not make a difference between actors and stakeholders as the Cockburn does because our study considers that each user (student or teacher) act as actors and stakeholders and there is not any difference between them. Thus, next information is provided in this method: (1) the name of the requirement; (2) the context of use in which the use case is focused; (3) the requirement objective; (4) the actors who can execute the task; (5) the level which specifies if it is summary, primary task or sub-function requirement; (6) a requirement description; (7) the actors and secondary actors who interact with the system; (8) the precondition that the system should comply to execute the requirement; (9) the success end condition after the execution of the task and the failed end condition that is produced when there is a failure; (10) the post-conditions triggered after the execution of the case use; (11) the step sequence of the requirement; and (12) the extensions and variations of the steps produced in the system in some circumstances.

G-08	Pause Autorefresh Conversation
Context of use	M-learning
Scope	The user can stop the auto-refresh conversation whenever wants.
Level	Primary Task.
Actors	Students and Teachers
Secondary Actors	1) People with motor disabilities 2) Users with few experience in mobile, web and chat applications 3) People with learning problems. 4) Foreign people.
Precondition	The user is logged in the tool and he is writing a sentence in a chat application.
Success End Condition	The system does not show more sentences.
Failed End Protection	–
Trigger	Stop conversation.
Normal Sequence	Step 1: The user presses the button Stop. Step 2: The system does not show more messages unless the user presses the button again. Step 3: The system informs participants. Thus, it shows the message the user is has stopped the conversation.
Extensions	Step: Branching Action.
Variations	Step: Branching Action.

Table 5.2: Use Case Description of the Pause Autorefresh Conversation

Scenarios

Previous methods - Natural language, UML Sequence Diagrams and Use Case Description - do not specify the user‘s interactions completely. Thus, they need to be complemented with Scenarios represented with Natural language.

> ”Rosa and Antonio are sending messages using the mobile chat application. Rosa writes a message. Rosa: ”Antonio, I do not understand the exercise number 7”. Antonio starts to answer it and before he finishes the message Rosa sends a message again. Rosa: ”Moreover, the second exercise is similar to the first exercise, isn’t it?” Antonio does not feel comfortable and as a result, he decides to pause the conversation and Rosa receives the ’Antonio is busy’ message. Consequently, Rosa realised that Antonio is not able to answer quickly and she waits. After that, Antonio sends a message and replies Rosa‘s message. ”Yes. You are right. They are similar and in the seventh exercise you have to answer with your own opinion”. At that moment, Antonio receives all the messages that Rosa has sent since Antonio paused the reception of messages.”

Storyboard

Some requirements are really difficult to be explained using natural language, formal methods or templates. Storyboard method helps representing complex requirements [Landay and Myers, 1996]. Next, the requirement modelled using a storyboard, which specifies a situation where the user needs to pause the reception of new messages, is represented in Figure 5.11.

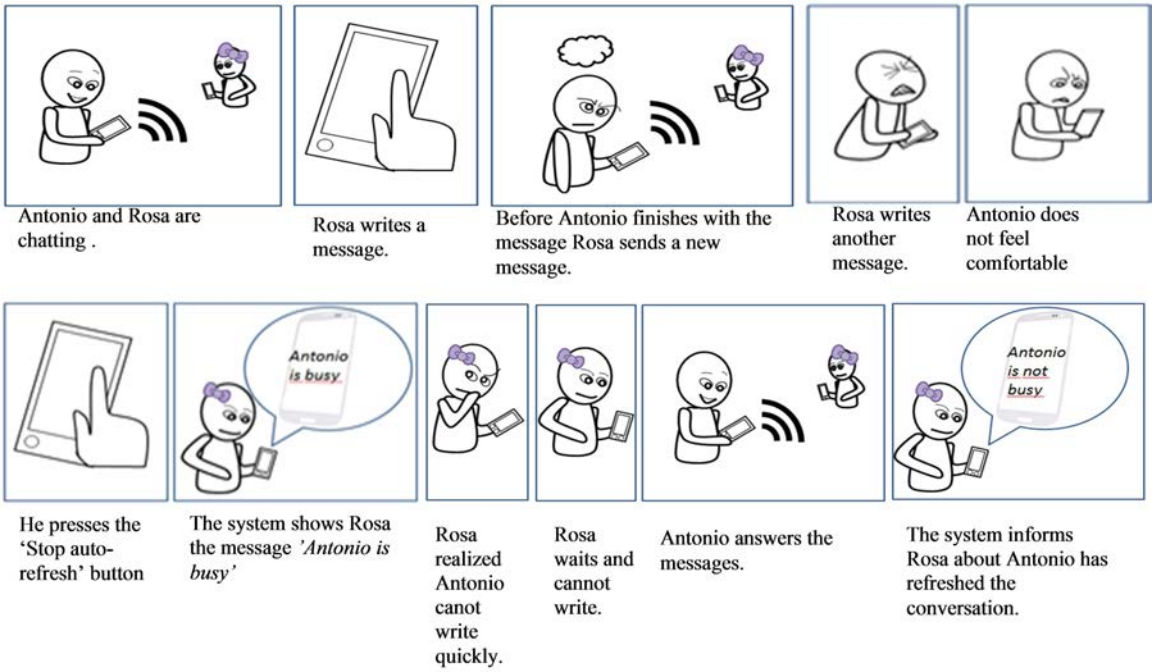

Figure 5.11: Storyboard: Situation in which user needs to *Pause AutoRefresh* the conversation

Mockup Prototype

After the requirement is formalised, the requirement could be designed for a specific environment. In this case, the Mockup prototype is based on the interface of the Whatsapp application [1] because it was identified in the previous study - see Chapter 3 - the most common used chat application by users was Whatsapp. The validation of the *Pause Autorefresh* functionality will be done using this layout in order to avoid possible bias in the study due to the chat interface. The Whatsapp interface will be used because this is a familiar chat application for users. The Mockup represents the interface of the Whatsapp application and it has been included the *Pause Autorefresh* functionality. This Mockup was designed from two different perspectives: the user pauses the reception of messages or other user pauses the reception of messages. Next, each perspective is described in detail.

The user pauses the reception of messages (Figure 5.12): The user can pause the reception of messages if pressing the "Pause" button. Then, the system shows the message: "You have paused the chat. Press the button "Refresh" to receive the new messages". The user will not receive more messages until they press the button "Refresh". When the user presses this button, the user will receive the messages which have been written by the other participant and the message "You have renewed the chat" is shown.

[1] Whatsapp https://www.whatsapp.com/

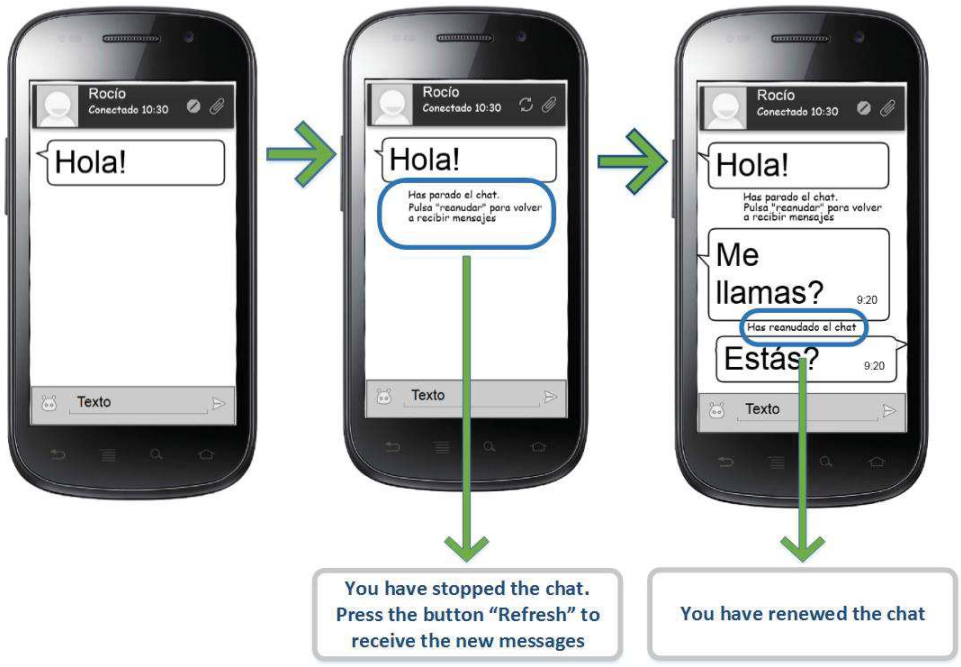

Figure 5.12: Mockup Prototype: The User Stops the Reception of New Messages

Other user pauses the reception of messages (Figure 5.13): If the user does not use the *Pause Autorefresh* functionality but another participant (Rocío) of the conversation uses this functionality, the user receives a system message "Rocío has stopped the chat. She does not receive more messages" when the other user has pressed the "Pause conversation" button. The user could write more messages but these messages will not be received by the other participant until this participant will renew the conversation. At this moment, the system shows the message "Rocío has renewed the chat".

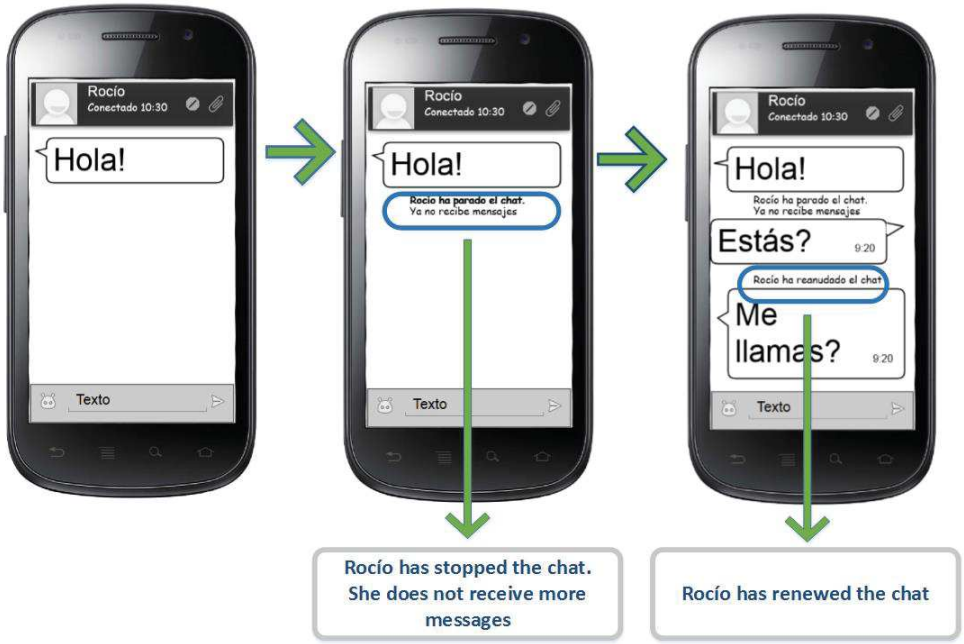

Figure 5.13: Mockup Prototype: Other User Pauses the Reception of New Messages

5.4.4. Discussion

This study aimed to specify how the system should behave before real users tested the *Pause Autorefresh* functionality in a real environment:

- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?

Considering the results of this study, users can pause the reception of new messages when the user feels overwhelmed. In addition, the system should inform the user that no more messages are been shown **(RQ2)**.

Meanwhile, users, who do not use the *Pause Autorefresh* functionality, should be informed about the status of the other participants at every particular moment.

It is important to remark that this functionality could be controversial for some people because it pauses the reception of new messages and the conversation could be affected. Moreover, some people could be ashamed to use this new functionality because they could think that other people are being bothered. Then, this new functionality needs to be evaluated to assure if this proposal is interesting and useful for students and teacher. Next sections validate the functionality in a *Hypothetical situation* to obtain the users‘ opinion about this new functionality before creating the prototype and evaluating the *Pause Autorefresh* functionality in a real situation.

5.5. *Pause Autorefresh* functionality: Adapt

As the previous section details, the *Pause Autorefresh* functionality could be useful for users but it needs to be validated by real users. To validate the new functionality, it needs to be created a tangible prototype which includes this functionality and proof it by real users. The Mockup designed in the previous phase was tested with real users in order to be improved and get user‘s opinions. Considering the feedback provided by real users, a software prototype was created.

This section specifies how the prototype was designed, created and validated as well as how the new functionality was integrated in the prototypes.

5.5.1. Research questions

The main aim of this research is to improve the Mockup designed in the previous phase. The research questions for this study are:

- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?

Next sections specify how this research has been conducted and the method followed in this study.

5.5.2. Method

This study obtains user‘s opinions about the created Mockup prototype in order to improve its design and develop a final software prototype.

Participants

Participants were students with and without disabilities who use chat applications everyday and have previous IT knowledge.

People with Disabilities A total of eight participants (two people with blindness, two people with partial vision, two people with motor disabilities, two people with cognitive disabilities and one person with hearing impairments) participated in the study. Table 5.3 shows the characteristics of each participant.

User	Age	Gender	Disability	Chat mobile	Assistive Technology	Mobile
U1	45-54	Male	Blind	Low	Screen reader	Old Mobile
U2	35-44	Male	Motor	High	None	Samsung Ace
U3	25-34	Female	Partial Vision and Motor	High	Screen Magnifier	Sony SZ
U4	25-34	Male	Blind	Low	Screen reader	Ericson
U5	55-64	Female	Partial vision	High	Screen Magnifier	Samsung SII
U6	25-34	Male	Cognitive	High	None	LG L3
U7	18-24	Female	Hearing	High	None	Iphone 4
U8	25-34	Male	Cognitive	High	None	Xperia

Table 5.3: Mockup Validation: People with Disabilities

Elderly People A total of twelve elderly students participated in this study. The average age is ($\tilde{X} = 68, 23$) with a typical deviation of ($\sigma = 1, 8$). Next, Figure 5.14 shows the expertise of elderly participants using mobile chat applications.

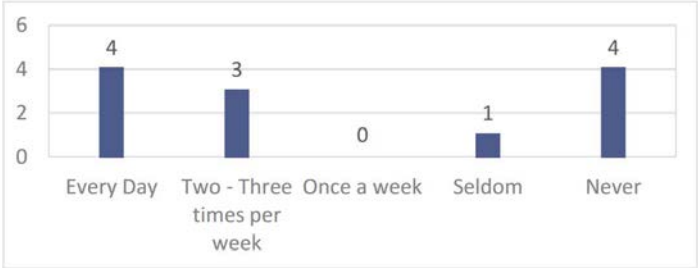

Figure 5.14: Mockup Validation: Elderly Expertise in Mobile Devices

People without Disabilities People without disabilities participated in the study in order to obtain their opinion about the Mockup prototype. Seven people participated in the study with different characteristics - see Table 5.4.

User	Age	Gender	Chat mobile	Mobile
U9	35-44	Male	High	Samsung GT
U10	35-44	Male	Medium	Samsung S2
U11	18-24	Female	High	Nexus 4
U12	25-34	Male	High	Samsung S3
U13	25-34	Female	High	Samsung ACE
U14	55-64	Male	Medium	LG
U15	55-64	Male	Low	Samsung

Table 5.4: Mockup Validation: People without Disabilities

Apparatus

When the studies were conducted, users were shown the Mockups prototypes designed in the previous session. The moderator showed a Mockup prototype at a time and the moderator explained the behaviour of each Mockup screen.

Design

In this research, three methods were carried out with real users in order to know their opinion about the prototype‘s interface. Users with and without disabilities participated in personal interviews and elderly people participated in group interviews and questionnaires.

A software prototype was created following previous users‘ opinions. Finally, the accessibility of this prototype was tested by three experts. Next section specifies how this study was conducted in detail.

Procedure

These methods aimed to obtain the user‘s opinions in order to improve the prototype. Users had to answer the following questions and Figure 5.15 shows the Mockup Validation Process.

- How would you like to represent the *Pause Autorefresh* functionality?
- Do you comprehend the *Pause Autorefresh* button?
- Do you prefer a button or a command?
- Do you prefer to be the button at the top or at the bottom?
- Do you understand the system’s messages?
- Do you prefer other order to show the messages?

Personal Interviews The interviews took thirty minutes and users answered the questions shown before while the sessions were recorded. Meanwhile, the interviewer was writing the most important quotes of the interviewees in a notebook to analyse these answers later.

Group Interviews The group interviews were carried out in groups of six people each in one hour sessions. The interviewer asked people one question and students specified their opinion about the specified question. Moreover, they had the possibility to discuss their opinion and other users‘ opinions

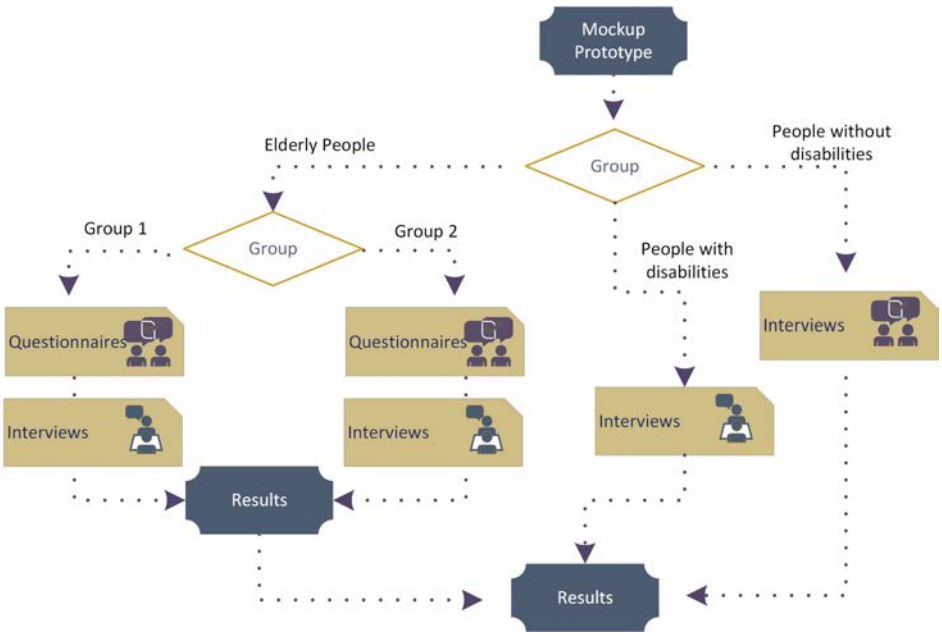

Figure 5.15: Procedure - UCD - Adapt Phase

Questionnaires Questionnaires were used to choose the button which could be identified better by users and to avoid confusions by users when they use the chat application.

Considering users' opinions, the interface of the prototype was improved and a software prototype was created. Then, three experts evaluated the software prototype in order to detect accessibility issues that users could face later.

Data collection

Interviews were recorded and notes were taken from them. Finally, The data obtained from the previous methods was recorded in a spreadsheet document to be analysed later.

Data analysis

The results obtained in the previous studies included qualitative and quantitative data which was analysed from different perspectives. Statistics were created using the quantitative data and the information collected from the qualitative data helped us to take decisions.

Considering the information obtained previously, decisions were made to improve the interface of the prototype. Then, a software prototype was created and three experts evaluated the software prototype in order to detect accessibility issues that users could face later.

5.5.3. Results

This section shows the results of each method: personal interviews, group interviews and questionnaires. Next, the obtained results are detailed.

Identification of the Functionality: The first intention was to identify the *Pause Autorefresh* functionality in the chat application in order to be better understood by the users.

Personal interviews: Users were asked about how they would like to identify the functionality. Then, they were asked about how the functionality should be named in the appli-

cation. They were asked if they identified the behaviour of the functionality if it was named stopped or paused vs. renewed or continued. The most selected answers between the students were: pause and renew as it is showed in the next graphics.

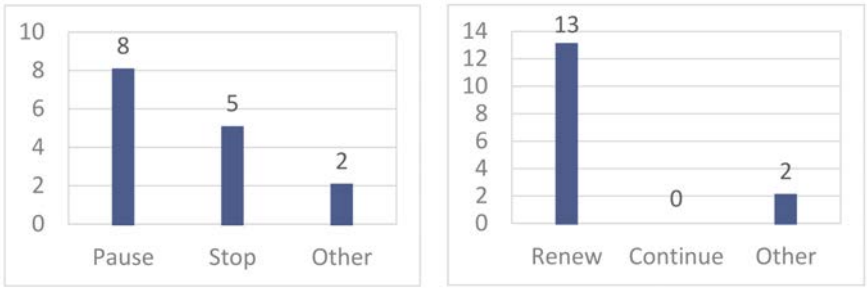

Figure 5.16: Identification of the functionality: Stop/Pause or Renew/Continue

Group interviews: The use of the word "Stop" was better accepted by the users than the word "Pause". Different users specified that the word "Pause" was used more in latinamerican countries but not in Spain. Moreover, other users considered that the word "Pause" could be related to technological aspects and people who do not have technological knowledge could have problems comprehending it. In contrast, they considered that the word "Renew " identified perfectly the concept to start receiving messages and continue with the conversation.

Interaction with the System to use the new Functionality The user interface is really important for users. This interface will make the system easy or difficult to use. Then, users were asked about how the *Pause Autorefresh* functionality should be represented.

Personal interviews: The new functionality could have been represented with a button or with a new command that users could execute in the screen in order to pause the reception of new messages. Users were asked about which way of interaction could be better for them - e.g. a button or a command. Only two out of fifteen people specified that a command to pause the reception of new messages could be better. And one person specified that he would not mind using a button or a command to pause the reception of new messages.

Besides, users had to specify how the button should be represented; it means if the new button should be represented with:

- **a stop icon:** To represent the pause of the reception of new messages.
- **a refresh icon:** To represent the refresh of new messages.

Users were shown the Mockup prototype and they were specified that they could explain their thoughts about the prototype as well as if they would like to change the icons. A total of nine out of fifteen people specified that the functionality could be represented with the "pause - play" buttons; four of the interviewed people said that the buttons were fine; one person specified that the refresh button could be confused for him because he associates the button with another functionality; and finally, another user specified that it could be a traffic light. Then, another important result obtained is the importance of using colours to identify when the reception of messages is pause or not because three out of fourteen people specified that it could be interesting to specify colours to identify when the reception of messages has been stopped or not.

Moreover, the situation of the button could be important for users. Thus, they were asked about it too. Most of the users, ten out of fifteen, considered that the button should be positioned at the bottom of the screen. Only three out of fourteen people specified that they preferred the button at the top and two out of fourteen people specified that they would not mind the button‘s position.

Group interviews: All users unanimously considered that the button would be better for them. They do not like the use of commands on the screen and they consider that the use of gestures is only for young people.

With regard to the image used to represent the *Pause Autorefresh* functionality, they were asked about the images which could represent better the new functionality. There were different opinions about it. As a result, it was decided to use the questionnaire technique in order to obtain quantitative data on their opinions. Four different images were shown to each person and they could select the best image which represents better the "Stop" and "Renew " of the conversation. Next images show the different images that each user could select to represent the "Stop" or "Renew " - see Figure 5.17.

Figure 5.17: Image Options to Identify the Stop or Renew of the Conversation

A total of ten people selected the image represented with a hand to pause the reception of new messages and five people selected the image represented with a play to identify the reception of new messages.

Finally, they were asked about the position of the *Pause AutoRefresh* button and they specified that they did not care where the button was placed if they were able to identify the functionality. Thus, it would be more important for them to represent the new functionality easily than the position of the button.

System‘s Messages how the system shows the information to the users could be really important. Users were asked how the system messages should be shown.

Personal interviews: considering the previous questions, it should be better to modify the messages with the specified information of the users previously. It means that users would like to use the verbs pause and Renew in the system‘s messages. Furthermore, users were asked about the size of the messages and most users prefer, thirteen out of fifteen, that the messages should be shorter because they will be able to read them quickly and they would not have too much information on the screen.

The order of messages is an important feature too. Users were asked about the message‘s order. From the point of view of users, who pause the reception of messages, all interviewed users prefer the following order for the messages:

You have stopped
You have renewed
Sent messages while the user stops
User messages.

However, if the user does not pause the reception of new messages and other user stops the reception of messages, all users prefer the following order:

Someone has stopped
Sent messages while the user stops
Someone has renewed
User messages.

Group interviews: In general, users prefer shorter than longer messages. It is important to emphasise that users were confused when they saw all messages on the screen. They did not understand the meaning of the messages and they understood them better when the researcher made them shorter on the blackboard.

From the point of view of the message‘s order, they considered that the order of the messages when they paused the reception of messages would be the same as obtained in the personal interviews.

To sum up, the Mockup prototype should be modified in order to be understood better by the users. Then, the next improvements should be done in the chat software prototype:

- **Identification of the functionality:** the new functionality should be identified with the words "Pause/Renew".
- **Interaction with the functionality:** use colours (Red and Green) to identify when the reception of messages is on or off. Moreover, the button should be shown at the bottom of the screen.
- **System‘s messages:** the messages should be modified in order to introduce the "Pause/ Renew" concept and they should be shorter. Furthermore, the order of the messages should be: *You have paused / You have renewed / Sent messages while the user paused / User messages* when the person pauses the reception of new messages; and it should be *Someone has paused / Sent messages while the user paused / Someone has renewed / User messages* when another person pauses the reception of new messages.

Considering these results, the second prototype, software prototype, was created. This prototype was based on the *Mockup* prototype‘s interface and includes the results obtained in the previous research. This prototype is more complex than the previous one, it represents the chat application interface, the user‘s interaction with the chat application and the *Pause AutoRefresh* Conversation functionality.

The chat prototype includes some technological improvements to enhance the accessibility of the prototype. These improvements are summarised next:

- **Responsive web design:** The prototype can be adapted to different viewports. It has been developed in a web environment because it can be executed in more mobile devices

than native applications. The technology used to create this prototype was: HTML5 and CSS3 to guarantee the layout adaptation in a huge variety of mobile devices [Gardner, 2011].

- **Screen Reader Improvement:** The requirements are improved using WAI-ARIA specification because it adds semantic information to HTML code to specify screen readers how to align keyboard navigation to landmarks, the page structure, updated content and expanded information [Abou-Zahra, 2013].
- **Follow Accessible Standards and Guidelines** Standards and guidelines related to mobile devices, accessibility and e-learning environments are followed. These guidelines are: WCAG 2.0, MWABP 1.0 and MWBP. These guidelines and standards are followed in order to make the chat accessible.

Two accessibility experts followed the Walkthrough method provided by Giorgio Brajnik [Brajnik, 2008] to obtain the main accessibility barriers that the prototype could cause for: blind, low vision, colour blind, motor impaired, deaf/heard of hearing, cognitive disability or mobile users. They evaluated each barrier that users could face and assigned an impact, persistence and severity. Later, they compared their assigned values and they decided the best value for each barrier.

The accessibility evaluation obtained that there were not any accessibility barrier that could affect users in the validation process.

5.5.4. Discussion

The main aim of this study was to improve the design of the chat prototype.

- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?

Users considered they wanted clear and simple messages sent by the system. It would help them to understand the status of the other user. In addition, users specified they would like to have a button to pause the reception of messages instead of a gesture or other type of interaction.

Regarding to how to name this new feature, users were asked if they would like to name it as Pause or Stop and users informed they would like to name it as Pause instead of stop because it would be more understandable for them.

Considering users‘ opinions, the prototype was improved (**RQ2**). This prototype needs to be tested in a real environment in order to assure how useful is the new feature for users. Next study validates this prototype with real users in a real environment.

5.6. *Pause Autorefresh* functionality: Test

This section explains how the validation of the *Pause Autorefresh* functionality, has been tested in a real situation with real users. The main hypothesis of this research is to confirm the *Pause Autorefresh* functionality will help students to communicate with their classmates and teachers using the chat application.

To achieve it HCI and SE methods, Annexe A, were used to validate the *Pause Autorefresh* functionality with real users in order to know if this feature could be useful or annoying for

them in m-learning environments. These validations were conducted joined with ILUNION [2] through the project UNINNOVA [3] as well as with the help of Leganes City Council. Next sections specify how these validations were carried out and the results obtained.

Next sections specify how the validations were carried out and the results obtained in these validations.

5.6.1. Goals - Research questions

The main goal of this study is to analyse if the *Pause Autorefresh* functionality could help students to communicate with their classmates and teachers. Basing on the research questions formulated at the beginning of this chapter, the following research questions will be answered.

- RQ1: Is the *Pause Autorefresh* functionality useful?
  - RQ1.1: How did users feel when they used the*Pause Autorefresh*functionality?
  - RQ1.2: Was the conversation affected when someone used the*Pause Autorefresh*button?
  - RQ1.3. Did users prefer Chat4LL (*Pause Autorefresh* functionality) over Moodle to control the reception of messages?
- RQ2: How the system should behave after the user used the *Pause Autorefresh* functionality?
  - RQ2.1: Would users use the *Pause Autorefresh* functionality in m-learning environments?
  - RQ2.2: Could teachers use the *Pause Autorefresh* functionality?
- RQ3: Were users, who did not use the *Pause Autorefresh* functionality, bothered?
  - RQ3.1: How did users feel when someone else used the *Pause Autorefresh* functionality?
  - RQ3.2: Did number of participants affect these feelings?

5.6.2. Method

This section details how the research was conducted. Next subsections - Participants, Apparatus, Materials, Design, Procedure, Data Analysis, etc. - explain this information in detail.

Participants

A total of 64 participants with different characteristics were selected and categorised into the following groups: people with disabilities, elderly people, people without disabilities and people without experience using mobile chat applications. These participants were recruited with the help of ILUNION organisation and with the help of Leganés city council and all participants gave informed consent to the purposes of the study.

To recruit these participants, a list of target groups and characteristics was detailed before the research was conducted. According to our previous phases of the research, we considered three main groups of people: people with and without disabilities; elderly and non-elderly

[2]Ilunion. http://www.ilunion.com/
[3]UNINNOVA. http://uninnova.es/es-ES/default.aspx

participants; and people with and without experience.

1. **Participants with and without disabilities**: In the user testing sessions, it was necessary to analyse if people with disabilities could get a benefit of the *Pause Autorefresh functionality*. Previous research phases were tested with people with different disabilities: people with visual impairments (blindness and partial vision); people with motor impairments; people with learning disabilities; and people with hearing impairments participated in the study. People with different visual impairments (blindness and people with low vision) participated in the study because the problems they face could be different. In addition, people without disabilities participated in the study because it was necessary to evaluate if people with disabilities and without disabilities could interact together using the *Pause Autorefresh* functionality.

2. **Elderly and young adults**: As the years gone by, people's abilities are deteriorated and users might experience similar problems as people with disabilities. In addition, most of elderly people did not use mobile devices or chat applications daily and they might face additional problems due to their lack of experience in these environments. This research, involves elderly people in order to evaluate if elderly people might get a benefit of the *Pause Autorefresh* functionality. Besides, young adults participated in the study to compare which group could get more benefits of the *Pause Autorefresh* functionality.

3. **Experienced and non-experienced participants using chat applications**: Participants who used mobile chat applications and participants who had not used chat applications before participated in this study. The research aimed to study if participants who did not have experience using chat applications could get a benefit of the *Pause Autorefresh* Functionality because they could interact with people who had more experience and could follow the conversation without facing problems. In addition, it was necessary to study how participants with and without previous experience using chat applications could interact all together using the new *Pause Autorefresh* Functionality.

Considering previous groups, it was necessary to recruit participants for the study. This was an arduous task and we were helped by the Leganés city hall and ILUNION to recruit and select participants.

Elderly participants were students who joined courses for elderly in the Leganés city hall. These participants had participated in previous phases of the research to understand the problems they face when they interact with chat applications; however, they did not use the *Pause Autorefresh* Functionality before and they had the same previous knowledge about the system.

Thanks to ILUNION and their project UNINNOVA [Calvo et al., 2014c] these validations were conducted. UNINNOVA project aims to share and promote accessibility in technological projects. This project puts in contact testers and Universities and organisations which develop software to improve accessibility. ILUNION helped us to recruit participants, who meet the specified characteristics, and gave us feedback on the design of the experiment basing on their previous experiences conducting researches with people with disabilities. It is important to emphasise that people with hearing impairments, who did not have experience using chat applications, did not participate in the evaluation process because there was not found anybody with these characteristics. ILUNION tried to recruit all the participants needed for the research but it was very difficult to find people with hearing impairments who did not use chat applications. Although ILUNION sent a message to all hearing impairments organisations, it

was not possible to find any participant with this characteristic because people with hearing impairments use chat applications to communicate with their colleagues and family every day. After agreeing the experiments design of the experiment, they planned the timetables and provided us a lab to carry out the experiment.

The 62 selected participants fulfilled a questionnaire before they participated in the research. In this questionnaire, they had to answer questions related to: their age, if they had any disability, their previous experience using mobile devices, chat applications, etc.

Regarding their Age, a representation of all ages group was selected. As this research aims to involve elderly users in order to assure the *Pause Autorefresh* functionality was useful for them, the number of elderly people was huger than normal. The following figure - Figure 5.18 - shows a summary of the age population.

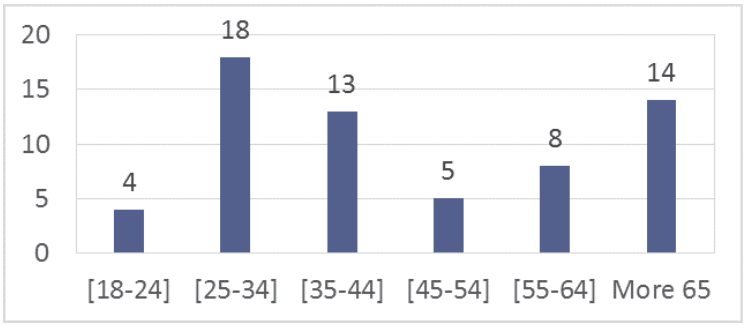

Figure 5.18: *Pause Autorefresh* Validation - Participants Age

In this research, males and females participated and there was no difference between genders. A total of 32 males and 30 females participated in the study - see Figure 5.19.

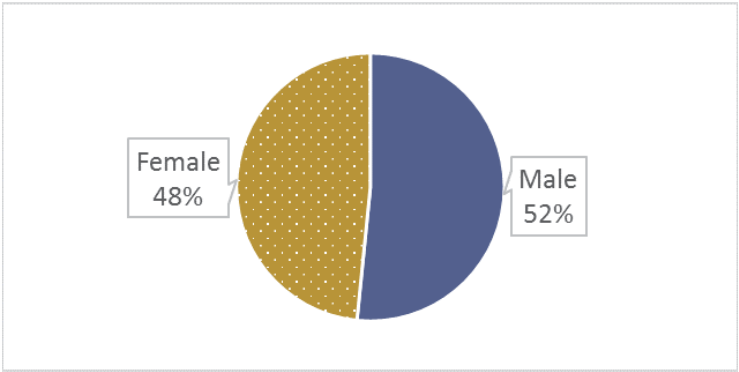

Figure 5.19: *Pause Autorefresh* Validation - Participants Gender

With regard to disabilities, 22 people with disabilities participated in the study. Different disabilities were considered and they were divided into: Blindness, Visual impairments, Hearing impairments, Motor impairments and Cognitive impairments. Next Figure 5.20 summarises the number of participants per disability, who participated in the study.

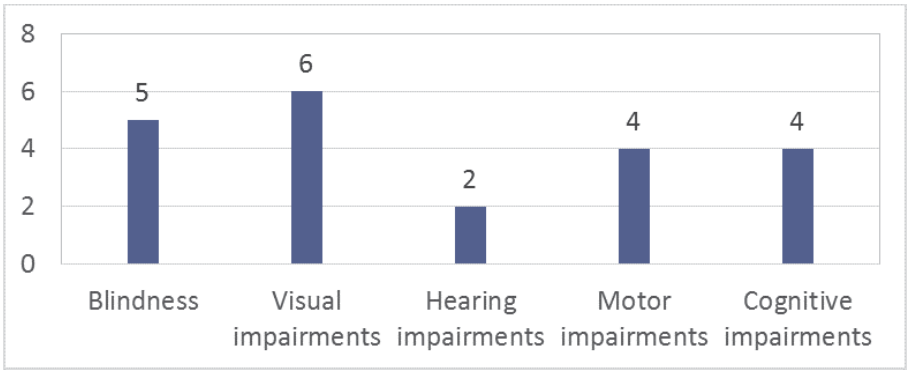

Figure 5.20: *Pause Autorefresh* Validation - Participants Disabilities

People with and without previous experience using mobile chat application tools participated in the study in order to analyse if people without previous experience using chat application tools could get a benefit of the *Pause autorefresh* functionality. Analysing the results of the questionnaires a total of 42 participants with previous chat experience participated in the study and 20 participants did not have previous experience using these tools - see Figure 5.21.

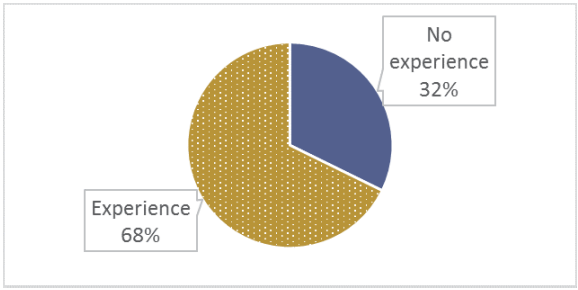

Figure 5.21: *Pause Autorefresh* Validation - Participants Experience

People, who had previous experience using these tools, were asked if they have problems following the conversation when they were using a chat application tool in one-to-one or one-to-many conversations. In general, people assured they did not have problems communicating with other students in one-to-one conversations. However, they experienced more problems when they interacted in one-to-many conversations - see Figure 5.22.

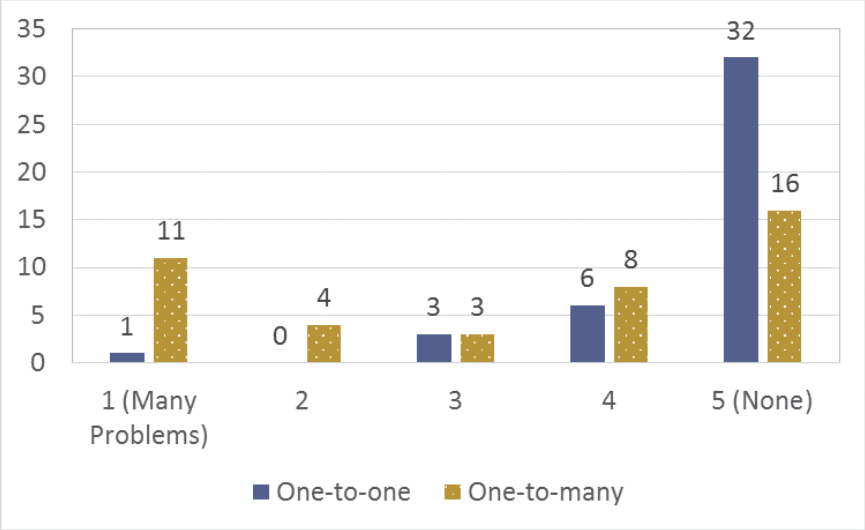

Figure 5.22: *Pause Autorefresh* Validation - Participants Problems Following the Conversation

In addition, they were asked if they have usually problems reading the messages sent in a one-to-one or one-to-many conversation. The results were similar, users experience more problems when they interact in one-to-many conversations because they miss messages and they cannot read all messages at a time - see Figure 5.23.

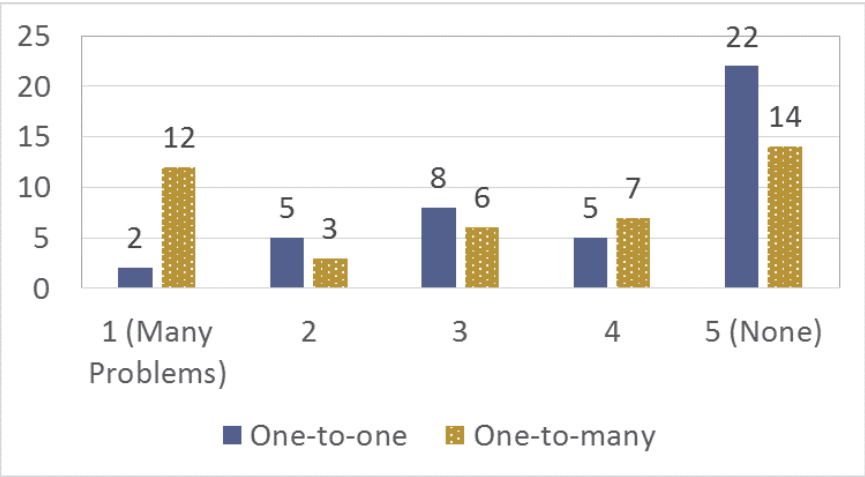

Figure 5.23: *Pause Autorefresh* Validation - Participants Problems Following the Conversation - Read

Finally, they were asked if they have problems replying messages in one-to-one or one-to-many conversations. Users experienced more problems when they had to write messages in general but these problems were more prominent when users participated in one-to-many conversations - see Figure 5.24.

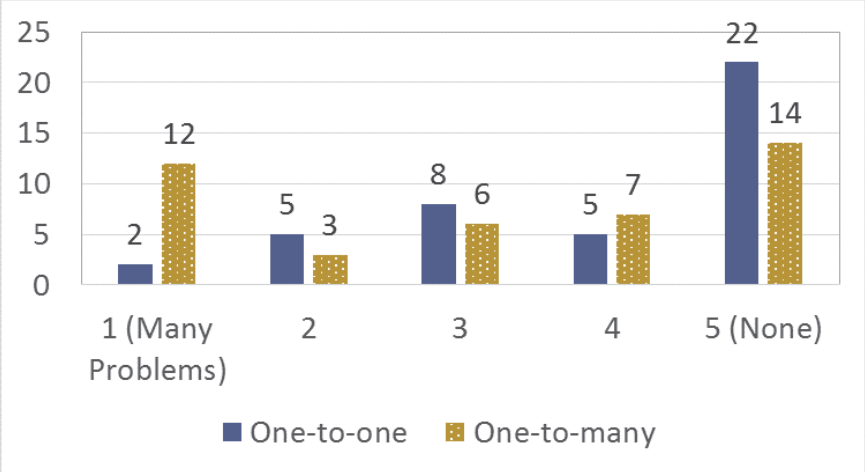

Figure 5.24: *Pause Autorefresh* Validation - Participants Problems to Follow the Conversation - Write

Apparatus

ILUNION provided us a lab to conduct the experiments and the Leganés City Council provided us rooms in one of their buildings. There, a lab was set up to carry out the experiments.

In this user testing sessions participants used a mobile device (7" tablet or 4" smartphone) to use the chat application. Users could decide to use Android (4.3) [4] or iOS (7) [5] operating system depending on the mobile device they have. The chat prototype was a web chat application which could be used in all browsers. Although, the user testing sessions were carried out in Mozilla Firefox [6] browser for Android and Chrome browser for Apple [7] . Meanwhile, the moderator used a Windows 7 [8] laptop to communicate with the participants using the chat application.

In one-to-one conversations, Skype was used to record participants interaction and the moderator laptop received the Skype video. This video and the messages sent in the chat application were recorded all together in order to analyse it better - see Figure 5.25.

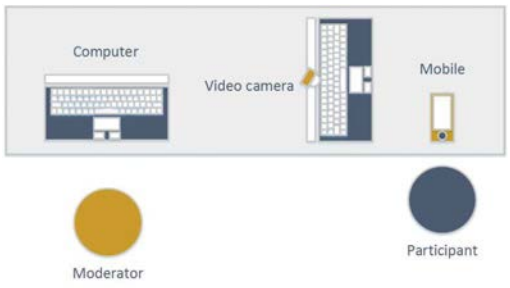

Figure 5.25: One-to-one Conversation Testing Configuration

On the other hand, one-to-one conversations interactions were not recorded. However, in

[4]Android https://www.android.com/
[5]iOS http://www.apple.com/uk/ios/ios-10/
[6]Mozilla Firefox https://www.mozilla.org/en-GB/firefox/new/
[7]Chrome for iOS https://itunes.apple.com/gb/app/chrome-web-browser-by-google/id535886823?mt=8
[8]Windows 7 https://www.microsoft.com/en-gb/software-download/windows7

these conversations one observer took notes about the problems users faced as well as their facial expressions - see Figure 5.26 which describes how the sessions were configured. At the end of the user testing sessions, semi-structured interviews were carried out. They were recorded using a recorder and were saved in order to analyse them later.

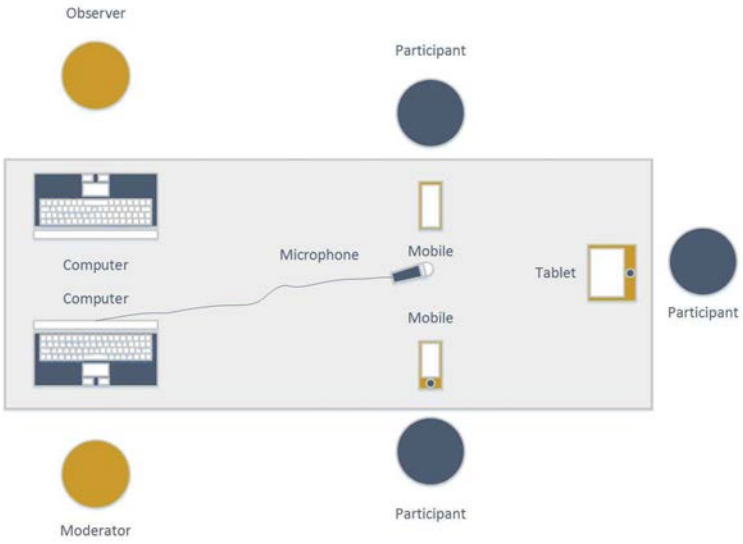

Figure 5.26: One-to-many Conversation Testing Configuration

Stimuli

As explained before, the main purpose of this evaluation was to assure if the *Pause Autorefresh* functionality could be useful for students in m-learning environments. Users participated in a m-learning chat conversation to learn how to recycle in Spain. This topic was selected because it was a trending topic in Spain and everybody was aware of it and because it was an easy topic to follow in case participants were not used to recycle. To assure participants were able to follow the conversation, two questions related to the content delivered in the conversations were asked in both chat application conversations.

Every conversation was carefully planned previously in order to replicate the same user feelings in each conversation and compare the results later. Annex G shows an example of how the conversation was structured.

The conversation simulated different situations that students could experience in a normal online chat with other students or teachers. These situations included: short and long messages; receive many messages at the same time; and do not receive messages for a short period of time. In addition, it was simulated how students felt when another participant in the conversation used one method to control the reception of messages.

In one-to-one conversations, users used Moodle and Chat4LL, participants faced the previous situations explained from the point of view of a user who used a method to control the reception of messages and from the point of view of a user who did not use any method to control the reception of messages. In addition, in both situations, users experienced situations where they received many messages at the same time and they did not receiv messages for a long period of time. Next tables and figures - Table 5.5 (Figure 5.27), Table 5.6 (Figure 5.28), Table 5.7 (Figure 5.29) and Table 5.8 (Figure 5.30)- explain in detail how the conver-

sations were designed, the number of messages sent and the seconds without sending messages.

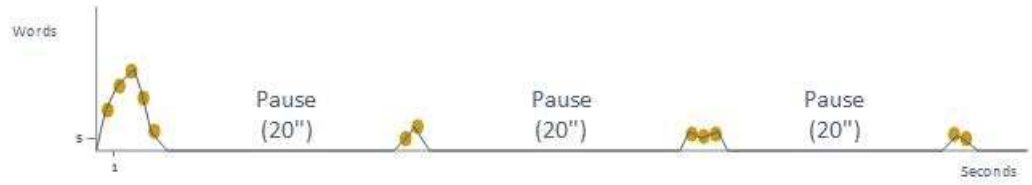

Figure 5.27: Moodle Testing: Part A. Teacher Controls Messages

Number of messages	**Words per message**
Send 5 messages	(18 words, 27 words, 34 words, 21 words and 9 words)
Wait 20 seconds	–
Send 2 messages	(5 words, 12 words)
Wait 20 seconds	–
Send 3 messages	(9 words, 8 words, 6 words)
Wait 20 seconds	–
Send 2 messages	(8 words, 5 words)
Wait 20 seconds	–

Table 5.5: Moodle Testing: Part A. Teacher Controls Messages

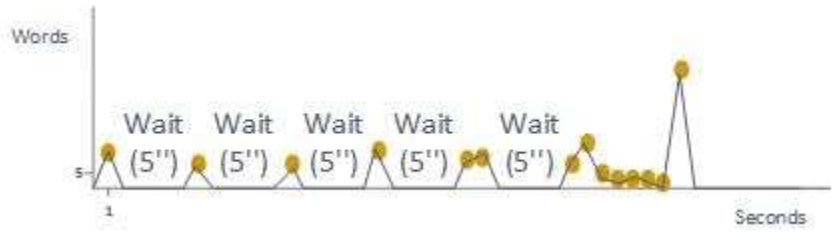

Figure 5.28: Moodle Testing: Part B. Student Controls Messages

Number of messages	**Words per message**
Send 5 messages	(18 words, 27 words, 34 words, 21 words and 9 words)
Wait 20 seconds	–
Send 2 messages	(5 words, 12 words)
Wait 20 seconds	–
Send 3 messages	(9 words, 8 words, 6 words)
Wait 20 seconds	–
Send 2 messages	(8 words, 5 words)
Wait 20 seconds	–

Table 5.6: Moodle Testing: Part B. Student Controls Messages

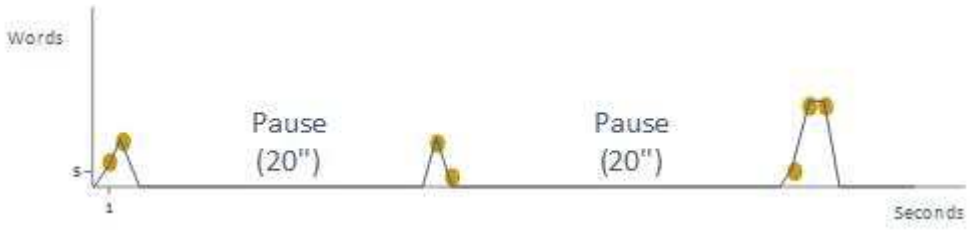

Figure 5.29: Chat4LL Testing: Part A. Teacher Controls Messages

Number of messages	**Words per message**
Send 2 messages	(9 words, 16 words)
Pause the reception of messages 20 seconds	–
Send 2 messages	(15 words, 2 words)
Pause the reception of messages 20 seconds	–
Send 3 messages	(6 words, 27 words, 27 words)

Table 5.7: Chat4LL Testing: Part A. Teacher Controls Messages

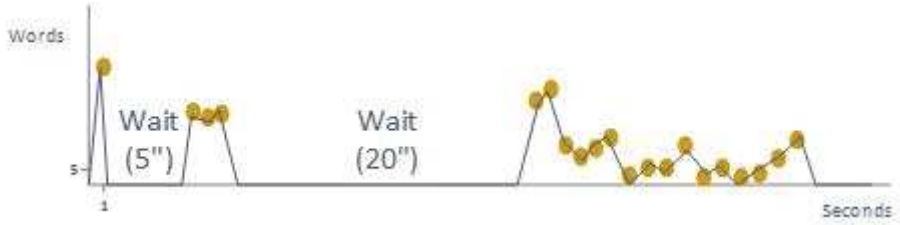

Figure 5.30: Chat4LL Testing: Part B. Student Controls Messages

Number of messages	**Words per message**
Send 1 message	(28 words)
Wait 5 seconds	–
Send 3 messages	(17 words, 13 words, 15 words)
Waite 20 seconds	–
Send 15 messages	(19 words, 23 words, 9 words, 6 words, 8 words, 11 words, 2 words, 5 words, 5 words, 12 words, 2 words, 6 words, 2 words, 4 words, 9 words, 14 words)

Table 5.8: Chat4LL Testing: Part B. Student Controls Messages

Regarding one-to-many conversations, students used Moodle and Chat4LL. However, some participants used a method to control the reception of messages (Moodle or Chat4LL buttons) and other participants did not use any method. When users used both chat applications, they experienced situations where they received many messages at the same time and they did not receiv messages for a long period of time. Next Table 5.9 (Figure 5.32) and Table 5.10 (Figure 5.32) show how the one-to-many conversations were structured.

Figure 5.31: Moodle Testing: Teacher and Student 1 Control Messages

Number of messages	**Words per message**
Send 5 messages	(18 words, 27 words, 34 words, 21 words and 9 words)
Wait 20 seconds	–
Send 2 messages	(5 words, 12 words)
Wait 20 seconds	–
Send 3 messages	(9 words, 8 words, 6 words)
Wait 20 seconds	–
Send 2 messages	(8 words, 5 words)
Wait 20 seconds	–

Table 5.9: Moodle Testing: Teacher and Student 1 Control Messages

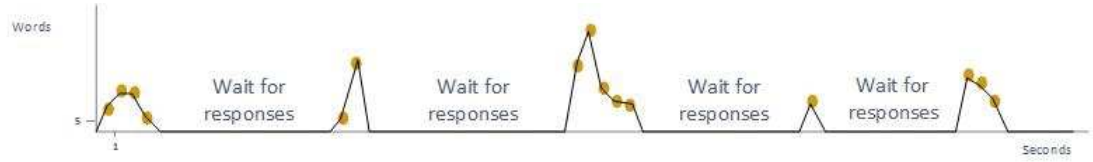

Figure 5.32: Chat4LL Testing: Teacher and Student 1 Control Messages

Number of messages	**Words per message**
Send 4 messages	(9 words, 16 words, 15 words, 5 words)
Wait until all answer	–
Send 2 messages	(6 words, 27 words)
Wait until all answer	–
Send 5 messages	(25 words, 39 words, 16 words, 13 words, 11 words)
Wait until all answer	–
Send 1 message	(12 words)
Wait until all answer	–
Send 3 messages	(23 words, 19 words, 13 words)
Users can send messages but it is not designed	–

Table 5.10: Chat4LL Testing: Teacher and Student 1 Control Messages

Design

The *Pause Autorefresh* functionality needed to be validated in a real environment with different groups of participants (People with disabilities, elderly people, people without disabilities and people without experience) using mobile chat applications. All of them tested two different chat applications which control the reception of messages but depending on the

participant, they had to test the tools in one-to-one conversations or in one-to-many conversations. Next sections describe the prototypes used in the experiment and how the user testing sessions were designed.

Prototypes To check if the *Pause Autorefresh* functionality was useful in a real environment, it was necessary to use a chat application prototype which included this functionality. The chat application developed in the previous section was used in the user testing evaluations and this was named Chat4LL. This chat application included the *Pause Autorefresh* functionality. However, this functionality needed to be compared with another functionality which allows users controlling the reception of messages in order to assure the usefulness of the *Pause Autorefresh* functionality.

In Section 5.1, Table 5.1 shows previous accessible chat tools which include a functionality to control the *Flow and Rhythm* of the conversation. One of these solutions, is included in the Moodle authoring tool. The accessible version of the Moodle chat application does not show new messages to students until they press a button to receive new messages. Users might be affected by this solution because they do not know other participants have sent new messages or not and they have to press this button continually to receive messages. This solution was selected because of many reasons:

- **E-learning:** This chat application is used in learning environments and it is included in a content management learning tool.
- **Accessibility:** In the Moodles website, it is specified that it is an accessible chat; although, this chat application has some accessibility issues.
- **Previous Users‘ opinions:** In our previous studies - see Chapter 3 - some interviewed users considered this chat application was annoying. Users had to press a button to receive new messages and it caused some difficulties for some users. As some users had used it before, they could compare it with our proposal.
- **Inclusion:** Users with and without disabilities can chat with each other using the same environment.
- **Information:** Users with and without disabilities can chat with each other using the same environment.

To compare these two chat applications, it was necessary to develop a Moodle chat application prototype. The layout of this prototype was similar to the prototype created previously to represent the *Pause Autorefresh* functionality. A similar layout was used in both chat applications because it was important to compare both functionalities and avoid possible bias related to the interface. The only layout difference was the icon-button to control the reception of messages.

To summarise, three prototypes with a similar interface were created : a prototype which does not allow users control the reception of messages **(Prototype A Classical Interface prototype)**; a prototype which reproduces the Whatsapp interface **(Prototype B Moodle Prototype)**, a prototype which includes the Moodle functionality to control the reception of messages **(Prototype C Chat4LL prototype)**.

- **Prototype A Classical Interface Prototype**: this prototype has an interface similar to the Whatsapps interface because in our previous study this chat application was the

most used application by our respondents see Chapter 3 and its behaviour is similar to a classical chat application. Users can send and receive messages but they cannot control the reception of messages. This prototype was used in the evaluation when the user was not allowed to control the reception of messages.

- **Prototype B Moodle Prototype**: this prototype includes a new button (the Refresh button) which simulates the Moodles chat application behaviour. Incoming messages are shown when the user presses the Refresh button only. Other participants in the conversation are not affected because they will use the Classical Interface Prototype at the same time.
- **Prototype C Chat4LL Prototype**: this prototype includes the *Pause Autorefresh* functionality. This functionality allows users to control the reception of messages when they feel overwhelmed. Users can press the *Pause Autorefresh* button and they do not receive new messages until they send a message or they press the button to receive new messages again. However, the other participants in the conversation will receive these messages and they will not be affected. Also, participants who did not use the *Pause Autorefresh* functionality were informed other person pressed the button and is not receiving messages. Finally, when the person presses the *Pause Autorefresh* button to receives the sent messages, the rest of participants are informed as well.

It is important to emphasise that every chat application was developed following accessibility standards and guidelines provided in Chapter 4. Next, the figures which represent each prototype are specified - see Figure 5.33.

Figure 5.33: Designed Prototypes. Prototype A, Prototype B and Prototype C (Showed in this Order)

Sessions User testing sessions were structured in a different way depending on the number of participants in the conversation: one-to-one conversations or one-to-many conversations.

One-to-one conversations were conversations with one participant (or student) and one moderator (or teacher). In contrast, one-to-many conversations were conversations with three participants (or students) and one moderator (or teacher). Only three participants participated in these conversations because we did not want to involve too many participants and make these conversations very difficult to follow because there could be many messages sent by the participants at the same time.

In one-to-one conversations, participants tested all prototypes from the point of view of a person who used a method to control the reception of messages (Moodle functionality or *Pause autorefresh* functionality) and from the point of view of a person who did not use any of these functionalities but the other participant used it. Meanwhile, the moderator used the chat application in the opposite way the user tester was using it. For example, if the user was using the Moodle chat application prototype and was using the method to control the reception of messages (Prototype B), the moderator was using the Moodle chat application prototype but was not using the method to control the reception of messages (Prototype A).

On the other hand, participants who participated in one-to-many conversations did not test all prototypes from both points of views. The person with disabilities or elderly person used the Moodle and Chat4LL prototypes from the point of view of a person who uses a functionality to control the reception of messages (Prototypes B and C). In contrast, the rest of participants used Moodle and Chat4LL prototypes from the point of view of a person who did not use any method to control the reception of messages (Prototypes A and C). Meanwhile, the moderator used both chat applications from both points of views (Prototypes A, B, C). The following Figure 5.34 shows how these sessions were structured.

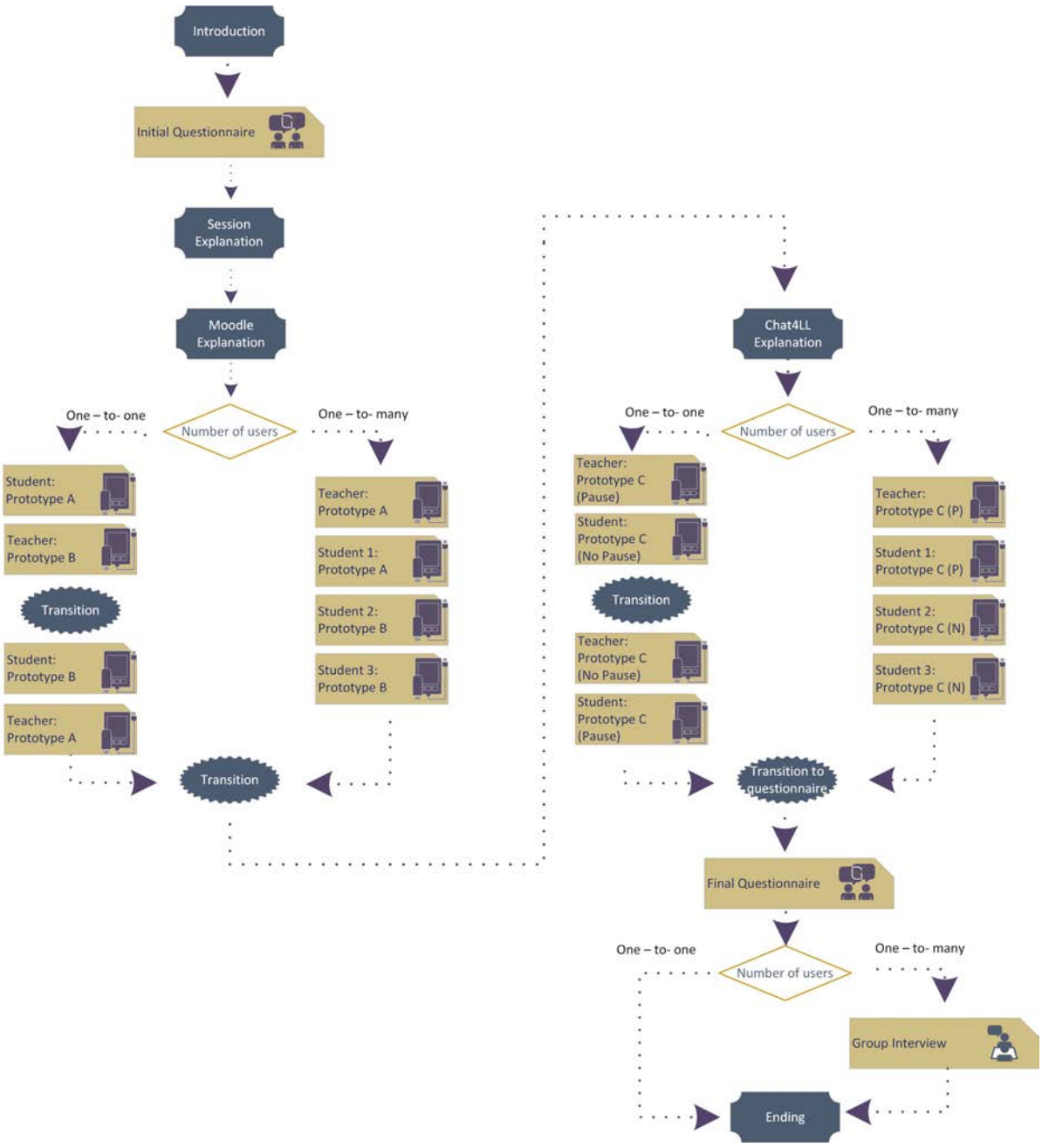

Figure 5.34: Conversations' Structure

These sessions were designed to be the more similar as possible in order to compare them later. However, it was not possible to make them completely similar. Depending on the participant, the conversation was slower or quicker. Some participants were able to send messages very quickly but others needed more time to read or to write. As a result, the number of minutes or messages could vary.

Procedure

The user testing sessions were conducted in the ILUNION offices or in the Leganés City Hall. The moderator was in the same room as the participants but they could not speak with the rest of participants or the moderator. As a result, users were not distracted and the

experiment was not affected.

Each user testing session was divided into the next parts: Introduction; Initial questionnaire; Session explanation; Moodle explanation; Testing Moodle application; Transition to Chat4LL; Chat4LL explanation; Testing Chat4LL application; Questionnaire about their impressions of the functionalities to control the reception of messages; Group interview. Next Figure 5.35 shows how the user testing sessions were divided into one-to-one and one-to-many user testing sessions.

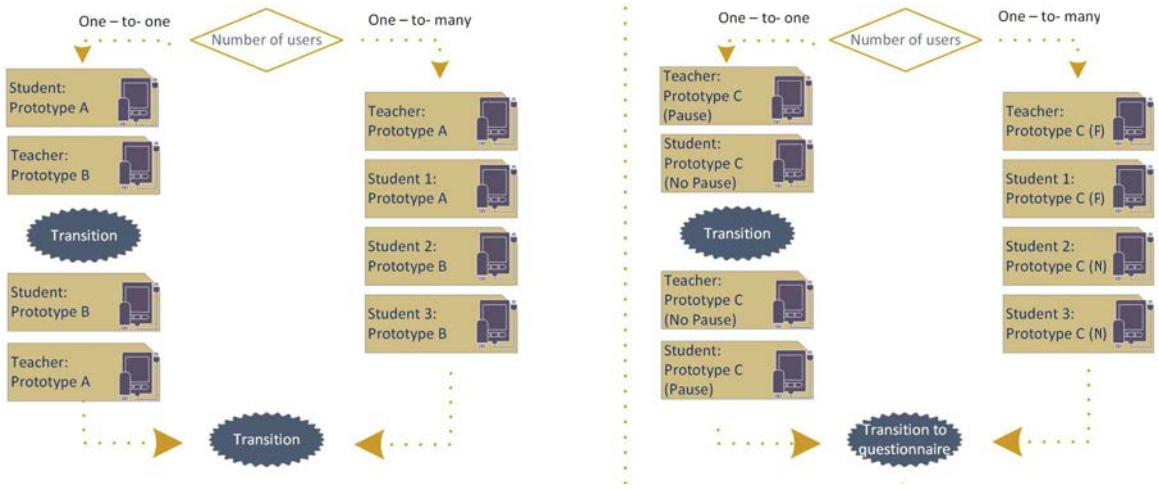

Figure 5.35: Sessions' Structure

One-to-one conversations were conducted for 50 minutes while one-to-many conversations were conducted for one hour and thirty minutes. In addition, the number of observers who participated in the session was different. Table 5.11 shows a summary of the experiment and explains its characteristics.

	One-to-one	One-to-many
Environment	Same office	Same office
Records	All the validation was recorded as well as the sent messages	Just the group interview was recorded and the sent messages
Participants	One student and one teacher	Three students and one teacher
Observers	n/a	One observer who took notes
Sent messages	Users could only answer questions	Users could just answer questions at the beginning and discuss with each other at the end of the conversation
Period of time	50 minutes	1 hour and a half
MDs	Tablet or iPhone	Each participant had one different MD including Tablets or Smartphones

Table 5.11: Characteristics of the Validation in One-to-one and One-to-many Conversations

Introduction When users arrived at the offices, they were explained they were going to be part of a user testing session to test new chat application tools. Depending on the user session, users were informed they were going to participate in a one-to-one or a one-to-many session. In addition, they were introduced the other participants, if there were, in order to make the user testing session more personal and simulate m-learning environments where students had met their colleague only once. After this housekeeping information, users had to complete a consent form to specify they agreed to participate in this user testing session and they agreed the information obtained in the session will be recorded and analysed for research purposes.

Initial questionnaire After explaining the user testing session, participants had to complete a questionnaire. The moderator asked each question to the participant and they had the possibility to explain their answers and feelings. Then, the moderator fulfilled the questionnaire basing on the answers provided by the participant. This questionnaire included: demographic questions E.g. age or studies - ; information about their previous experiences using mobile devices; the assistive technologies they used; if they had used chat applications before; and if they considered themselves as quick users or slow users when they read or write content in a chat application tool.

Session explanation After this interview, the moderator explained users how the user testing was divided and the system's behaviour. Besides, users who had not used any chat application before were explained how a chat tool is used in deep. In addition, participants - see Figure 5.36 - had time to use the chat application by their own in order to get used to the interface and understand how to interact with the system before the session started.

Figure 5.36: Participant Using the Chat Application

Once users were ready, they were explained that they were going to participate in a m-learning class and they would be the students in this class. Furthermore, they were explained the topic of this class was Recycling in Spain. Participants were informed they should communicate using the chat application only; so, they were not allowed to communicate with their classmates verbally. In addition, they were explained they had to answer the questions the teacher asked but they could not deviate the topic.

Finally, they were explained they were going to use two different tools and they were informed that additional instructions will be given after that.

Moodle explanation Users were explained they were going to use the first chat application, Moodle chat application. They were not explained the whole user testing session in one go because users might be overwhelmed. However, this explanation was informed immediately before the user had to test each chat application.

In one-to-one conversations users tested the app from two different perspectives (Moodle Part A and Moodle Part B) in order to understand users' behaviours when they used or not a Moodle chat application - see Figure 5.37. As a result, the session was divided into two different parts:

- **Moodle Part A:** Teacher used the Moodle's chat application (Prototype B) but the student did not use it (Prototype A).
- **Moodle Part B:** Student used the Moodle's chat application (Prototype B) but the teacher did not use it (Prototype A)

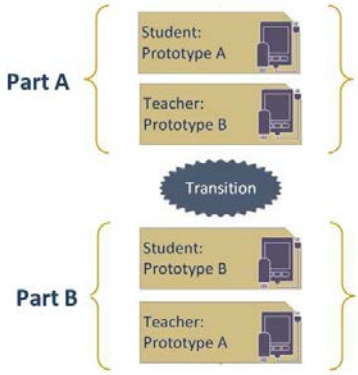

Figure 5.37: One-to-one Conversations - Moodle Testing

In contrast, participants, who tested the application in a one-to-many user testing session, tested Moodle Prototype A or Moodle Prototype B exclusively. The teacher (moderator) and one student used the Prototype B which allows users controlling the reception of messages. This student was the student who: had a disability, did not use chat applications before or was an elderly person. In contrast, the other students used the prototype A and they did not use any method to control the reception of messages. It was limited the number of participants who used a method to control the reception of messages because one of the purposes of this study was to analyse if users, who used a method to control the reception of messages, and users, who did not use a method to control the reception of messages, could collaborate in the same m-learning environment. Next Figure 5.38 describes and summarises this information.

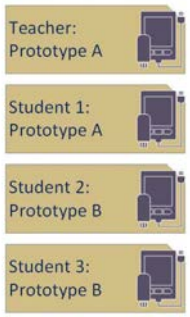

Figure 5.38: One-to-many Conversations - Moodle Testing

Testing Moodle application As it was explained in the *Stimuli* section, the moderator sent messages to the rest of students and she was in charged of the conversation. Meanwhile, students replied to the questions asked by the moderator.

One-to-one conversation In the Moodle Part A phase, it was simulated that the teacher (Moderator) used the Moodle chat application while she was sending messages with the student (User). As the teacher was using this method, messages were sent slower than usual in some specific moments.

When this phase was finished, the student was sent a link to test the next prototype. Then, the student clicked on this link and the Prototype B was loaded on their screen. The moderator explained to the participant that he was going to use the Moodle chat application tool to control the reception of messages but the teacher (moderator) would not use it. When everything was ready, the moderator explained they were going to continue the conversation using the chat application tool.

On the other hand Moodle Part B phase, it was simulated that student used the Moodle method to control the reception of messages. In this situation, it was sent too many messages at the same time in order to evaluate if the student was lost when he was using a method to control the reception of messages.

The conversation was previously designed carefully. Thus, this research could be replicated again. The stimuli section shows how many messages were sent and the second interval between one message was sent and the other message was sent again.

One-to-many conversation Regarding to one-to-many conversations, the conversation was similar to the one-to-one conversation with one exception, participants did not use both Moodle Prototypes (Prototype A and B) when they tested the Moodle application. In this case, users interacted with the system using the Prototype A or the Prototype B. Meanwhile, the observant took notes about important behaviours or comments the user raised during the chat application conversation.

In this phase, the teacher (moderator) simulated different situations that could occur in a m-learning session. It means that many messages were sent at a time, there was some seconds between messages, etc. Participants were able to reply messages only when the teacher asked. However, before the end of the Moodle phase, users had five minutes to change the topic of the conversation and to send as many messages as they wanted.

Transition to Chat4LL After testing the Moodle chat application, all participants changed the prototype. In this testing environment, they used Chat4LL chat application.

Chat4LL explanation Users used Chat4LL chat application. They were not explained the whole user testing session in one go because users might be overwhelmed. However, this explanation was informed immediately before the user had to test each chat application.

In one-to-one conversations, users tested Chat4LL application (Prototype C) from two different perspectives (Chat4LL Part A and Chat4LL Part B) in order to understand users behaviours when they used or not a method to control the reception of messages - see Figure 5.39. As a result, the session was divided into two different parts:

- **Chat4LL Part A**: Teacher used the *Pause Autorefresh* functionality to control the reception of messages. In contrast, the student could not use this functionality.
- **Chat4LL Part B**: Student used the *Pause Autorefresh* functionality to control the reception of messages. In contrast, the teacher could not use this functionality.

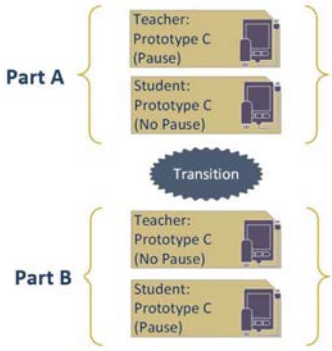

Figure 5.39: One-to-one Conversations - Chat4LL Testing

On the other hand participants, who tested the application in a one-to-many user testing session, tested Chat4LL application too but only some participants could use the method to control the reception of messages included in the Chat4LL application. The teacher (moderator) and one student could control the reception of messages. This student was the same student who used the Prototype B in the previous phase and this student was the student who: had a disability, did not use chat applications before or was an elderly user. In contrast, the other students used the prototype C but they were not allowed to control the reception of messages. As in the Moodle testing session, it was limited the number of participants who used a method to control the reception of messages because it was necessary to analyse if users, who used a method to control the reception of messages, and users, who did not use a method to control the reception of messages, could collaborate in the same m-learning environment. Next Figure 5.40 describes and summarises this information.

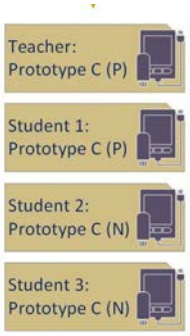

Figure 5.40: One-to-many Conversations - Chat4LL Testing

Testing Chat4LL application As it was explained in the *Stimuli* section, the moderator sent messages to the other students and she was in charge of the conversation. Meanwhile, students replied to the questions asked by the moderator.

One-to-one conversation In the Chat4LL Part A phase, the teacher (Moderator) sent messages to the students using the Chat4LL application. In this phase the teacher was the person who could use the *Pause Autorefresh* functionality. In contrast, students were not allowed to use it. As the teacher was using this method, the teacher simulated that she was not able to follow the conversation and as a result, the teacher needed to press the *Pause Autorefresh* button to Pause the reception of messages.

When this phase finished, the student was informed that he could use the *Pause Autorefresh* button at any time. If he considered that he was lost in the conversation and he needed more time. In addition, the student was informed that the teacher (moderator) would not use it. When everything was ready, the moderator explained they were going to continue the conversation using the chat application tool.

Regarding the Chat4LL Part B phase, the user received many messages at a time in order to force students to use the *Pause Autorefresh* functionality. In this situation, it was evaluated if the student did not get lost when used the *Pause Autorefresh* functionality and if the student got a benefit of this new functionality.

The conversation was previously designed carefully. Thus, this research could be replicated again. The stimuli section shows how many messages were sent and the interval of seconds between one message was sent and the other message was sent again.

One-to-many conversation Regarding one-to-many conversations, the conversation was similar to the one-to-one conversation with one exception, participants were allowed to use the *Pause Autorefresh* functionality or not. Meanwhile, the observant took notes about important behaviours or comments the user raised during the chat application conversation.

In this phase, the teacher (moderator) simulated different situations that could occur in a m-learning session. It means that many messages were sent at a time, there was some seconds between messages, etc. Participants were able to reply messages only when the teacher asked. However, before the end of the Moodle phase, users had five minutes to change the topic of the conversation and to send as many messages as they wanted.

Final questionnaire Finally, a semi-structured interview was carried out with the user in order to know their opinion about this new functionality and their general opinion comparing both chat applications.

Users were asked about their feelings when they interacted with the system and they could express their opinion. Every user was asked about their feelings and opinions when they were using every chat interface:

- Participants, who used Moodle or Chat4LL , were asked about their feelings before, during and after using these functionalities.
- Participants, who did not use Moodle or Chat4LL, were asked about their feelings before, during and after the teacher or other student used these functionalities.

These feelings were based on the feelings provided by Petrie [Petrie and Precious, 2010] in her research about how to evaluate the user's feelings in websites. As the mother tongue of the participants was Spanish, these feelings were translated to Spanish basing on two English-Spanish dictionaries, WordReference and FreeDictionary. Users catalogued their feelings selecting how they felt basing on the SAM user experience monitor scale [Bradley and Lang, 1994].

Finally, users had to specify which chat interface they preferred and if they would used these functionalities in the future in m-learning or general situations (non learning situations). For more information about the questions asked in the interview - see Annexe G.

Group interview In one-to-many interviews, users were asked to share their feelings with the other students and they participated in an informal interview. Users had the possibility to explain why they felt comfortable or not using the chat applications; how did they feel when someone else used the chat application; if they would use it in their real live; as well as if they would improve it.

Data Collected

Each session was conducted with real users and in a real environment. To assess whether the system could be useful for users, different perspectives were considered. These include: participants' opinions, participants interactions and conversations scripts in the session. Next table - Table 5.12 - describes the data collected in each modality:

	One-to-One conversation	**One-to-Many conversation**
Before user testing	Questionnaire	Questionnaire
During user testing	Video recording, Messages logs	Observer notes, Messages logs
After user testing	Questionnaire	Questionnaire, Group interview

Table 5.12: Data Collected - Summary

Questionnaires An initial and final paper-based questionnaire with open questions and Likert scales were used before and after the sessions. The moderator asked the participants each question and the moderator completed the questionnaire with the answers provided by the participants.

Video recording During one-to-one conversations, it was recorded the user's interaction. A webcam was used to broadcast the session using Skype. This session was recorded in the moderator‘s laptop.

Messages logs The messages sent through the chat application were recorded in the server. These logs included: the time-stamp, the person who sent the message and the chat application the user was using.

The observer notes Notes were taken by the observer during the sessions. These notes served various purposes, ranging from participants behaviours to any note or reminder for the future sessions.

Group interviews The group interview conducted at the end of one-to-many user testing sessions was recorded.

Data Analysis

After conducting the research, qualitative and quantitative data was analysed. The information was analysed from the point of view of different categories. Firstly, the data was analysed without clustering users into groups. As a result, all participants were not clustered into groups of people. Secondly, users were divided into:

- Disabilities: People with disabilities vs people without disabilities. In addition, people were divided into people with learning disabilities, with motor impairments, with visual impairments (including low vision), and with hearing impairments.

- Experience: People with experience vs people without experience.
- Age group: <18, 18-25, 26-35, 36-45, 46-54, 55-65, >65
- Modality: one-to-one vs one-to-many conversations

Those groups were created in order to compare the results between them later on. This data could not be analysed in the same way. Next, it will be explained how data was analysed.

Qualitative data Qualitative data was analysed using NVIVO software. This software was used to categorise data and tag the information obtained during the sessions.

The categorised data was obtained from the initial questionnaire, the observer notes, video recording, the final questionnaire and the group interview. All data obtained during the sessions were imported into a project in NVIVO. Then, the data was categorised into the groups specified before.

Quantitative data To analyse all the information obtained in the conversations, SPSS 20 was used to analyse the quantitative data obtained in the research and Microsoft Excel software was used to create all graphics to represent this data .

Quantitative data was obtained from the initial and final questionnaire done for each participant. The first questionnaire included demographic questions related to their previous experiences. In contrast, the questionnaires included questions which needed to categorise peoples feelings see Appendix G for more information about the questions asked. These questions followed a Likert scale combined with the SAM scale in order to make the users decisions easier. For example, users were asked:

> Were you unrelieved or relieved because you did not know why I sent messages really slowly?

Users had the option to specify how they felt and they could select Very unrelieved, Unrelieved, Neutral, Relieved and Really relieved. Every option was categorised as: -2, -1, 0, 1, 2 respectively in order to analyse as a quantitative data.

After assigning a value to each answer, the data was stored in SPSS. Then, it was studied which parametric test should be applied in the data analysis.

Firstly, it was determined if the data was normally distributed or not. After analysing the histograms shapes, the Shapiro-Wilks test (p¿.05) was applied as well as a visual inspection of the normal Q-Q plots. These analysis depicted that the results are not normally distributed for Chat4LL and Moodle. This means that non-parametric (or distribution-free) methods should be used in the analysis. In this case, the same population participated in the study to compare their opinion between Chat4LL and Moodle. Thus, the Wilcoxon signed-rank test was used to compare both sets of scores for the same population [Wilcoxon et al., 1970]

Conversation analysis

To analyse if users were able to continue with the conversation, it was analysed the messages sent by the participant during the conversation. In this analysis, it was selected participants who used a method to control the reception of messages using Moodle or Chat4LL. It was analysed the first and second messages sent by this participant. If the message was related

to the other messages that the rest of participants had sent, it was considered the user was able to take part in the ongoing conversation. In contrast, if the user did not answer previous messages or if the user answered old messages, it was considered the user was not able to follow the ongoing conversation.

In order to assure the consistency of the previously categorised data, it will be considered the inter-rater reliability method [Kraemer, 1982] to assure that the classification of the rater was made correctly. One rater more will analyse a piece of data to assure its consistency. In this case, it was selected the conversation number 16 because it was analysed by the previous rater that the participant lost part of the conversation three times.

After applying this method, the Kappa value obtained is K=0.5. There is no universal agreement as to what a good value of kappa is. One fairly common convention those values between 0.4 and 0.75 are fair-to-good. Then, basing on the obtained value of Kappa (K= 0.5), it could be affirmed that the categorisation way is fair-to-good.

5.6.3. Results

This section explains the results obtained after the data was analysed following the previous described methodology.

RQ1:How useful is the *Pause Autorefresh* functionality?

The main important objective of the study is to know if people consider the *Pause Autorefresh* functionality is useful or not for them. After doing the evaluations, users were asked their opinion about this new functionality using the interview method. Next sections describe the analysis design of the collected data through these methods.

RQ1.1. How did users feel when they used the *Pause Autorefresh* functionality? After using the Moodle and Chat4LL prototypes, users were asked through a personal guided interview some questions related to their feelings when they used the *Pause Autorefresh* button. They were asked if:

1. they were **unrelieved** or **relieved** because they thought they could lost part of the conversation.
2. they were **confused** or **confident** when they received all the messages that were in the queue.
3. they were **disappointed** or **happy** to use the button.

Histograms are analysed to understand how the population's opinion is divided. The histograms of Moodle and Chat4LL for every feeling are shown - see Figure 5.41, Figure 5.42 and Figure 5.43.

A total of 7 people considered they were unrelieved when they used Chat4LL. These people were people with disabilities (3 out of 7) and people without disabilities (4 out of 7). Analysing the results from the user's expertise using chat applications, they were people with previous chat experience (4 out of 7) and (3 out of 7). People felt unrelieved when they used Chat4LL because they were interacting with something new and they did not know the behaviour of the system.

> User62:" At the beginning it was difficult because it was new and it took me much time to comprehend everything"

Analysing the results of people who used Moodle, 18 people who used Moodle were unrelieved or really unrelieved when they used Moodle. There are no significant differences between the groups analysed. As a result, it cannot be concluded specific results for each group. Some of the participants, who considered they would use Moodle, were people with disabilities and others were elderly people. In addition, from the point of view of experience, some had previous experience and others were people without experience. Most of them explained they did not know if they were losing part of the messages.

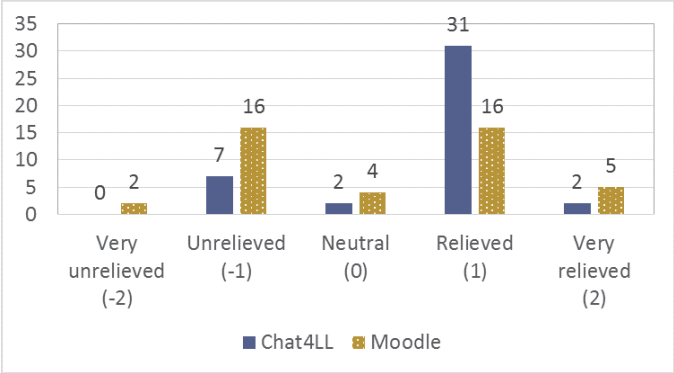

Figure 5.41: Unrelieved vs Relieved

From the point of view of confident feeling, 10 people agreed not to be confident when they used Chat4LL. People, who were not confident, considered they received too many messages at the same time and they were a bit confused about this.

> User 69: "I was confident because I received all the messages; however, I was a bit confused because I was not answering the conversation at the same time as other people."

In contrast, a total of 18 people considered they were confused when they used Moodle. Most of them (12 out of 18 people) were people who did not have experience using chat applications before. This is significant because there are no previous bias as they were not used to use chat application tools.

Many people were not reading the most recent messages and they were answering these messages. In addition, some of them were worried about pressing the button continually and did not know if they have received all messages or not.

> User 90: "I lost part of the conversation and I had to scroll up and down to read the messages in context and answer."

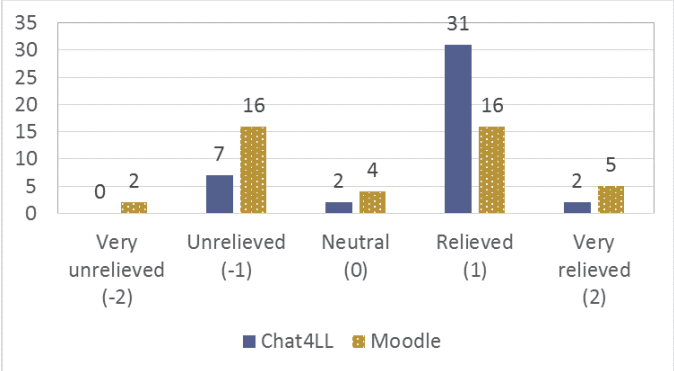

Figure 5.42: Confused vs Confident

Only one person explained he was not happy using Chat4LL application. This person explained he did not have problems following the conversation and as a result, he did not need this button. However, 16 people considered that they were disappointed and really disappointed when they used Moodle to interact with the system. Most people considered they did not like pressing the button continually and they were not aware if there were more messages or not.

> User 33: "I was a bit stressed because I had to press the button. The problem was that I did not know if there were more messages or not. It could be a good idea to show the number of messages that are in the queue."

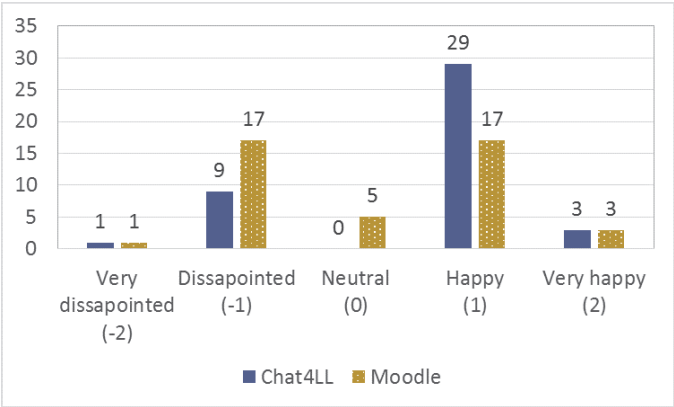

Figure 5.43: Disappointed vs Happy

In order to compare if users got an improvement when they used Chat4LL comparing it with Moodle, Wicoxon signed-rank test was applied. The H0 and H1 hypothesis were set up and they were the following:

- H0: There is no difference between chat applications Moodle and Chat4LL (The median difference is zero versus)
- H1: There are differences between both chat applications (The median difference is not zero α =0.05)

After applying Wilcoxon signed-rank test, the table shows that 34 (Positive values + ties) of the 42 participants who used any chat feature to control the reception of messages, their relieved score when they used Chat4LL was greater or similar than Moodle, indicating greater

unrelieved when they used Moodle. This occurs when the results are compared with the other two variables Confident and Happy. Therefore, we can reject H0 and we can conclude that people, who used Chat4LL tool to control the reception of messages, experienced a significant increase in reliability (z=-2.579 , $\rho = 0.05$), confidence (z=-2.314 , $\rho = 0.05$) and happiness (z=-3.508 , $\rho = 0.05$) when people used Chat4LL.

Did users age affect these feelings? Results are analysed from the point of view of participants ages because it could affect them in their feelings. The Figures 5.44, 5.45 and 5.46 depicted the results obtained for the feelings Unrelieved vs Relieved, Confused vs. Confident, Disappointed vs Happy. For all these feelings, the most selected option on the Likert scale was 1. The means and standard deviation of each group were calculated and these means were compared using a graphic. These graphics show people were more relieved, confident and happy in the conversation when they used the Chat4LL functionality.

From the point of view of Relieved feeling, all analysed groups were more relieved while they were using Chat4LL rather than Moodle. However, people between [25, 35) and [55,65) years old were more relieved when they used Chat4LL rather than when they used Moodle but the difference is not really significant - see Figure 5.44 and 5.13.

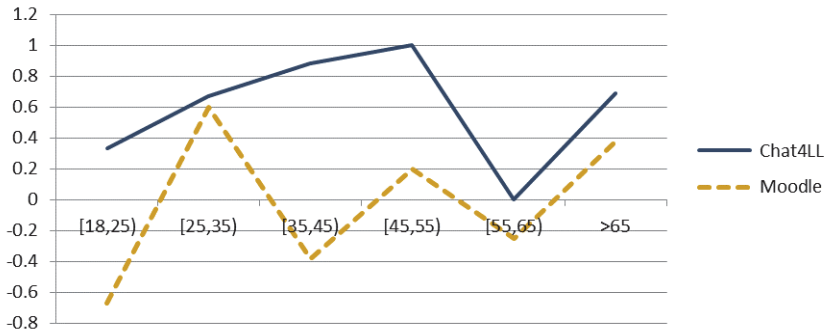

Figure 5.44: Unrelieved vs Relieved: Age

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
[18,25)	3	0.33	1.16	3	-0.67	0.58
[25,35)	10	0.67	0.71	10	0.6	1.5
[35,45)	8	0.88	0.84	8	-0.38	0.92
[45,55)	5	1.00	0	5	0.2	1.1
[55,65)	4	0	1.16	4	-0.25	1.5
>65	13	0.69	0.86	13	0.38	1.04
Total	43	-	-	43	-	-

Table 5.13: Unrelieved vs Relieved: Age

From the point of view of confident feeling, all analysed groups were more relieved while they were using Chat4LL rather than Moodle. The Chat4LL graphic is a flat graphic and tends to 0.5. There is no difference between analysed groups. However, the Moodle graphic does not show a trend and depending on the group, people were more or less relieved when they used Moodle. For example, people between [18,25) years old were the least relieved group

when they used Moodle (Chat4LL $\tilde{X}$=0.33 vs Moodle $\tilde{X}$=-1) - see Figure 5.45 and Table 5.14 .

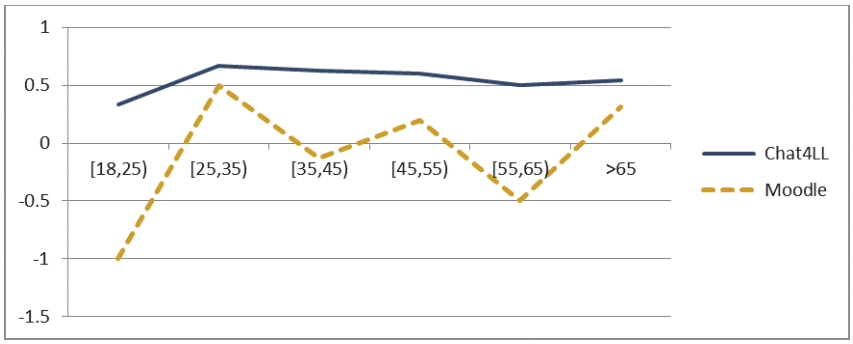

Figure 5.45: Confused vs Confident: Age

Confused vs Confident	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
[18,25)	3	0.33	1.16	3	-1.00	0.00
[25,35)	10	0.67	1.00	10	0.50	1.08
[35,45)	8	0.63	0.86	8	-0.13	0.99
[45,55)	5	0.60	0.89	5	0.2	1.30
[55,65)	4	0.50	1.00	4	-0.5	1.00
>65	13	0.54	1.18	13	0.31	1.11
Total	43	-	-	43	-	-

Table 5.14: Confused vs Confident: Age

After analysing the results of the Happy feeling, people were happier using Chat4LL than using Moodle. All groups analysed considered they were happy when they used Chat4LL (between $\tilde{X}$=0.50 and $\tilde{X}$=1.00). However, the Moodle results showed a variation. People elder than 55 were happier using Chat4LL but the difference between Moodle and Chat4LL results was smaller (Chat4LL $\tilde{X}$=1.00 vs Moodle $\tilde{X}$=0.5) - see Figure 5.46 and Table 5.15

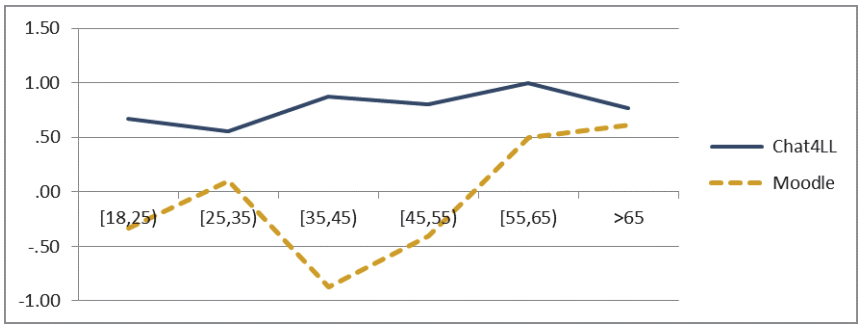

Figure 5.46: Disappointed vs Happy: Age

Disappointed vs Happy	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
[18,25)	3	0.67	0.58	3	-0.33	0.58
[25,35)	10	0.56	0.73	10	0.10	1.29
[35,45)	8	0.88	0.64	8	-0.88	0.64
[45,55)	5	0.80	0.45	5	-0.40	1.34
[55,65)	4	1.00	0.00	4	0.5	1.00
>65	13	0.77	0.60	13	0.62	0.87
Total	43	-	-	43	-	-

Table 5.15: Disappointed vs Happy: Age

Did users experience affect these feelings? The results were analysed from the point of view of people's experience. There is not a common feeling. People did not agree if they were more relieved, confident or happy when they used Moodle. The Moodle graphic depicted that there is not a trend in the results as there are two modes for -1 value and 1 value in both groups (people with and without experience). However, if the Chat4LL results are analysed, people with and without experience were more relieved when they used Chat4LL the results are clustered around the value 1 - see Figure 5.47.

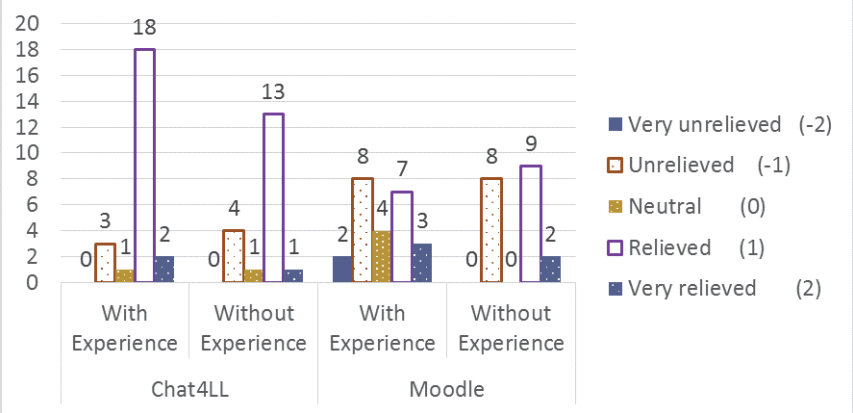

Figure 5.47: Unrelieved vs Relieved: Experience

In addition, if the mean and standard deviations of Moodle and Chat4LL are compared, people with experience were more relieved when they used Chat4LL if this is compared with Moodle results. However, opinions are more varied because the standard deviation is higher for Moodle - see Table 5.16. From the point of view of people without chat expertise, the difference average is not really significant because it is only 0.28 higher for Chat4LL. **It might be related to the fact that users were not used to any previous way of interaction and they were not expecting any specific system behaviour.**

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With disabilities	24	0.74	0.75	24	0.04	1.23
Without disabilities	19	0.58	0.9	19	0.26	1.15
Total	43	-	-	43	-	-

Table 5.16: Unrelieved vs Relieved: Experience

Analysing the results of the Confident feeling, the graphic shape was similar to the Relieved feeling graphic, there were two modes for the Moodle chat graphic and one mode (Value 1) for the Chat4LL graphic. Comparing the Chat4LL and Moodle $\tilde{X}$, the Chat4LL results were higher for both groups 0.36 higher for people with previous chat experience and 0.63 higher for people without previous experience; but the standard deviation shows that people without experiences opinions were more different. Comparing Chat4LL and Moodle, **people might be more confident when they interacted with Chat4LL**. The reason could be that they controlled the reception of messages when they needed. This difference is more noticeable when people without experience used Chat4LL, they were more confident when they used Chat4LL than when they used Moodle. See Table 5.17 for additional information about this feeling.

Confused vs Confident	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With experience	24	0.74	0.86	24	0.38	0.97
Without experience	19	0.37	1.12	19	-0.26	1.15
Total	43	-	-	43	-	-

Table 5.17: Confused vs Confident: Experience

From the point of Disappointed vs Happy feeling, the graphic shape is similar to the Relieved graphic too. If the $\tilde{X}$ results are compared, the value is higher for Chat4LL than Moodle. (With experience 0.69 higher and 0.78 higher). In this case, the standard deviation for Moodle is higher than the Chat4LL standard deviation - see Table 5.18. **These results show that people‘s opinion were more similar when they used Chat4LL rather than Moodle.** This can be related to the fact that people had to remember they had to press a button continually and if they forgot it, they will have more messages to read the next time.

Disappointed vs Happy	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With experience	24	0.65	0.65	24	-0,04	1.08
Without experience	19	0.89	0.46	19	0.11	1.12
Total	43	-	-	43	-	-

Table 5.18: Disappointed vs Happy: Experience

Did users‘ disabilities affect these feelings? These results should be analysed from the point of view of disabilities. Thus, the results of people with disabilities and people without disabilities are compared in order to study if users disabilities could affect their feelings. In addition, these results are analysed grouped per disability.

The graphics related to every feeling did not depict any additional information because the shape was similar as described in the previous sections. There are two modes for the Moodle chat graphic and there is only one mode (around value 1) in the Chat4LL chat application graphic. In addition, if the means of each chat for the three feelings are compared, the results are really similar to the comparative between people with experience and without experience - see Table 5.19, Table 5.20, Table 5.21.

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With experience	21	0.70	0.80	21	0.10	1.18
Without experience	22	0.64	0.85	22	0.18	1.22
Total	43	-	-	43	-	-

Table 5.19: Unrelieved vs Relieved: Disabilities

Confused vs confident	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With disabilities	21	0.74	0.75	21	0.04	1.23
Without disabilities	22	0.58	0.90	22	0.26	1.15
Total	43	-	-	43	-	-

Table 5.20: Confused vs Confident: Disabilities

Disappointed vs Happy	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With disabilities	21	0.6	0.82	21	0.00	1.00
Without disabilities	22	0.55	1.14	22	0.18	1.18
Total	43	-	-	43	-	-

Table 5.21: Disappointed vs Happy: Disabilities

Analysing the results from the point of view of type of disability, five different clusters were created: Blindness, Visual impairments, Hearing impairments, Motor impairments and Cognitive impairments - see Table 5.22, Table 5.23 and Table 5.24.

In general, all users were more relieved in the conversation while they were using Chat4LL. Specially, people with blindness, people with visual impairments and people with hearing impairments were more relieved. In contrast, people with cognitive disabilities and people with motor impairments were more relieved but there is not a huge difference between the obtained results. This can be explained because the number of participants was not very high.

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
Blindness	5	1.2	0.45	5	0.8	1.1
Cognitive	4	0.25	0.96	4	0.0	1.41
Hearing imp.	2	1	0	2	-1	0
Motor imp.	4	0.5	1	4	0.25	0.96
Visual imp.	6	0.67	0.82	6	-0.17	1.33
Total	21	-	-	21	-	-

Table 5.22: Unrelieved vs Relieved: Per Disabilities

From the point of view of confidence, people with blindness, with cognitive disabilities and with hearing impairments were more confident when they used Chat4LL (if the results are compared with Moodle results). However, people with motor impairments were equally

confident when they interacted with both systems and people with visual impairments were only 0.33 more confident when they used Chat4LL.

Confused vs Confident	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
Blindness	5	1	0	5	0.4	0.9
Cognitive	4	0.5	1	4	-0.5	0.56
Hearing imp.	2	1	0	2	-1	0
Motor imp.	4	0.5	1	4	0.5	1.23
Visual imp.	6	0.33	1.03	6	0	1.01
Total	21	-	-	21	-	-

Table 5.23: Confused vs Confident: Per Disabilities

Analysing the results from the point of view of happiness, all groups but one (cognitive disabilities) were happier using Chat4LL button to control the reception of messages.

Disappointed Vs Happy	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
Blindness	5	0.6	0.56	5	-0.4	1.14
Cognitive	4	0.75	0.5	4	1	0
Hearing imp.	2	1	0	2	-1.5	0.71
Motor imp.	4	0.75	0.5	4	-0.75	0.5
Visual imp.	6	0.83	0.41	6	-0.17	1.33
Total	21	-	-	21	-	-

Table 5.24: Disappointed vs Happy: Per Disabilities

Did one-to-one or one-to-many modalities affect these feelings? The results were analysed from the point of view of people who participated in the conversation. In this case, the distribution of the results was similar to the distribution which included all the population. If the means obtained for every feeling, users were more relieved, confident and happy when they used Chat4LL than when they used Moodle - see Table 5.25, 5.26 and 5.27. Furthermore, if the one-to-one and one-to-many results are compared, the use of tools to control the reception of messages was more accepted by users when they were participating in one-to-one conversations. Also, **Chat4LL got better results in one-to-one conversations than in one-to-many conversations**.

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
One-to-one	33	0.76	0.71	33	0.24	1.23
One-to-many	10	0.33	1.12	10	-0.20	0.92
Total	43	-	-	43	-	-

Table 5.25: Unrelieved vs Relieved: Modality

Confused vs Confident	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
One-to-one	33	0.6	0.82	33	0.00	1.00
One-to-many	10	0.55	1.14	10	0.18	1.18
Total	43	-	-	43	-	-

Table 5.26: Confused vs Confident: Modality

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
One-to-one	33	0.73	0.88	33	0.18	1.07
One-to-many	10	0	1.23	10	-0.20	0.92
Total	43	-	-	43	-	-

Table 5.27: Disappointed vs Happy: Modality

RQ1.2: Was the conversation affected when someone used the *Pause Autorefresh* button? The use of the *Pause Autorefresh* button could cause problems understanding the conversation. The messages sent during the conversation were analysed to confirm if people who used any method to control the reception of messages were able to participate actively in the conversation without suffering problems understanding the conversation. It was analysed the first and second messages sent by this person. If the message was related to the other messages that the rest of participants had sent, it was considered the user was able to take part in the ongoing conversation. In contrast, if the user did not answer previous messages or if the user answered old messages, it was considered the user was not able to follow the ongoing conversation.

Firstly, it was analysed if participants were able to maintain a conversation using a chat application and if they did not lost part of the conversation. The results shown people who used Moodle experienced more problems following the conversation (21 out of 44 people did not follow the conversation at least once when they used Moodle). In contrast, only 10 out of 44 people experienced these problems when they used Chat4LL - see Figure 5.48.

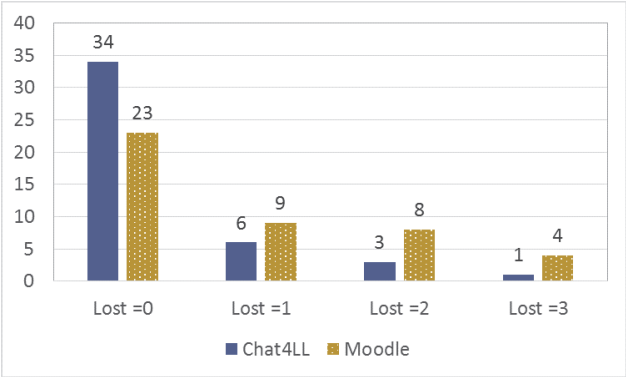

Figure 5.48: Lost Conversation Analysis

Previous results were analysed from the point of view of one-to-one conversations and one-to-many conversations in order to assure if the use of the *Pause Autorefresh* feature could

affect one-to-one conversations, one-to-many conversations or both.

From the point of view of one-to-one conversations, a total of 17 people were lost in the conversation once, twice or three times when they used Moodle. In contrast, only 8 people had problems continuing with the conversation when they used Chat4LL. In addition, some people were never got lost during both Chat4LL and Moodle conversation but 16 participants were not lost during Moodle conversations and 25 were not lost during the Chat4LL conversation - see Figure 5.49. These results shown that people got lost in the conversation fewer times when they used Chat4LL.

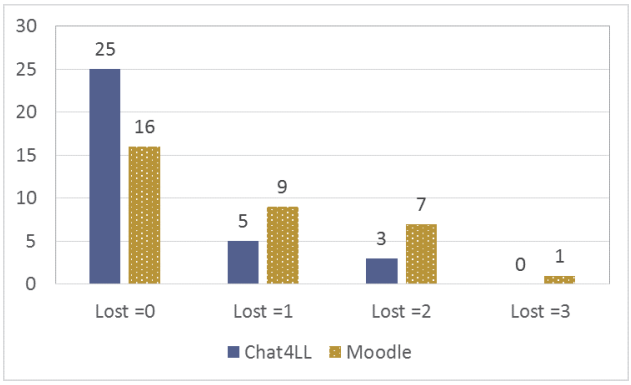

Figure 5.49: Lost Conversation Analysis - One-to-One Conversations

On the other hand, results were analysed from the point of view of one-to-many conversations. In this case, the number of people who got lost three times were increased when they used Moodle or Chat4LL chat applications. However, users were lost fewer times when they used Chat4LL chat application - see Figure 5.50.

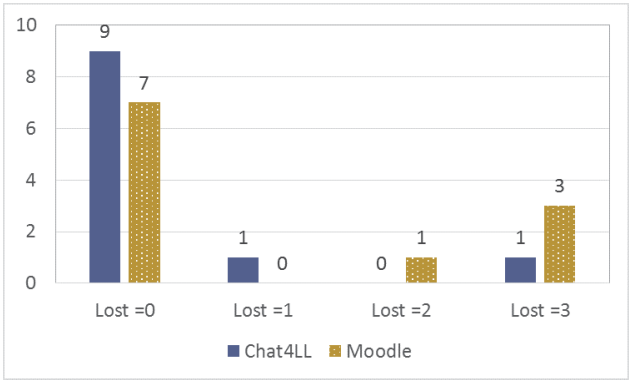

Figure 5.50: Lost Conversation Analysis - One-to-Many Conversations

RQ1.3. Did users prefer Chat4LL over Moodle to control the reception of messages? Every user in the personal guided interview was asked to compare both chats in order to know which one is better for them from the point of view to control the reception of messages. This question was an open-ended question where users could specify their whole feelings.

Firstly, their opinions were categorised into four different groups according to the chat which was selected.

1. People who used a method to control the reception of messages
    - Selected Moodle
    - Selected Chat4LL
2. People who did not use a method to control the reception of messages

This variable is considered as a categorical variable and it is calculated the frequency and percentage as the only method of statistical analyses. After the categorisation, it can be concluded that 36 of participants preferred Chat4LL (80%), 7 of participants preferred Moodle (16%) , 3 of participants (4%) did not pressed the *Pause Autorefresh* functionality and 17 participants did not use the Chat4LL as active users. It was evaluated if the selection of one or other chat could be related to the age, experience, disability or type of conversation. And the only result obtained was that the three people that did not use the chat were people who participated in group conversations. People, who selected Moodle, had a common pattern. They were people without previous chat or mobile device experience (6 out of 7 people). Also, they were elderly people or were people in their late fifties (5 out of 7 people). In addition, the people who had disabilities (3 out of 7) were people with visual impairments and participated in group conversations (2 out of 3).

People selected Chat4LL because of different reasons. The most common reason was users could use it when they needed. So, it was a feature they can decide to use or not. In contrast, the most common answer of people who selected Moodle was that it was easier for them. This is similar to the reason which explains that three people did not press the button. Next figure shows a summary of the people's answers and the number of people who selected this answer - see Figure 5.51.

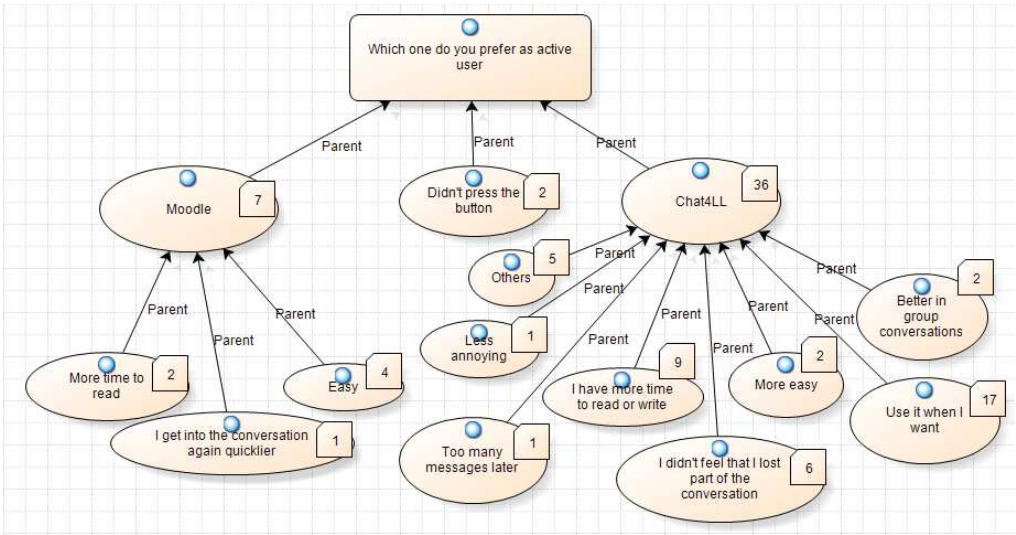

Figure 5.51: Chat Application User Preference

Chat4LL Users selected Chat4LL chat because they could control the reception of messages when they needed or wanted (17 users said that). In contrast, Moodle forced users to press the button whether they wanted to press it or not.

> User1:"I prefer the second one because I only Pause the reception of messages when I have many messages and I cannot read them. For me it is annoying to press the Moodle's button continually to read the messages"

The second most common answer was the *Pause Autorefresh* functionality gave them more time to answer and read the conversation. As a result, they could be more immersed in the conversation (9 users said that).

> User19: "I can Pause to read the messages. Moreover, if there were difficult words, I could Pause to understand them or to search for them. I think that I have a break specifically in important conversations because you could have more time to read. I have paused because I could read carefully what you wrote."

> User46:"In my opinion it was more natural. You could read and write and you had more information about your situation. It did not feel there was a machine between us."

Comparing Chat4LL with Moodle, people had the feeling that they would receive many messages at the same time and they would not have time to read them (1 users said that) or they could lose part of the conversation (6 users said that) when they used Moodle.

> User5: "I did not know if you were writing and how many messages I would receive later"

> User61: "I was worried because of the button not because of the messages. Moreover, I was even more worried because I was waiting a large number of messages"

Other people said other reasons such as: Chat4LL was less annoying; it was easier; the Chat4LL might be more useful in one-to-many conversations; or the Chat4LL helped them to not use the scrollbar a lot, so, they could press the button and the scrollbar would not moved.

Moodle People selected Moodle because it could be easier for them as they did not have to think in two buttons, they had only one button to press and they should not make any mistake (4 people said that).

> User26: I had to press only one button. I did not have to press two buttons and think about two steps. I think that it is simpler, there is one step and it is similar to the email

The second most common answer was that people had more time to read the messages and they could establish the rhythm of the conversation (2 people said it).

> User7: "I had more time to read"
> User34: "I could establish the rhythm"

Other people considered that if they used Chat4LL, they could miss part of the conversation and they would not be available to follow it (1 person said it).

> User51: "When I used the second chat, I had the feeling that I answered the messages late."

Did not use the *Pause Autorefresh* functionality The three participants, who did not press the button, were a person with visual impairments, a person with hearing impairments and a person without previous experience in the use of chats. All of these people participated in group conversations; so, it could be the reason because they did not press it.

The person with visual impairments (Low vision) needed to focus her sight in one part of the screen in order to read the messages. She was really close to the screen to see these messages. She did not use the button because she was really concentrated on the conversation and she preferred to not participate in the conversation (writing messages) and pausing the reception of messages. She paused the reception of messages because we asked her to do it, she preferred reading messages instead of participating actively. To sum up, it was really difficult for her to: move her eyes; search for the *Pause Autorefresh* button; press it; and finally, continue reading the messages sent. Maybe, it could be useful for her to had another type of interaction, not just a button. For example, she could get a benefit of a microphone or speak assistive tool to pause the reception of messages instead of pressing a button because she would not need to move her eyes.

The person with hearing impairments uses chat applications tools on mobile devices every day to communicate. Therefore, during the conversation she was really quick to answer and follow the conversation. So, she did not use the *Pause Autorefresh* functionality. Also, she said that she was used to receive all messages continually in other chat applications and she would not need any feature to control the reception of messages. In addition, she felt that maybe she was not receiving the messages; so, she did not trust on the chat application.

The other person was a person who did not have any disability and did not have many experience using chat applications previously. This person had not used a tactile keyboard previously and she was not comfortable when she was chatting with more people. She did not participate actively in the conversation because people typed messages quicker than her. She considered that the use of the *Pause Autorefresh* functionality was really complicated for her because she had to press the button, type and continue reading.

RQ2: Is it useful for m-learning environments?

As the main aim of the *Pause Autorefresh* functionality is to improve the *Flow and Rhythm* in m-learning environments, it is important to analyse if users would be able to understand the information exchanged through the chat application. Furthermore, they answered a question about if they consider that this new functionality would be useful for m-learning situations exclusively or it is also useful for other type of conversations. Also, people who participated in one-to-many conversations explained their thoughts about teachers using the *Pause Autorefresh* functionality without affecting the conversation.

RQ2.1: Would users use the *Pause Autorefresh* functionality in m-learning environments? After using Chat4LL, users had the possibility to specify if they would use the chat application in real environments. This question was an open question and users could explain in detail their opinions and feelings. Participants could explain if they would use it in m-learning environments exclusively or not and if they would like to use it in other environments such as: professional or informal environments. In addition, they were asked if they would use the new functionality depending on the number of participants in the conversation. It is important to emphasise that some one-to-many-conversation participants did not use the *Pause Autorefresh* functionality because only one participant was allowed to use this functionality. However, participants who did not use this functionality answered this questions too but their opinion was based on a hypothetical situation instead on their own experience.

The collected data was analysed into different ways. Firstly, their opinions were categorised into three different groups which are described next:

- Opinion: Yes, no or maybe.

- Environment: M-learning or other environments.
- Number of participants: One-to-one conversations, one-to-many conversations or both kind of conversations.

Users could express their copinion and they could explain if they would use it in real situations or not. This variable is considered as a categorical variable and it is calculated the frequency and percentage as the only method of statistical analyses. After this categorization, it can be concluded that 79% of respondents considered they would use it in real situations meanwhile the percentage of respondents who said they would not use was 16%; and only 5% of respondents were not sure if they would use it or not - see Figure 5.52 .

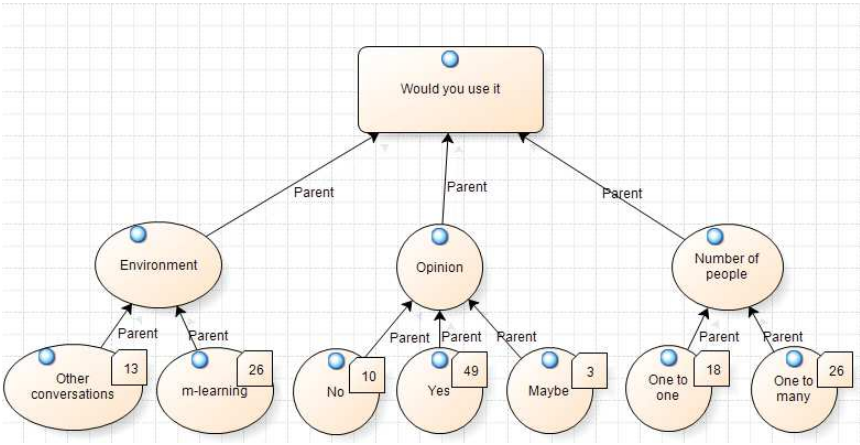

Figure 5.52: Would Users use the New Functionality?: Opinion's Categorisation

Participants were asked if they used it in m-learning environments or other environment such as: At work or In personal conversations. Most of the participants (26 participants) explained they would use it in m-learning environments or environments where they should pay much attention (E.g. At work). In contrast, 13 participants said that they would use it always and they would use it even when in informal conversations (E.g. With friends).

Participants explained that it was useful in m-learning environments because of different reasons. Some of them considered that they usually need more time to read and write in m-learning conversations because the information is more important and more difficult to understand or need more concentration.

> User42: "I would use it when I would be in a conversation which need much concentration"

Other participants detailed that they would use this new functionality always because they could feel overwhelmed despite the type of conversation. They could get a benefit of this new functionality because they could control and read the conversation.

> User47: "I would use it in general to inform people that I need more time and to read and write slowly"

> User46: "Yes, I would use it in all situations, it does not matter the context - e.g. friends, school, one-to-one or one-to-many conversations."

Finally, people explained they could use this functionality in other situations such as: when they wait for the bus or when they are doing other tasks. Using this functionality, they could inform other participants they are not going to be available or able to answer quickly.

> User30: "If I were on the bus and I could not write, I could press the button and inform other participants that I cannot answer."

The number of participants in the conversation could influence users. Most participants (26 participants) considered they would use Chat4LL in one-to-many conversations. In contrast, other participants considered they would use Chat4LL in one-to-one conversations exclusively (18 participants).

RQ2.2: Could teachers use the *Pause Autorefresh* functionality? This question was asked only in group interviews at the end of the one-to-many conversations. This question was an open question and participants could explain their feelings in detail.

Some people considered that the teacher used the *Pause Autorefresh* functionality because this person needed time to do something else instead of thinking that the teacher needed more time to read or write the messages (People of 2 one-to-many conversations said that).

> GroupConversation1: "I thought that you were really slow. Besides, I could think that you were in the Toilet or doing anything else

The conversation might be affected because people were waiting for someone to conduct the conversation and guide them in the conversation (People of seven conversations said that).

> GroupConversation3: "I was waiting for the teacher and I was reading the conversation"

> GroupConversation8: "As you were the person who was conducting the conversation, it was different when you Paused the reception of messages. If another student paused the reception of messages, nothing happened. If you paused, I realised that the conversation was getting slower; however, if another student used it, I was not affected. I follow the rhythm of the teacher."

To sum up, people considered that the conversation was affected when the teacher used the *Pause Autorefresh* functionality because they were waiting for someone who guided them. Then, students might be confused and the learning process might be affected. As a result, teachers might use the *Pause Autorefresh* functionality but students should be informed previously that teachers would press the button when they needed more time. Then, students would have extra time to review the conversation.

RQ3: Were users bothered by people who used the *Pause Autorefresh* functionality?

One of the objectives of this research was to know if people, who experience problems following the *Flow and Rhythm* of the conversation, and people, who do not have problems following the *Flow and Rhythm* of the conversation, could use the same application and environment at the same time. In this case, nobody would be get bothered about the use of the new functionality and everybody could collaborate using this environment.

To answer this question, users were asked which chat application they preferred as well as their feelings when another participant used Chat4LL. Next sections explain in detail how the information was collected and analysed.

RQ3.1: How did users feel when someone else used the *Pause Autorefresh* functionality? After using the Moodle and the Chat4ll chat applications, users were asked in an interview some questions related to their feelings when someone else used the *Pause Autorefresh* functionality. In this interviews, they were asked if:

- they got bored or were interested in the conversation after someone pressed the *Pause Autorefresh* button.
- they were annoyed or pleased by the velocity of the messages.
- they were unrelieved or relieved because they did not have enough information about why the messages were so slow (Moodle) or I paused the reception of messages (Pause Autorefresh functionality).

The results show that people were more interested, pleased and relieved when someone else used the Chat4LL chat than when this person used Moodle - see Figure 5.53, Figure 5.54 and Figure 5.55. The histogram shows that the data is clustered around the value 1 (interested, pleased and relieved).

On the other hand, regarding people who were more bored when someone else used the Chat4LL (Value -1), four people answered they got bored. They might be bored mainly because the conversation was really slow:

> User59: I would be a bit bored, if it happened at home or with my mobile. At these circumstances, I would close the mobile or I would have started talking with other people

There is not a clear pattern, which explains why these people considered this chat was more boring. Two of them participated in one-to-many conversations while the other two participated in one-to-one conversations. Also, two of them had any disability (visual or cognitive disability) and the other two did not have any disability. The experience did not make any difference either; two of them had previous experience and two of them did not have experience. However, all of them were young women between 28-43 years old.

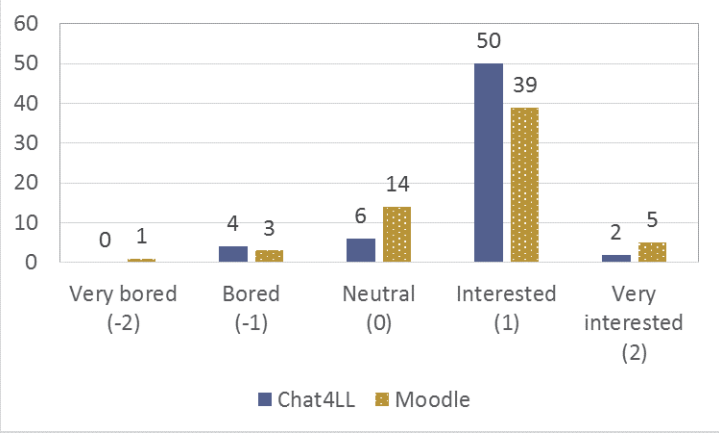

Figure 5.53: Were Users Bothered when Someone used the New Functionality?: Bored vs Interested

Only four people were annoyed when someone else used the Chat4LL application(Value -1 or -2). In this case, the pattern, which might be obtained after analysing the data, explains that the three of them have no experience and no disability. In addition, three of them

were elder than 55 years old. However, none of them added additional comments to this reason.

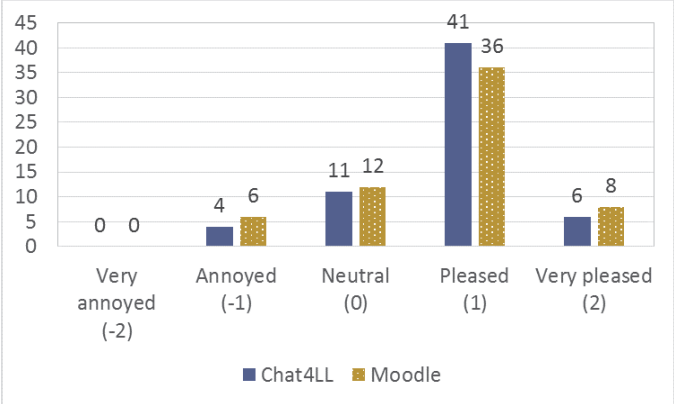

Figure 5.54: Were Users Bothered when Someone used the New Functionality?: Annoyed vs Pleased

People, who said they were unrelieved when someone else used the *Pause Autorefresh* functionality, considered it because they did not have enough information. They did not know why people pressed the button. However, there is not any pattern of people, who considered it was unrelieved, because half of the participants did not have experience. They explained that they felt unrelieved because they did not know exactly why the other person Paused the conversation and if it was an urgent conversation, they would be even more unrelieved. Also, it is important to emphasise that even people who considered that they were relieved while they were in the conversation, they could be unrelieved in urgent conversations for example (17 people said that).

User43: I was worried because I was waiting and I did not know the reason

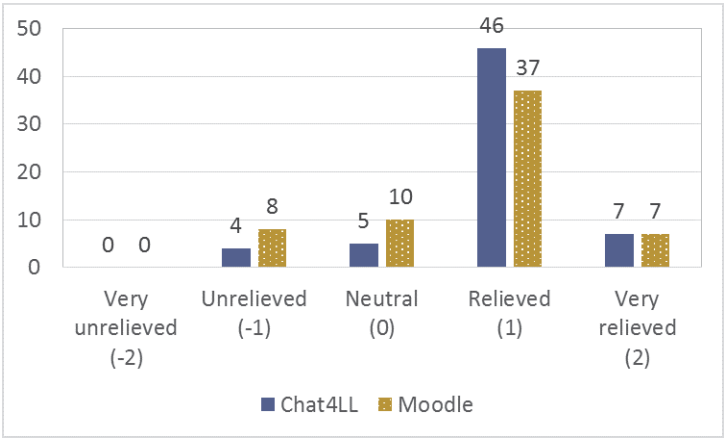

Figure 5.55: Were Users Bothered when Someone used the New Functionality?: Unrelieved vs Relieved

This analysis explains how the distribution of the obtained results was but it does not explain if users were more bored when someone else used Moodle chat application than when they used Chat4LL application. Thus, it is important to analyse if Chat4LL made people more interested, pleased and relieved while they participated in the Chat4LL conversation. As both Chat4LL and Moodle distributions do not follow the normal distribution, non-parametric (or

distribution-free) methods should be used in the analysis. In this case, the same population participated in the study to compare their opinion between Chat4LL and Moodle. Thus, the Wilcoxon signed-rank test was used to compare both sets of scores for the same population. The H0 and H1 hypothesis were set up and they were the following:

- H0: There is no difference between chat applications Moodle and Chat4LL (The median difference is zero versus)
- H1: There are differences between both chat applications (The median difference is not zero α =0.05)

After applying this method, the table shows that 36 of the 62 participants were less bored. Indicating that there is not a huge difference between both chats. Also, comparing Chat4LL and Moodle Annoyed and Unrelieved feelings, the results show that there is not any difference between both results. We observe the p-value is greater than 0.05 [Interested (z=-0.848 , ρ=0.396), Pleased (z=-0.570 , ρ=0.569) and Relieved (z=-1.090 , ρ=0.276)]; then, we cannot reject the null hypothesis (H0) and there is no evidence of a difference in the median scores of the feelings (Bored, Annoyed and Unrelieved) from the two chat applications compared. As a result, it can be concluded that considering all the participants, who participated in the conversation and did not use any tool to control the reception of messages, there is no evidence that users will be affected by the chat used by the other participant to control the reception of messages.

Did users age affect these feelings? Age might affect users opinion; thus, it is necessary to analyse the results from the point of view of age. The means and standard deviation of each group were calculated. In addition, they were compared using a graphic. The Figures 5.56, 5.57 and 5.58 compare the means of every age group and show people were more interested, pleased and relieved in the conversation when someone else used the Chat4LL application; however, the age influences users preferences.

In general, elderly people were more interested in the conversation when people used Chat4LL functionality to control the reception of messages. However, people over 60 years old were more interested in the conversation when someone else used the Moodles functionality to control the reception of messages - see Figure 5.56 and Table 5.28 which show the average and standard deviation for each age.

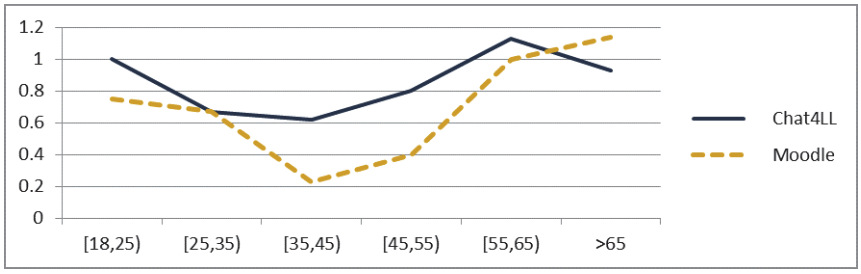

Figure 5.56: Were Users Bothered when Someone Used the New Functionality?: Bored vs Interested - Age

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
[18,25)	4	1	0	4	0.75	0.5
[25,35)	18	0.67	0.77	18	0.67	0.91
[35,45)	13	0.62	0.77	13	0.23	0.71
[45,55)	5	0.80	0.45	5	0.4	0.89
[55,65)	8	1.13	0.35	8	1	0
>65	14	0.93	0.27	14	1.14	0.54
Total	62	-	-	62	-	-

Table 5.28: Were Users Bothered when Someone Used the New Functionality?: Bored vs Interested - Age

It cannot be concluded that people were more pleased or annoyed when someone else used one chat or another to control the reception of messages because the difference is really small - see Table 5.29 and Figure 5.57. However, people between 45 and 65 years old might be more affected and they could consider that Moodle is better for them.

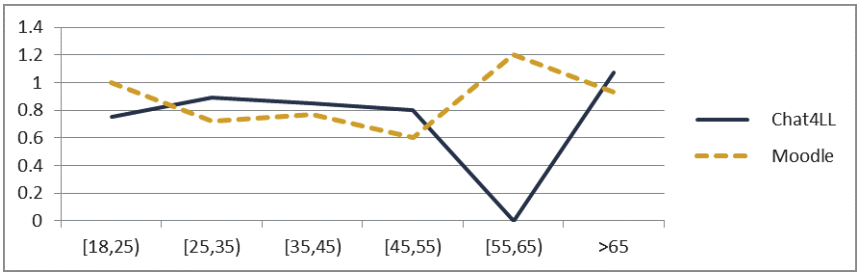

Figure 5.57: Were Users Bothered when Someone Used the New Functionality? Annoyed vs Pleased - Age

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
[18,25)	4	0.75	0.5	4	1	0.00
[25,35)	18	0.89	0.83	18	0.72	0.9
[35,45)	13	0.85	0.38	13	0.77	0.6
[45,55)	5	0.80	0.45	5	0.6	0.89
[55,65)	8	0	0.93	8	1.2	1.4
>65	14	1.07	0.48	14	0.93	0.73
Total	62	-	-	62	-	-

Table 5.29: Were Users Bothered when Someone Used the New Functionality?: Annoyed vs Pleased - Age

From the point of view of relieved feeling, an age pattern cannot be obtained either. In general, younger adults prefer Chat4LL because they know the state of the other user continually. However, people between [18,25) and [55,65) prefer Moodle because they do not need to know the situation of the other person - see Table 5.30 and Figure 5.58.

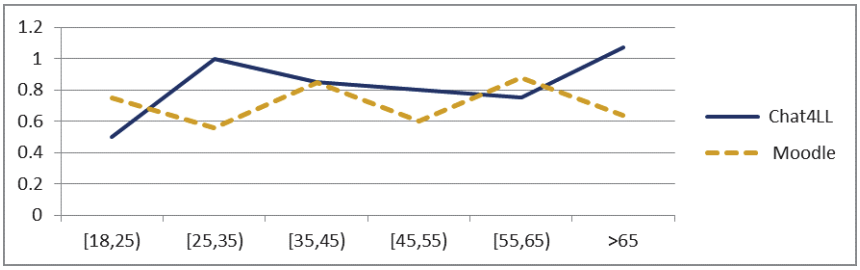

Figure 5.58: Were Users Bothered when Someone used the New Functionality?: Unrelieved vs Relieved - Age

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
[18,25)	4	0.5	1	4	0.75	0.5
[25,35)	18	1	0.77	18	0.56	1.1
[35,45)	13	0.85	0.38	13	0.85	0.8
[45,55)	5	0.80	1.1	5	0.6	1.14
[55,65)	8	0.75	0.89	8	0.88	0.35
>65	14	1.07	0.27	14	0.64	0.75
Total	62	-	-	62	-	-

Table 5.30: Were Users Bothered when Someone Used the New Functionality?: Unrelieved s Relieved - Age

To conclude, young adults were more interested in the conversation when someone else used Chat4LL to control the reception of messages. It might be related to the fact that older adults were not used to Chat applications and they received more messages when the other person used Chat4LL application. However, the means show a small difference between elderly people and young adults from the point of view of pleased and relieved feelings. Moreover, it cannot be concluded that people were more pleased or relieved in the conversation when someone else used Chat4LL to control the reception of messages.

Did users expertise affect these feelings? People who had used chat applications before were not more bored/interested or annoyed/pleased in the conversation than people without previous experience if someone else used Chat4LL. The data distribution does not change and it is similar to the data distribution which includes all participants. In this case, data is clustered around the value 1. The $\tilde{X}$ difference value is only 0.1 higher comparing with Moodle - see Table 5.31 and Table 5.32.

Bored vs Interested	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With experience	35	0.77	0.66	35	0.66	0.84
Without experience	27	0.85	0.6	27	0.78	0.64
Total	62	-	-	62	-	-

Table 5.31: Were Users Bothered when Someone Used the New Functionality?: Bored vs Interested - Experience

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With experience	35	0.89	0.63	35	0.80	0.76
Without experience	27	0.67	0.78	27	0.67	0.88
Total	62	-	-	62	-	-

Table 5.32: Were Users Bothered when Someone Used the New Functionality?: Annoyed vs Pleased - Experience

Analysing the results from the relieved feeling, although the most common value is 1 (relieved; M=17 experienced people and M=20 people without experience), the value -1 (unrelieved) has been voted on seven occasions by people with experience - see Figure 5.59. This means that people with experience were more unrelieved when someone else used Moodle. It might be related to the fact that people with experience are used to interact with chat applications and if someone else used a different way of interaction, they would like to know it. However, people without experience did not use another chat application before and they were slower sending and reading messages. Also, they were receiving more messages at the same time because they received confirmations when someone was receiving messages. As a result, they might be more overwhelmed because they received more messages or they might be confused because they had to understand and see which messages were system messages or user messages.

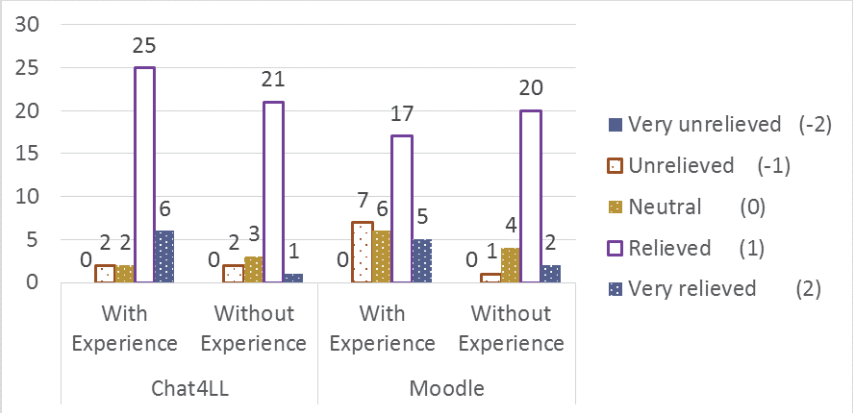

Figure 5.59: Were Users Bothered when Someone Used the New Functionality?: Unrelieved vs Relieved - Experience

Comparing means of people with experience and people without experience, people with experience were more relieved when someone else used Chat4LL ($\tilde{X}$ =1; σ=0,89) than when other person used Moodle ($\tilde{X}$=0,57; σ=0,98). In contrast, people without experience were more relieved when someone else used the Moodles chat application ($\tilde{X}$ =0,85; σ=0,6) than Chat4LL ($\tilde{X}$=0,78; σ=0,6) - see Table 5.33.

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With experience	35	1	0.89	35	0.57	0.98
Without experience	27	0.78	0.64	27	0.85	0.6
Total	62	-	-	62	-	-

Table 5.33: Were Users Bothered when Someone Used the New Functionality?: Unrelieved vs Relieved - Experience

Did users disabilities affect these feelings? Analysing the results from the point of view of disabilities, the distribution does not reflect any change comparing it with the distribution of all the population. In these cases, the data is clustered around the 1 value (Interested) too. Comparing the median obtained in both groups, it can be concluded that people with disabilities were more interested in the conversation when someone else used Chat4LL [Chat4LL $\tilde{X}$ =0.76; Moodle $\tilde{X}$=0.52]. However, there is no evidence that people without disabilities were more interested in the conversation when someone used Chat4LL comparing it with Moodle [Chat4LL $\tilde{X}$ =0.83; Moodle $\tilde{X}$ =0.8]. Next, Table 5.34, Table 5.35 and Table 5.36 represent the information of the median and standard deviation of the population divided into people with and without disabilities.

Bored vs Interested	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With disability	21	0.76	0.63	21	0.52	0.75
Without disability	41	0.83	0.59	41	0.80	0.75
Total	62	-	-	62	-	-

Table 5.34: Were Users Bothered When Someone Used the New Functionality?: Bored vs Interested - Disability

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With disability	21	0.76	0.77	21	0.81	0.66
Without disability	41	0.8	0.7	41	0.71	0.66
Total	62	-	-	62	-	-

Table 5.35: Were Users Bothered When Someone Used the New Functionality?: Annoyed vs Pleased - Disability

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
With disability	21	1	0.63	21	0.43	0.87
Without disability	41	0.85	0.69	41	0.83	0.80
Total	62	-	-	62	-	-

Table 5.36: Were Users Bothered When Someone Used the New Functionality?: Unrelieved vs Relieved - Disability

The results were analysed from the point of view of type of disability. Thus, participants

were divided into clusters: Blindness, Visual impairments, Hearing impairments, Motor impairments and Cognitive impairments - see Table 5.37, Table 5.38 and Table 5.39.

Bored vs Interested	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
Blindness	5	1	0	5	0.4	0.89
Cognitive	4	0.25	0.96	4	1.25	0.5
Hearing imp.	2	1	0	2	0.5	0.71
Motor imp.	4	1	0	4	0	0.82
Visual imp.	6	0.67	0.82	6	0.6	0.56
Total	21	-	-	21	-	-

Table 5.37: Were Users Bothered When Someone Used the New Functionality?: Bored vs Interested - Per Disability

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
Blindness	5	1	0.71	5	0.8	1.1
Cognitive	4	0.75	0.96	4	1.25	0.5
Hearing imp.	2	1.5	0.71	2	1.5	0.71
Motor imp.	4	1	0	4	0.75	0.5
Visual imp.	6	0.17	0.75	6	0.33	0.82
Total	21	-	-	21	-	-

Table 5.38: Were Users Bothered When Someone Used the New Functionality?: Annoyed vs Pleased - Per Disability

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
Blindness	5	1.2	0.45	5	0.2	0.84
Cognitive	4	0.75	1.23	4	0.75	0.5
Hearing imp.	2	0.5	0.71	2	0.5	0.71
Motor imp.	4	1	0	4	0.75	1.26
Visual imp.	6	1.17	0.41	6	0.17	0.99
Total	21	-	-	21	-	-

Table 5.39: Were Users Bothered When Someone Used the New Functionality?: Unrelieved vs Relieved - Per Disability

Considering these results, people with disabilities are more likely to use Chat4LL than Moodle chat application. However, people with cognitive disabilities preferred Moodle chat application. People with cognitive disabilities might consider that the Chat4LL is more complex because they might not understand why they were receiving these messages and they had to understand the messages. With the Moodle chat application, they did not have to think about the situation of the other person. In addition, some people with visual impairments did not get any difference when they used one or the other chat application. Although, they could prefer Moodle as well because less system messages were sent and they had to read less information.

Did number of participants affect these feelings? From the point of view of the number of people who participated in the conversation, the distribution is similar to the distribution which includes all the population. Comparing means, there is not a huge difference between the chat application used and the conversation where it was used. In general, people considered that Chat4LL application was slightly better than Moodle application - see Table 5.40, Table 5.41 and Table 5.42.

Bored vs Interested	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
One-to-one	33	0.85	0.51	33	0.82	0.81
One-to-manu	29	0.76	0.69	29	0.59	0.68
Total	62	-	-	62	-	-

Table 5.40: Were Users Bothered When Someone Used the New Functionality?: Bored vs Interested - Modality

Annoyed vs Pleased	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
One-to-one	33	0.79	0.7	33	0.82	0.85
One-to-many	29	0.79	0.73	29	0.66	0.77
Total	62	-	-	62	-	-

Table 5.41: Were Users Bothered When Someone Used the New Functionality?: Annoyed vs Pleased - Modality

Unrelieved vs Relieved	Chat4LL (N)	Chat4LL ($\tilde{X}$)	Chat4LL (σ)	Moodle (N)	Moodle ($\tilde{X}$)	Moodle (σ)
One-to-one	33	0.85	0.76	33	0.58	0.87
One-to-many	29	0.97	0.57	29	0.83	0.81
Total	62	-	-	62	-	-

Table 5.42: Were Users Bothered When Someone Used the New Functionality?: Unrelieved vs Relieved - Modality

RQ3.2: Did users prefer Chat4LL more than Moodle when one of the participants use a method to control the reception of messages? Users had to compare both chat applications in order to know which one bothered them less. This question was an open question and users could specify their opinion as well as they had to decide which chat application was better for them.

After obtaining all the information, users opinions were categorised into three different groups. Depending on the chat application selected, these group opinions were: people who selected Moodle; people who selected Chat4LL; and people who considered both chats were fine.

This variable is considered as a categorical variable and it is calculated the frequency and percentage. After this categorisation, it can be concluded that 51 of respondents preferred Chat4LL (82.26 %), 8 of respondents preferred Moodle (12.9 %) and 3 of respondents (4.84 %) considered that both chats were rated in the same way. These results are really similar to

the results obtained previously. In that case, people decided Chat4LL chat application was better to control the reception messages (80% Chat4LL, 16% Moodle and 4% do not need this option). People selected Chat4LL application because of different reasons. These reasons can be divided into:

1. Easier: People considered that Moodle application was not easy.
2. Understand the situation of other people: They knew other participants needed it.
3. Provide more information and do other things meanwhile: Participants knew exactly what was the conversation situation in every moment and they could organise themselves better.

In contrast, other participants considered they preferred Moodle because of other reasons. These opinions were grouped too and they were organised in the following groups - see Figure 5.60:

1. Less information: The system showed less information and participants get less overwhelmed.
2. Calm: They were calmer as they did not have to read more information.
3. Time: It took them more time to understand the new functionality.
4. Not leave conversation: They did not feel participant had left the conversation.

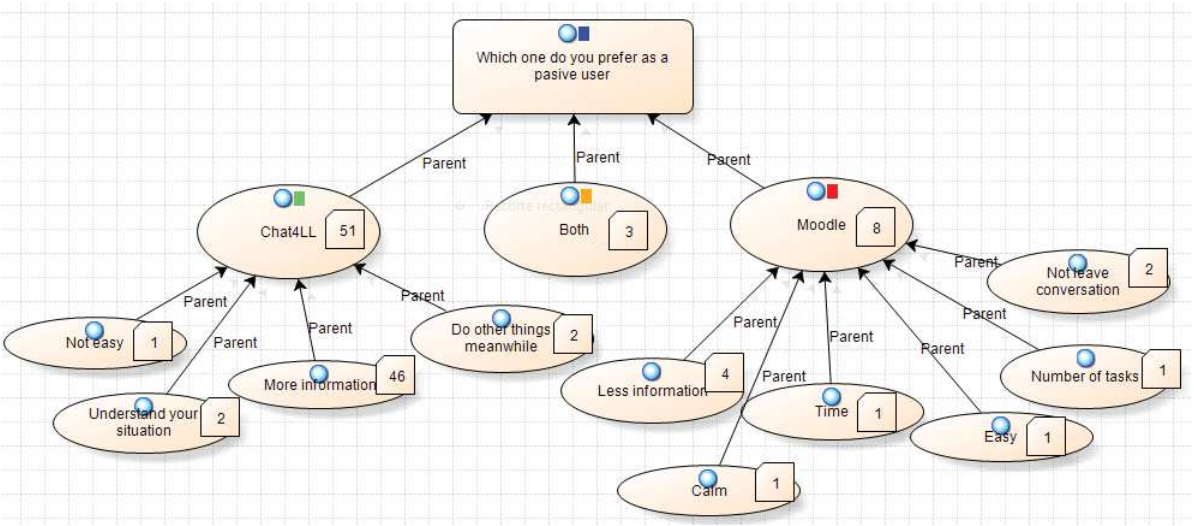

Figure 5.60: Were Users Bothered When Someone Used the New Functionality?: User's opinions

Chat4LL Chat4LL provides additional information for users and it is the most common reason for selecting this chat. Users considered that it was important for them because they could know what was happening in every moment.

> User4: "I knew that you had paused the reception of messages and I was not worried about it."

Other people said that informing them about the situation, they knew if they could do other things meanwhile or not.

> User9: "I could take more time to do another thing while you paused the reception of the message. Then, I could read the conversation or I could write more messages carefully."

Users seamed to be really conscious about the situation and they understood that people used the *Pause Autorefresh* functionality because they needed this at that moment.

> User24: "I knew that you had paused the reception of messages and I started to write more slowly"

Moodle In contrast, Moodle is selected by people who consider that informing them about the situation of users in every moment might be too much.

> User39: "I would like to know if the other person has used it or not"

However, depending on the situation and the conversation reason, people might consider that the messages are useful and they would like to be aware if someone paused the reception of messages or not.

> User41: "I prefer to not be informed. However, if the topic would be important I prefer to receive the information"

Other people considered that the messages shown to inform participants that someone has Pauseed the reception of messages were really impersonal and they could consider that the other person has abandoned the conversation.

> User51: ". . . it looks like you were outside the conversation. If it said "Rocío needs time", I would prefer the second because I understand that you need more time and it does not mean that you are leaving the conversation"

In addition, people considered that this chat was easier for them because the number of tasks that they had to execute was fewer if it is compared with the number of tasks that people had to execute when they used Chat4LL.

> User43: "it is easier, I have to do fewer tasks"

Both chat applications Finally, some people considered that they would rate both chat applications in the same way and both of them might be selected.

These results are analysed from the point of view of experience, age, disability and number of people who participated in the conversation. After analysing these results, there is no evidence that the degree of experience using chat application tools, age, disability or the number of people who participated in the conversations will affect people peoples chat selection.

5.6.4. Discussion

The main aim of this study was to analyse if the *Pause autorefresh* functionality was useful, could be used in m-learning environment and if other participants would be bothered by this functionality. Thus, the research questions that were analysed in this research were:

- RQ1: Is the *Pause Autorefresh* functionality useful?
- RQ2: Is the *Pause Autorefresh* functionality useful for m-learning environments?
- RQ3. Could users, who do not use the *Pause Autorefresh* functionality, be bothered?

In this research it was analysed if people could be able to follow conversations when they used the *Pause Autorefresh* functionality. Also, it was necessary to evaluate if this new way of interaction could be useful in m-learning environments or not, as well as, if teachers could use it and students would not be affected. Finally, it was analysed if other participants might be bothered if someone else used this functionality. Next a summary of the results obtained in the research is detailed.

Participants, who used the *Pause Autorefresh* functionality, informed they were more relieved, confident and happy when using this functionality - see Figure 5.41, Figure 5.42 and Figure 5.43 (**RQ1**). If the results are analysed from the point of view of age, all groups experienced an increment in those feelings but in [25,35) and [55,65) groups. In addition, if the results are analysed from the point of view of modality, participants‘ experience and participants‘ disabilities. The results shown that people preferred Chat4LL functionality, specifically people with visual impairments, blindness and hearing impairments. However, it is important to remark that people with cognitive disabilities had problems understanding how the *Pause autorefresh* functionality works.

As it was mentioned before, the application was tested in a m-learning environment in order to check if the functionality would be useful for learning purposes (**RQ2**) Participants specified this functionality would be useful for them to understand better the information discussed in these chat conversations. They could pause the reception of messages and they could read and reply to the conversation easily - see Figure 5.52. However, it was specified during these sessions that users would not like if the teacher paused the conversation because they would feel lost.

Finally, users were asked if they were bothered when someone used the *Pause autorefresh* functionality (**RQ3**). Most of the users specified they were not bothered (51 out of 62). However, some users confirmed they were bothered because more information was shown on the screen and they had to read it. This could be solved if users could personalise the information shown on the screen every time the user pauses the conversation. This is related to previous research studies where it has been identified students should personalise learning platforms [Santos et al., 2014].

5.7. Conclusions

Some chat applications have included methods to control the reception of messages - see Table 4.1. However, there are no relevant studies that have analysed people‘s opinions about these methods to control the reception of messages.

This research aimed to confirm if the *Pause Autorefresh* functionality could be useful for people to help them interact with chat applications easily. To confirm this, a UCD approach was followed to involve users in every phase of the study - Research, Design, Adapt, Measure. Users were involved in each phase and different studies were conducted with them.

In the research phase, users were asked their opinions about the *Pause Autorefresh* functionality and if they considered it could be useful for them or not. Users specified it could be

useful for them and informed they would not be bothered if someone else used this functionality.

Considering this feedback, a paper prototype was created to represent the *Pause Autorefresh* functionality. This prototype was shown to the participants and they explained how this prototype could be improved. Finally, this prototype was adapted basing on their feedback and a software prototype was developed.

The final version of this software prototype was used to validate if the *Pause Autorefresh* functionality: is useful; could be used in m-learning and if teachers could use it, or other people could be bothered. To confirm this, the *Pause Autorefresh* functionality was compared with the functionality included in Moodle to control the reception of messages. This application was used because this is included in a learning platform and we wanted to validate the Chat4LL application in a m-learning environment. Both functionalities were compared in order to confirm if users could prefer the *Pause Autorefresh* functionality or Moodle functionality.

As it was explained before, the main reason of this research was to assure if the Chat4LL functionality would be useful or not in m-learning environment. The following questions were answered in this study and are explained in detail next.

RQ1. Is the *Pause Autorefresh* functionality useful? Most participants were relieved, confident and happy to use Chat4LL instead of Moodle - see Figure 5.41, Figure 5.42 and Figure 5.43 - and if users‘ feelings are compared, it can be concluded that there was a significant increase in their reliability, confidence and happiness when they used Chat4LL - Reliability (z=-2.579 , $\rho = 0.05$), confidence (z=-2.314 , $\rho = 0.05$) and happiness (z=-3.508 , $\rho = 0.05$). The data was divided into clusters depending on their age, disability, experience and modality (one-to-one or one-to-many) conversations. Analysing the results from the point of view of age, it can be concluded that people were more relieved, confident and happy to use Chat4LL but people in the groups of [25,35] and [55,65] did not show a considerable preference for Chat4LL - see Figure 5.44, and 5.46, and 5.45. However, if the results are analysed from the point of view of people with experience vs people without experience and modality, all groups of people preferred Chat4LL instead of Moodle - see Figure 5.47. Finally, people with disabilities were more relieved, confident or happy in Chat4LL conversations. Specially, people with blindness, people with other visual impairments and people with hearing impairments were more relieved. In contrast, people with cognitive disabilities and people with motor impairments were more relieved but there is not a huge difference between the obtained results - see Table 5.22, Table 5.23 and Table 5.24.

The conversations were analysed to confirm the conversation was not affected when using the *Pause Autorefresh* functionality. The results shown people, who used Moodle, experienced more problems following the conversation because they did not follow the conversation at least once when they used Moodle. In addition, if the results are analysed from the point of view of modality, the results show that people got lost in the conversation fewer times when they used Chat4LL in one-to-one conversations see Figure 5.49 and Figure 5.50. Although, the number of people who got lost three times were increased when they used Moodle or Chat4LL chat applications in one-to-many conversations; users were lost fewer times when they used Chat4LL chat application.

People were asked about which chat application preferred. They selected Chat4LL rather than Moodle because people could use the Chat4LL functionality when they needed. In contrast, they had to use the Moodle functionality always. One participant said: "If I used Moodle, the machine controlled me. However, if I used Chat4LL, I controlled the machine"

they used Moodle, the machine controlled them". Participants felt more relieved, confident and happy when they used Chat4LL than when they used Moodle. The number of participants in these conversations, the person's disability or the person's experience did not affect users' opinions - see Figure 5.51.

RQ2. Is the *Pause Autorefresh* functionality useful for m-learning environments? A total of 79% of participants specified they would use this application no matter the environment. If we focus on m-learning environments, 26 (out of 42) participants said they would use it in m-learning and 13 said they would use it in m-learning as well as other environments. Participants considered that using this functionality would help them to read and understand the conversation better when they needed more time to comprehend the information - see Figure 5.52. They considered it would be helpful for them in learning or working environments mainly. However, they considered if they were sending messages to their colleagues, it might not be necessary. Furthermore, teachers could use the Chat4LL functionality but students could be disoriented because teachers were leading the conversations and they might get lost.

RQ3. Could users, who do not use the *Pause Autorefresh* functionality, be bothered? All participants were more interested, pleased and relieved when someone else was using Chat4LL chat application instead of Moodle see Figure 5.53, Figure 5.54 and Figure 5.55. Users, who were bothered by Chat4LL, explained they received too much information and they needed more time to read this information. In contrast, other participants liked this because they knew what was happening. The feelings' results of Moodle and Chat4LL were compared in order to determine if people's feelings were much better when they were using Chat4LL. In this case, it was concluded that considering all the participants, who participated in the conversation and did not use any tool to control the reception of messages, there was not a significant evidence that users will be affected by the chat application used by the other participant to control the reception of messages.

In addition, users were asked which chat application they would like more to interact with when other participants used a method to control the reception of messages. People prefer Chat4LL (51 out of 62) when another participant used a feature to control the reception of messages because they were informed about the situation of the other person in every moment. However, some users considered they preferred Moodle because they received less information - see Figure 5.60.

A solution for people, who did not select Chat4LL application, could be to provide options to customise the interface. Users could be able to configure the information they want to receive. For example, they might consider they do not want to be notified when a user has paused the reception of messages. Finally, there is not any evidence to assure users prefer Moodle or Chat4LL if the results are analysed from the point of view of disability, experience, age or type of conversation.

Additional findings during the research Users who used the Chat4LL application informed us they might not use the *Pause Autorefresh* feature because they might be in an important conversation and they could need to communicate immediately with the other person. In this case, the user who did not use the feature could have the possibility to send important messages tagged as Important and send them even when the user has paused the reception of messages. The *Pause Autorefresh* functionality might be a complex functionality because users need to press a button and they have to remember it. It could be useful to add shortcuts, specific gestures or specific voice commands which will allow users to pause the

reception of messages without pressing this specific button.

To summarise, it can be concluded that the Chat4LL application would be useful for people regardless of their disabilities, age or experience. Also, this tool can be useful in different environments and specifically in m-learning environments. People who do not use this functionality would not be bothered if someone else uses it but it would be useful to provide a feature to customise the settings according to users‘ necessities.

Chapter 6

Conclusions

This chapter summarises the main conclusions of this thesis, discusses the findings, and outlines future research directions that the research could follow. Next sections show a summary of the information provided in the main chapters in which the Ph.D. is divided and specifies some conclusions taken after the research carried out as well as the results' dissemination.

6.1. Chapter summaries

The use of Information and Communications Technology (ICT) in learning environments is being increased and it is important to make these interfaces inclusive and accessible for everybody. As a result, people with and without disabilities will not be discriminated because they will not have problems to interact with these new software and technology. One of the tools that is being used nowadays in learning environments is Chat applications. Current chat applications present accessibility barriers. These accessibility problems do not help people with disabilities to access technology in the same way as people without disabilities.

This thesis has been focused on chat applications for mobile learning environments and this thesis provides three main contributions:

1. **Identify Chat's accessibility barriers**: Extraction of the main accessibility barriers that users face when they use chat applications (Chapter 3. Involving Users for Eliciting Accessibility Barriers in Chat Applications)

2. **Elicit requirements needed to create an accessible chat:** Elicit accessibility requirements that chat applications in m-learning environments should include to avoid barriers for people with disabilities (Chapter 4. Eliciting Accessibility Requirements for m-Learning Chat Applications).

3. **Proposal to improve the chat interaction:** Provide a functionality to improve the interaction of users with chat applications in m-learning environments and solve the *Flow and Rhythm* problem (Chapter 5. A New Functionality for Improving m-Learning Chat Applications' Interaction).

After carrying out each research, it is important to summarise the results and contributions provided by this thesis. Next sections explain in detail the results obtained in each phase of the study.

6.1.1. Chapter 3 summary: Involving Users for Eliciting Accessibility Barriers in Chat Applications

Most used chat applications were studied in this research work in order to obtain the main problems that people face when they use these chat applications in their daily life. Experts and real users participated in different studies which analysed these tools and identified the learning features included in mobile learning applications.

The expert analysis of existing m-learning chat applications showed there are learning features included in these tools which are not included in non-learning environments. These features are really useful for students because they will help participants in their learning process - see Table 3.4. For example, it is important to help users to establish roles (who is going to manage the conversation, who is not going to manage it...). Besides, it is important to allow teachers to control the messages sent during these conversations because some of them could not be useful, unnecessary or inadequate. These are some of the features that have been identified during the studies conducted in these studies.

Moreover, experts and users have identified these tools have accessibility problems for people with disabilities which will provoke barriers for them because they will not be able to learn in the same conditions as their colleagues. Three main groups of people are affected by these problems: people with disabilities; elderly people; and people without disabilities.

People with disabilities experience more barriers when they want to use chat applications in Mobile Device (MD) and desktop computers. The second group of people who experience more difficulties are elderly people, they experience difficulties because of the "disabilities" which are being developed as the years gone by and because of their expertise level using ICTs. Finally, people without disabilities could experience some problems because of the situational impairments that they face when they use chat applications in MDs in specific conditions and because they are not used to use chat applications in MDs or desktop computers.

Apart from confirming problems identified in previous studies, this research found problems faced by people with disabilities that have not been identified before such as: chat applications use sensory characteristics - e.g. colours to convey information; colour contrast issues; headings and skip links are not provided to navigate between chat sections. Also, real users identified other accessibility problems that they experience using chat applications. For instance, they experience problems because there are not confirmations showed on visual and audio; content is not adapted correctly to the interface; language used in the conversations is not simple or understood by the participant; problems to participate in group conversations with many people; lack of spelling or auto correction mistakes; use of emoticons that are not tagged correctly or are not understood visually; and use of small buttons or target interfaces.

In addition, elderly people and people without disabilities experienced problems; although, they experienced fewer. For example, they had difficulties to understand concepts such as: online or offline as well as if the messages were going to be there all the time; they experienced problems with small icons and buttons, and they had problems with orthography errors that were not marked on the screen.

Finally, it was detected that every analysed group had problems related to the *Flow and Rhythm* of the conversation. These problems could be provoked because of different reasons such as: they are not able to follow the conversation, they are not able to write quickly or they need more time to read messages.

Considering these problems, every analysed group could face difficulties and could be discriminated in learning environments where teachers and students use chat applications to communicate with each other due to the problems that this research has identified.

These problems could be solved if developers and designers considered accessibility when they are developing or designing software. The second study - Chapter 4 - aimed to help these professionals to include accessibility requirements when they are designing or developing software.

6.1.2. Chapter 4 summary: Eliciting Accessibility Requirements for m-Learning Chat Applications

Nowadays there are many accessibility standards and guidelines that specify recommendations to create accessible software, interfaces, applications, etc. These accessibility standards and guidelines have been created and validated by consortiums, companies and associations related to this sector. They provide guidelines for developers to design and develop accessible software. However, these accessibility standards and guidelines are sometimes difficult to understand and to interpret. Specially, if people do not know anything about accessibility. In addition, there is not any guideline or standard which specifies the features that accessible m-Learning chat applications should include, and usually, these standards and guidelines are general and not specific to the environment or software.

The purpose of this study was to analyse the standards and guidelines related to accessibility for m-learning chat applications and understand their differences as well as their overlaps. Then, these guidelines were extrapolated to m-learning chat applications; and finally, it was specified the requirements that an accessible chat application should have for m-learning environments basing on the selected accessibility standards and guidelines. In addition, solutions, explained in a SE format, for the accessibility barriers identified in the previous study were provided.

These requirements specify the main features that accessible m-learning chat applications should include in order to make easier and more inclusive collaborations between people with and without disabilities in on-line learning environments.

The requirements are categorised into six groups: (1) Login; (2) Personalisation; (3) Contacts; (4) Conversations; (5) Messages; (6) Exchange files. Some of the requirements that are not included usually in m-learning chat applications are:

- Personalise information shown per message, per participant and on screen.
- Personalise interface.
- Provide mechanisms to control the reception of new messages.
- Provide a glossary of terms to specify information about content shown on the conversations.
- Provide mechanisms to catalogue messages.

These requirements were validated by designers and accessibility experts - see Section 4.4 - in order to assure these are valid requirements that can be understood by accessibility and

non-accessibility professionals. This study helped identify inconsistencies and wording problems. Basing on these results, the requirements were improved.

These requirements will be useful for developers and designers to know what accessibility features need to be included in their processes. Not all requirements were validated due to time constraints. Only those requirements which are marked as high priority, were validated by users.

Considering the barriers detected in Chapter 4, the most common accessibility issue is the *Flow and Rhythm* problem. A requirement - G-8 Control reception of new messages - was specified to help to solve this issue. This was the selected requirement to be tested with real users in order to assure the new functionality was useful for users or not. Next section specifies the results obtained after testing the requirement with real users.

6.1.3. Chapter 5 summary: A New Functionality for Improving m-Learning Chat Applications' Interaction

A common problem identified by most of the groups of people was related to follow the *Flow and Rhythm* of the conversation. This problem could be caused by different reasons: problems to write quickly, problems to read quickly, problems to answer the conversation, etc. These problems are faced by all the analysed groups of people and cannot be avoided by users even if the software is well designed and developed according to the current accessibility standards and guidelines. The "G-8 Control reception of new messages" requirement aims to help users avoid the *Flow and Rhythm* problem, which is faced by all the analysed groups of people.

This research aims to improve the interaction of people with chat applications and avoid problems related to the *Flow and Rhythm* of the conversation. Thus, a new functionality *Pause Autorefresh*, detailed in the "G-8 Control reception of new messages" requirement, could be helpful for users to control the reception of new messages. Users can use this new functionality to pause or resume the reception of messages when they feel overwhelmed with the number of messages they are receiving.

A User Centered Design (UCD) process was followed to design the requirement and after different iterations, it was decided to represent this functionality using a button in the chat interface. As a result, a prototype - Chat4LL - was created. Users could press this functionality when they could feel overwhelmed. Then, the reception of new messages will be paused until the user pressed the resume button again. Meanwhile, the other participants of the conversation could continue writing as many messages as they would like and they would be informed when the participant, who paused the reception of messages, renewed the conversation again.

Finally, after the feature was designed, users were asked to validate this functionality in a real environment. This application was tested in one-to-one and one-to-many conversations in a m-learning environment and in these sessions, people with and without disabilities participated. This functionality was compared with the functionality included in Moodle LCMS to control the reception of messages. Moodle does not show new messages unless the user presses a refresh button. In contrast, Chat4LL allows participants pausing the reception of messages when they felt overwhelmed, this includes the *Pause Autorefresh* functionality.

After the user testing sessions, participants specified their opinions about the *Pause Autorefresh* functionality and the results showed the new functionality could be a useful functionality for students.

Users preferred Chat4LL instead of Moodle because they were more relieved, confident an happy regardless of their experience, disability or age. Although, there were not enough significative results to assure users preferred Chat4LL for two age groups of people people between [25,34] years old and people between [55,64] years old. If the results are analysed from the point of view of disabilities, people with blindness and visual impairments were more relieved, confident and happy when they used Chat4LL. In addition, regardless the number of participants per conversation, users were lost fewer times when they used Chat4LL.

Also, the results showed users would use the *Pause Autorefresh* functionality in any type of environment but especially they would use it in learning environments because they could pressed the button when they wanted to read and reply messages more carefully. However, if teachers are guiding the conversation and they used the Chat4LL functionality, students could be disoriented because teachers were leading the conversation.

Besides, it was necessary to analyse if users who do not have problems related to follow *the Flow and the Rhythm* could be bothered when someone is using the *Pause Autorefresh* functionality. The results shown, users would not be bothered because they were more interested, pleased and relieved when someone else used this Chat4LL's functionality instead of Moodle. Users preferred the messages shown in Chat4LL because they were more informed about the situation of the other participants. In addition, users concluded they could get a benefit of this functionality in some circumstances or environments.

To conclude, all these studies have helped us to understand and identify the accessibility problems that people face when using chat application. In order to help people with disabilities in m-Learning environments, solutions have been suggested for these problems and requirements have been defined in order to help designers and developers to create more accessible chat applications for m-learning environments. Finally, one of these solutions, *Pause Autorefresh* functionality, has been tested with real users and it can be concluded that users with and without disabilities could get a benefit of this new functionality when they are sending messages using m-learning chat applications. However, due to time restrictions and constraints this thesis has some limitations that are described in the next section.

6.2. Thesis Limitations

Due to time restrictions, budgets and other project constraints, the thesis has some limitations such as:

- **Number of participants:** The number of people included in the experiments covers a representative sample of each group. More than 200 participants helped in different phases of the research. However, due to the diversity of users included in this research, it was really difficult for us and other collaborators (e.g. UNNINOVA and ILUNION) to increase the number of people for each disability needed for the study (especially for learning, cognitive and hearing impairments) in a significant way.
- **M-learning:** Due to enshrine the thesis in a specic environment, the thesis was tested in a m-learning environment in order to compare results adequately. In this case, it was selected m-learning because this environment is one of the most common environments where collaborative learning tools - e.g. chat applications - are used nowadays; and because of previous researchers‘ expertise. These researchers are familiarised with m-learning and have participated in m-learning researches previously.

- ***Pause Autorefresh* validation:** The *Pause Autorefresh* validation has been conducted in a m-learning environment in order to compare results and enclosed the study. Besides, the validation was conducted using a specific number of participants in order to compare conversations later.

6.3. Future Work

Due to the limitations of the thesis specified previously, different lines of research could emerge in the future. This future research lines will be useful: to identify accessibility problems in other learning tools or chat accessibility problems in other environments; to identify solutions to these problems; and to improve the *Pause Autorefresh* functionality. Next future research lines are described.

- **Additional learning tools:** This thesis has been focused on chat applications because they can cause more accessibility issues for people with disabilities. These tools are real time communication tools and it is necessary to reply quickly. However, other learning tools cause problems for people with disabilities and the results obtained in this thesis might not be extrapolated to these environments. In the future, other tools used in learning environments - e.g. blogs, video conference, forums - can be used to obtain the accessibility problems that people face when they use these tools and define requirements to solve these issues.

- **Test *Pause Autorefresh* functionality in other environments:** Due to obtain results that can be compared, the functionality was tested in a simulated environment - an online class - using a chat application. In the future, the functionality could be tested by users in a real environment - outside a testing lab - in order to assure this functionality is useful and helpful in the non testing situation.

- **Improve *Pause Autorefresh* functionality:** After the results were obtained, it was identified that this new functionality could be improved in order to satisfy all peoples necessities. Because of this, different research lines could be created to improve the *Pause Autorefresh* functionality. For example, some people mentioned the messages shown on the screen could be improved. These messages could be changed by the user, or the user could decide if they wanted to see these messages, or not.

- **Study all disabilities in deep:** This study has involved people with different disabilities (people with visual impairments, people with learning disabilities, people with hearing impairments and people with motor impairments). Some of these disabilities were covered very briefly because it was difficult to find people with these disabilities who wanted to participate in the study. In future researches, these disabilities could be covered in deep - if it is possible to find people with those characteristics - in order to obtain more problems that people could face and understand more their necessities.

- **Validate and implement all defined requirements:** As it has been mentioned before, only high priority requirements have been validated by experts. Every requirement could be validated in the future by experts in order to assure they can be understood by designers and developers.

- **Other environments:** The research has been focused on m-learning environments due to obtain better results and to make the research consistent. During this research, it has been identified that some participants would like to use the *Pause Autorefresh* functionality in other environments e.g. at work or with friends. Besides, some of the requirements and problems identified during this research are applicable to other environments, it is

possible that other requirements or problems have not been identified. Because of this, in the future, similar researches could be conducted in other environments - e.g. at work or with friends - in order to identify problems that people can face when using chat applications and to provide solutions to these problems. .

6.4. Results' Dissemination

The results of this research work have been published in different journals, chapter's books, conferences and a doctoral consortium. The main objective of the research has been presented in a Doctoral Consortium of an international conference, RCIS 2013 [Calvo 2013], in order to improve the Ph.D and the final results have been published in: conferences, books chapters and journals. Besides, basing on the research area a Special Track "Collaborative Learning Applications for All in Mobile Devices" was organised by the International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion (DSAI 2013) [Iglesias 2013].

- (Calvo 2013) Rocío Calvo (2013). Accessible Chats for Computer Supported Collaborative Learning Environments in Mobile Devices (Doctoral Consortium), Seventh IEEE International Conference on Research Challenges in Information Science (RCIS 2013), Paris, France 29-30 May 2013
- (Iglesias 2013) Ana Iglesias and Rocío Calvo (2013). Special track of the 5th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion (DSAI 2013), Vigo, Spain 13-15 November 2013

This research work is enshrined in SINTONIA research group which is part of the Computer Science Department of the Universidad Carlos III of Madrid. Besides, it has been partially supported by the GEMMA (TSI-020302-2010-141) and SAGAS (TSI-020100-2010-184) research projects which are financed by the Spanish Ministry of Industry, Tourism and Commerce and the network MA2VICMR (S2009/TIC-1542) supported by the Spanish Government of the Madrid Community. Besides, the thesis has been partially supported by the Spanish Ministry of Economy and Competitiveness under eGovernAbility project [TIN2014-52665-C2-2-R] and by ECHORD++ (European Clearing House for Open Robotics Development Plus Plus). Subproject smart CLinic Assistant Robot for CGA (CLARK). European Union (FP7), ID-601116.

Next, the thesis results can be divided into three different groups: accessibility problems in learning environments and specifically in the CSCL tool, chat; chat's accessibility requirements; and the *Pause Autorefresh* improvement of the chats' interaction.

6.4.1. Accessibility Barriers in Chat Applications

The framework where this thesis is enshrined was published on the CSEDU conference [Calvo 2011]. This research explains the main steps that should be followed to make collaborative learning accessible in mobile devices.

- (Calvo 2011) Rocío Calvo, Ana Iglesias, Lourdes Moreno(2011). A theoretical accessible approach for collaborative learning in mobile devices. *International Conference on Computer Supported Education (CSEDU 2011).* Noordwijkerhout, Netherlands, May, 2011

Different evaluations were carried out to obtain accessibility barriers that students could face. Firstly, it was made an evaluation of four LMSs from the point of view of four parameters: accessible templates and themes, WYSIWYG editors (What You See Is What You Get),

Javascript and tables for layout. This evaluation was published in a JCR Journal [Iglesias 2011]. After that, an evaluation of the accessibility of Moodle for screen reader users was carried out and was published in the international conference WEBIST [Calvo 2011b]. Besides, it was selected as one *Best Paper*[Calvo 2011c]. Later, the method followed to carry on accessibility evaluation was published on a Book Chapter[Moreno 2011]. Moreover, the accessibility of Moodle was evaluated from the point of view of ATAG 2.0 guidelines to check if the authoring tool is an accessible authoring tool and if the authoring tool generates accessible content [Calvo 2013b]

- (Iglesias 2011) Ana Iglesias, Lourdes Moreno, Paloma Martínez, Rocío Calvo (2011). Evaluating the accessibility of three open-source learning content management systems: a comparative study. *Computer Applications in Engineering Education.* [JCR(2011): 0.333] Wiley Online Library
- (Moreno 2011) Lourdes Moreno, Ana Iglesias, Rocío Calvo, Sandra Delgado, Luis Zaragoza (2011). Disability Standards and Guidelines for Learning Management Systems: Evaluating Accessibility, *Book Chapter: Higher Education Institutions and Learning Management Systems: Adoption and Standardization* , August, 2011, IGI Global , ISBN: 9781609608842, pp: 199-218
- (Calvo 2011b) Rocío Calvo, Ana Iglesias, Lourdes Moreno(2011). Accessibility Evaluation of Moodle Centred in Visual Impairments, *In Proceedings of the 7th International Conference on Web Information Systems and Technologies (WEBIST 2011)*, Noordwijkerhout, Netherlands, May, 2011
- (Calvo 2011c) Rocío Calvo, Ana Iglesias, Lourdes Moreno(2011). Is Moodle Accessible for Visually Impaired People?, Web Information Systems and Technologies - 7th International Conference, *WEBIST 2011 (Revised Selected Papers) Lecture Notes in Business Information Processing*
- (Calvo 2013b) Rocío Calvo, Ana Iglesias, Lourdes Moreno(2013). Accessibility barriers for users of screen readers in the Moodle learning content management system. *Universal Access in the Information Society* [JCR(2012): 0.532] Springer

Considering the accessibility problems that collaborative learning tools have, the chats and forums of four of the most popular LMSs have been evaluated from the point of view of WCAG 2.0 and ATAG 2.0 guidelines. Two articles have been published in two international conferences where it has been explained some guidelines to create accessible chats and forums [Calvo 2013c] and an exhaustive evaluation of some most common problems that chats and forums have [Calvo 2013d]. Later, commercial chats have been evaluated from the point of view of UDL guidelines to obtain which of them are more suitable for learning environments [Calvo 2013e]. Besides, the most suitable mobile chats for learning environments were evaluated from the point of view of accessibility standards and guidelines [Arbiol 2013]. Finally, the paper [Calvo 2013e] was selected to be published in the UAIS journal as one of the selected papers from the DSAI conference. This research was extended and it was evaluated the accessibility of the most common chat applications for learning environments as well as it was studied those learning features included in these chat applications [Calvo 2016]

- (Calvo 2013c)Rocío Calvo, Ana Iglesias, Beatriz Iglesias, Almudena Gil(2013). Are Chats and Forums accessible in e-learning systems? A heuristic evaluation comparing four Learning Content Management Systems. *In Proceedings of ITiCSE 2013 - ACM SIGCSE Conference on Innovation and Technology in Computer Science Education*, Canterbury, UK, July, 2013

- (Calvo 2013d)Rocío Calvo, Ana Iglesias, Beatriz Iglesias, Almudena Gil(2013). Accessibility evaluation of Chats and Forums in e-learning environments. *FECS'13: The 9th International Conference on Frontiers in Education: Computer Science and Computer Engineering*, Las Vegas, USA, 2013

- (Calvo 2013e) Rocío Calvo, Alberto Arbiol, Ana Iglesias (2013). Are all Chats suitable for learning purposes? A study of the required characteristics. *5th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion DSAI.* Vigo, Spain, 2013

- (Arbiol 2013) Alberto Arbiol, Rocío Calvo, Ana Iglesias (2013). Chat's accessibility in mobile learning environments. *Accessible E-Learning. W3C Accessibility Initiative, Online Symposium* December, 2013

- (Calvo 2016) Rocío Calvo, Ana Iglesias, Leonardo Castaño. (2016) Evaluation of accessibility barriers and learning features in m-learning chat applications for users with disabilities. *Journal Universal Access in the Information Society* pp 1-15 DOI: 10.1007/s10209-016-0484-x [JCR (2015) O.656] Springer

6.4.2. Analysis of Standards and Guidelines

From the point of view of Chat's accessibility guidelines the elicitation phase to obtain the main accessibility requirements that a chat should have basing on *Personas* and *Scenarios* methods was presented in an international conference [Calvo 2012]. Moreover, this article was selected as one of the best papers of the conference and was published in a journal [Calvo 2012b]. The requirements and the difficulties that students without disabilities could face in m-learning environments was published in the m-learning international conference [Calvo 2014].

- (Calvo 2012) Rocío Calvo, Lourdes Moreno, Ana Iglesias (2012). Requirements elicitation to design an accessible chat as a synchronous tool in m-learning environments. *III Congreso Iberoamericano sobre Calidad y Accesibilidad de la Formación Virtual (CAFVIR 2012).* Madrid, Spain, 2012

- (Calvo 2012b) Rocío Calvo, Lourdes Moreno, Ana Iglesias (2012). Requirements elicitation for designing an accessible chat. *REICIS. Revista Española de Innovación, Calidad e Ingeniera del Software.* v8(1). pp: 7-21

- (Calvo 2014) Rocío Calvo, Ana Iglesias, Lourdes Moreno (2014). Overlapping Chat's Accessibility Requirements between students with and without disabilities due to the mobile limitations. *Mobile Learning 2014 International Conference.* Madrid, Spain 28 February, 2, March, 2014

6.4.3. A Proposal for Improving Chat's Interaction

The improvement of the chat's interaction was published in different conferences. The software prototype design was published in the HCII conference [Calvo 2013f]. In addition, the previous user's opinions about the new functionality were published in another international conference, International Conference Interacción 2013, [Calvo 2013g] and also in this conference, the idea to improve the chat's interaction won the special mention, Jesus Llorens Award, promoted by the Spanish HCI Association. As a result, this paper was selected to be published in the Journal of Universal Computer Science as one of the best papers and it was explained the methodology followed to conduct this research [Calvo 2014b]. In addition, this thesis was selected by Ilunion to be a pilot study for the project UNINNOVA and the

experience of using UNINNOVA for validating accessible project was exposed for the academia in the Congreso Internacional Universidad y discapacidad [Calvo 2014c].

- (Calvo 2013f) Rocío Calvo, Ana Iglesias, Lourdes Moreno (2013). An Accessible Chat Prototype for Screen Reader Users in Mobile Devices. *15th International Conference on Human-Computer Interaction.* Las Vegas, USA, July, 2013
- (Calvo 2013g)Rocío Calvo, Ana Iglesias, Lourdes Moreno (2013). Chats for all: A user survey to improve chats' interaction. *XIV Congreso Internacional de Interacción Persona-Ordenador. Celebrado en el Marco del CEDI* Madrid, Spain, September, 2013
- (Calvo 2014b)Rocío Calvo, Ana Iglesias, Lourdes Moreno (2014) User-Centered Requirement Engineering for Accessible Chats in m-Learning. Journal of Universal Computer Science, vol. 20, n7, pp. 964-985, 2014 [JCR (2014):0.466].
- (Calvo 2014c) Rocío Calvo, Ana Iglesias, Lourdes Moreno (2014) Evaluación con personas reales de un Chat accesible a través de la plataforma UNINNOVA. CIUD, II Congreso Internacional Universidad y Discapacidad, Madrid, 27 y 28 de noviembre de 2014, pp. 60-70

6.4.4. Other research contributions

During these years I have done two research stays in one American University and one European university were I acquired new knowledge about how to conduct researches and how to follow different approaches. I got two grants provided by the Universidad Carlos III de Madrid to conduct these two researches.

In summer 2013, I stayed three months at the University of Maryland Baltimore County with Shaun Kane and Amy Hurst. During this stay I conducted a research under their supervision about the accessibility problems that people with disabilities could face when using Amazon Mechanical Turk. This research was published in the ASSETS 2014 conference [Calvo 2014c].

- (Calvo 2014c) Rocío Calvo, Shaun, K. Kane and Amy Hurst (2014). Evaluating the accessibility of crowdsourcing tasks on Amazons Mechanical Turk (poster). Proceedings of ASSETS 14, ACM, 2 pages.

In addition, in summer 2014, I stayed three months at the Kings College University with the supervisors Sarah Lewthwaite, Stylianos Hatzipanagos and Deesha Chadha. A research was conducted about how companies involve users and accessibility resources in the software development process. This research consisted in the development of a questionnaire which is spread out through companies related to the development of software and websites. However, this research has not been completed and published yet. Both research stays have been founded by the Universidad Carlos III de Madrid because two "Programa propio investigación" grants have been awarded to Rocío Calvo.

Other researches have been conducted in my current job - accessibility and usability consultant. These researches have been focused on studying the accessibility problems that people with visual impairments face when they use search engines [Seyedarabi 2016]. In addition, I have conducted a research about the issues that are not covered in Web Content Accessibility Guidelines but are recognised as accessibility issues by experts [Calvo 2016b]

- (Seyedarabi 2016) Faezeh Seyedarabi, Rocio Calvo (2016) Search Engines: new widgets, new accessibility challenges *DSAI Conference* 2016, ACM
- (Calvo 2016b) Rocío Calvo, Faezeh Seyedarabi, Andreas Savva (2016). Beyond Web Content Accessibility Guidelines. Expert Accessibility Reviews. *DSAI Conference* 2016, ACM.

Finally, I have been reviewer in different conferences CAFVIR2012, CAFVIR 2013, DSAI2013, CAFVIR 2014, ATICA 2016 and W4A 2017. I have collaborated in the talk "INCLUSIVE VR: LEAD THE CHANGE" for the HCID 2016 [Clegg-Vinell 2016] and the Digital Accessibility and the User experience - BCS conference with the talk "Making Accessible PDF documents in Virtual Environments: PDF guidelines for UK lectures in Higher Education" [Seyedarabi 2016]

- (Clegg-Vinell 2016) Raphael Clegg-Vinell, Adi Latif and Rocio Calvo (2016) INCLUSIVE VR: LEAD THE CHANGE. HCID Open Day 2016 Organised by City University.
- (Seyedarabi 2016) Faezeh Seyedarabi, Rocío Calvo (2016). Making Accessible PDF documents in Virtual Environments: PDF guidelines for UK lectures in Higher Education. *Digital Accessibility and the User experience - BCS conference*

Currently, I am part of the International Association of Accessibility Professionals (IAAP) committee to design and verify the questions for the Certified Professional in Accessibility Core Competencies (CPACC) exam.

Appendix A

HCI and SE Methods used

This Appendix specifies the main HCI and SE methods used in the thesis. Next tables (Tables A.1, A.2, A.3, and A.4 show the technique, the disciplines which use these techniques, if this technique is used in the study and the reason.

Method	HCI	SE	Used	Reason
Identify Stakeholders	Yes	No	Yes	This technique is used to specify the users and stakeholders of the system. It has been used in the research because it is necessary to carry out the RE process from the point of view of teachers and students.
Context of use	Yes	No	Yes	The context of use of the system is specified to obtain the requirements in an efficiently way. In this RE process is necessary to specify the context of use, m-learning, to obtain requirements specific for this environment.
Survey of existing users / Questionnaires	Yes	Yes	Yes	This technique is used by both disciplines. The HCI discipline uses it to ask users about their main problems with regard to the system and the second one uses this technique to know the problem domain and knowledge of the application. It is used from the HCI point of view to obtain the users' accessibility problems and necessities.
Interviews	Yes	Yes	Yes	The technique is used by both disciplines. HCI uses it to obtain user problems more in detail than questionnaires and SE uses it to understand the problems and obtain the objectives of the application. This technique has been used from the first point of view to obtain the users' accessibility problems and necessities.
User observation	Yes	No	Yes	This technique is used by HCI discipline to observe users when they are using the system. This technique has been used to determine the specific problems that elderly face.
Diary keeping	Yes	No	No	Diary keeping provides a record of user behaviour during a period of time. It is not used for this research because of it cost and because users are resistant to spent too much time in the research.

Table A.1: SE and HCI Methods and Their Use in This Research

Method	HCI	SE	Used	Reason
Task Analysis	Yes	No	No	The technique is used by HCI to understand the current system. However, as the tasks are simple to understand, it has not been considered necessary to carry out a task analysis of each task.
JAD	No	Yes	No	It is a group technique use to capture requirements by all the stakeholders of the project. This technique could be considered as an alternative to interviews. Thus, as interviews and questionnaires methods were carried out, it was considered not to use it in the research.
Brainstorming	Yes	Yes	Yes	This method is used by both disciplines. The HCI discipline uses it in the requirements specification (RS) phase to create the prototype and SE uses it to provide solutions to the obtained problems in the requirements elicitation and analysis (REA) phase. This research uses it from the second point of view of SE to provide solutions to the obtained problems.
Stakeholder Analysis	Yes	No	Yes	The HCI discipline uses the method to obtain the main roles, responsibilities and task goals. This method is used in the research to obtain the teachers and students roles, responsibilities and task goals.
User cost-benefit analysis	Yes	No	No	This method aims to obtain the costs and benefits for different user groups. However, this technique is not used in the research because users are not divided into groups.
Focus Groups	Yes	No	No	Users are joined together in a discussion group. As users prefer not to spend a lot of time in the research and users should carry out a group interview. It has been decided to not include the method in the research.
Standards and Guidelines	Yes	Yes	Yes	Both disciplines use these techniques. However, SE uses it in the REA phase to elicit requirements and HCI to design the prototype using them. In this section the research uses the first point of view to analyse previous system competitors.
Scenarios	Yes	Yes	Yes	This method is used in different ways and in different phases depending on the discipline. HCI uses in REA phase to elicit user requirements and RS uses it to formalize the requirements in the RS phase. This research uses the fisrt point of views to elicit the requirements needed to create accessible chats.
Personas	Yes	No	Yes	This method obtains how hypothetical personas could interact in the scenarios. Thus, this technique has been used in the research to obtain requirements related to the user interaction with the chat

Table A.2: SE and HCI Methods and Their Use in This Research (2)

Method	HCI	SE	Used	Reason
Existing system/ competitor analysis	Yes	No	Yes	Existing systems must be analysed to obtain their problems and accessibility improvements. Thus, existing chats are analysed to obtain their accessibility problems and if they solve any accessibility problem.
Task /function mapping	Yes	No	No	The method specifies how each task will be performed. Thus, this method is not used because in the RS phase it has been used SE formal methods to specify the requirements.
Allocation of function	Yes	No	No	Requirements must be divided into the requirements executed by the system or user. This research does not use this method because the Categorize Requirements method is used.
Categorize Requirements	Yes	No	Yes	This method divides requirements into: user, usability or organizational requirements. This research categorizes the requirements but it has been used the categories provided by [41]to categorize the requirements.
Parallel Design	Yes	No	No	Different possible system concepts are designed in parallel. However, this technique has not been used because the research work is being carried out by a small group of people.
Storyboarding	Yes	Yes	Yes	Both disciplines use this method. HCI uses to formalize the requirements and SE to elicit the requirements. This research uses storyboarding from the point of view of HCI to formalize some complex requirements.
Card Sorting	Yes	No	No	This method is used to group concepts. However, it is not used because the navigation of the chat is simple.
Paper Prototyping	Yes	Yes	Yes	Both disciplines use the creation of prototypes to specify the requirements. This research does not create a paper prototype, but a mockup prototype, which is similar to paper prototypes, has been used.
Affinity Diagram	Yes	No	No	This method is used to organize the system structure. However, as the chat is a simple system this method has not been carried out.
Software Prototyping	Yes	Yes	Yes	Both disciplines use the creation of prototypes to specify the requirements. This research creates a prototype has been developed to integrate the system interaction.
Other Prototypes	Yes	Yes	No	The prototypes specify the requirements. However, as two prototypes have been created it is enough.
Natural Language	No	Yes	Yes	This technique is used to describe requirements. This technique is used to express all the requirements.
Use Cases Analysis	No	Yes	Yes	This method is used to specify the requirements in a formal way and is used in the research.

Table A.3: SE and HCI Methods and Their Use in This Research (3)

Method	HCI	SE	Used	Reason
Templates	No	Yes	Yes	Templates are used as a complement of the use of Use Cases Analysis method because it could be ambiguous. This method is used in the research and each use case is detailed with the ****Cockbuch*** template
Formal Language	No	Yes	No	This method is a complement to natural description a formal language to describe requirements. However, it is complex and difficult to be understood by users. Because of this, the method is not used in the research
Review /Audit	No	Yes	Yes	The documentation is reviewed and audited to assure that the requirements have been documented properly.
Participatory, controlled and assisted evaluation	Yes	Yes	Yes	Evaluations are carried out by users and specialists control it. This technique is used in the research. However, due to its cost, the users evaluations where not carried out in person. They were conducted evaluations which were carried out by telephone.
Heuristic or expert evaluation	Yes	No	Yes	Experts must evaluate the prototype. This research uses this technique and to carry out it, the Walkthrough method has been used to evaluate the prototype.
Other User experience methods	Yes	No	Yes	This method is carried out after the user evaluations to obtain the user experience. This research conduct guided post-experience interviews following a satisfaction questionnaire to obtain the user opinion with regard to the system.
Critical Incidents	Yes	No	Yes	Critical incidents detected in the user evaluation are noted and corrected. Thus, it is used to improve the system.

Table A.4: SE and HCI Methods and Their Use in This Research (4)

Appendix B

Personas

The Appendix shows the *Personas* created in the study. These *Personas* correspond to the main people who could use chats in m-learning environments.

The main students who participate in chats for m-learning are young students. They do not usually have problems to interact with chats and they use ITs everyday. The *Persona* Rosa represents to this group of people - see Figure B.1.

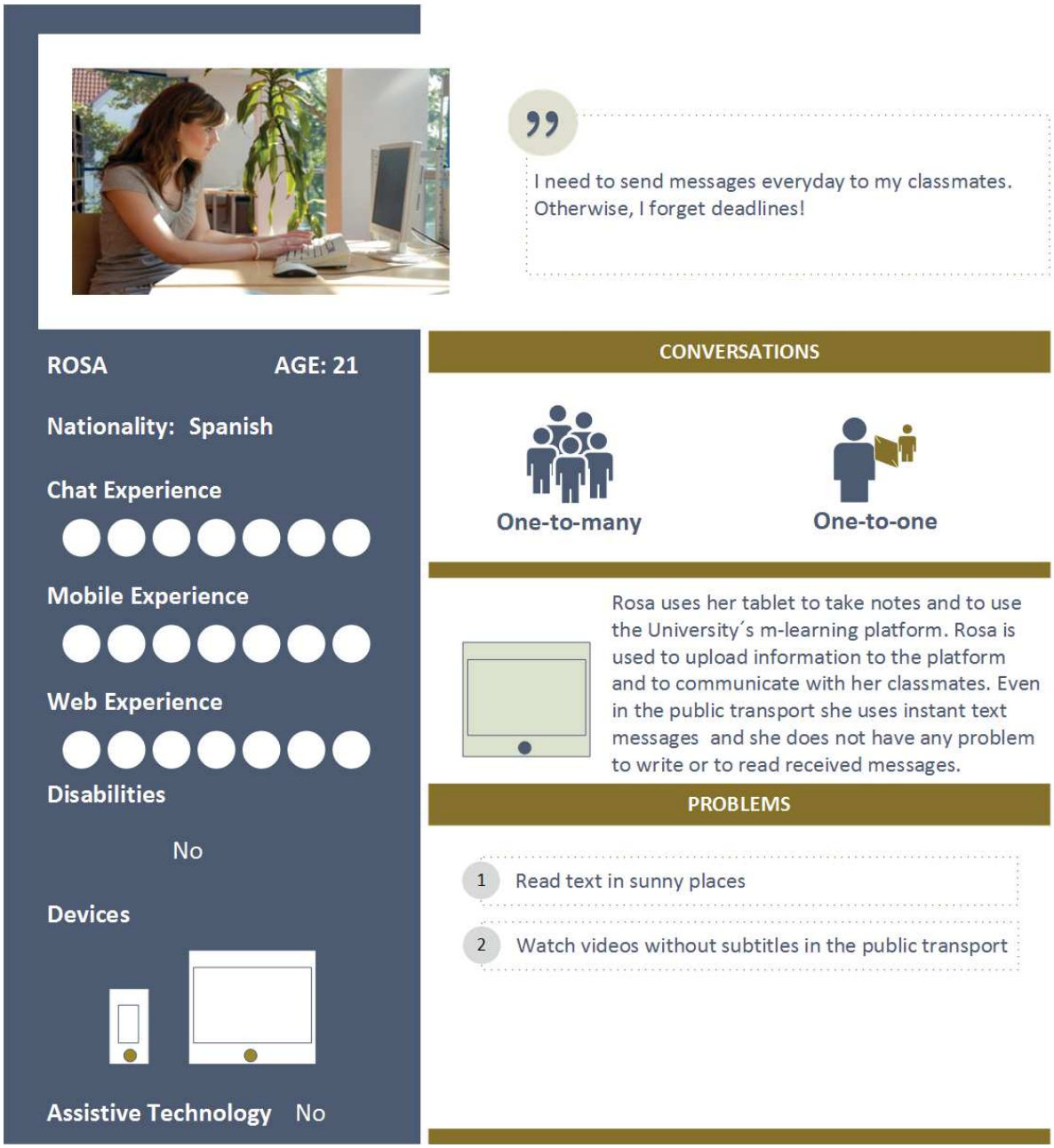

Figure B.1: Persona Rosa

Due to the new ways of learning and to exchange of students between learning centres, there are many non native users in classes. Moreover, nowadays most students use glasses and depending on their interests, students could have more expertise on MDs or not. Shannon represents a group of exchange students who goes to other countries to study - see Figure B.2.

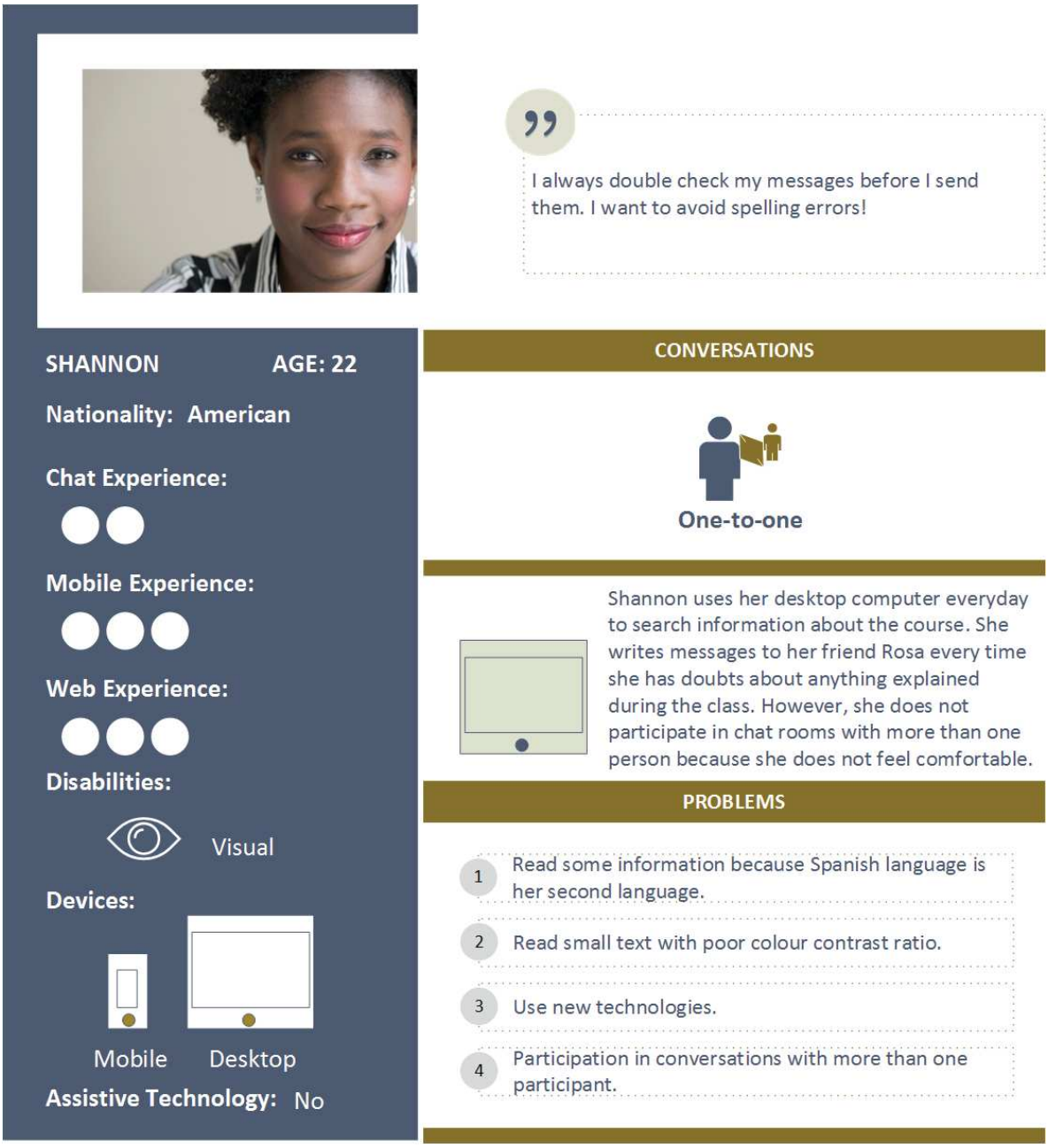

Figure B.2: Persona Shannon

Another group of people, who could have problems to use chats in m-learning environments, are people with hearing impairments. Students can have problems to attend classes because if they are not able to read lips, sometimes they cannot follow classes. Thus, they could use virtual learning environments to study and use CSCL tools as chats to communicate with their colleges and teachers. Considering all these things, it is important to consider people with hearing disabilities in the study too. The *Persona* Felipe represents to this group of people - see Figure B.3.

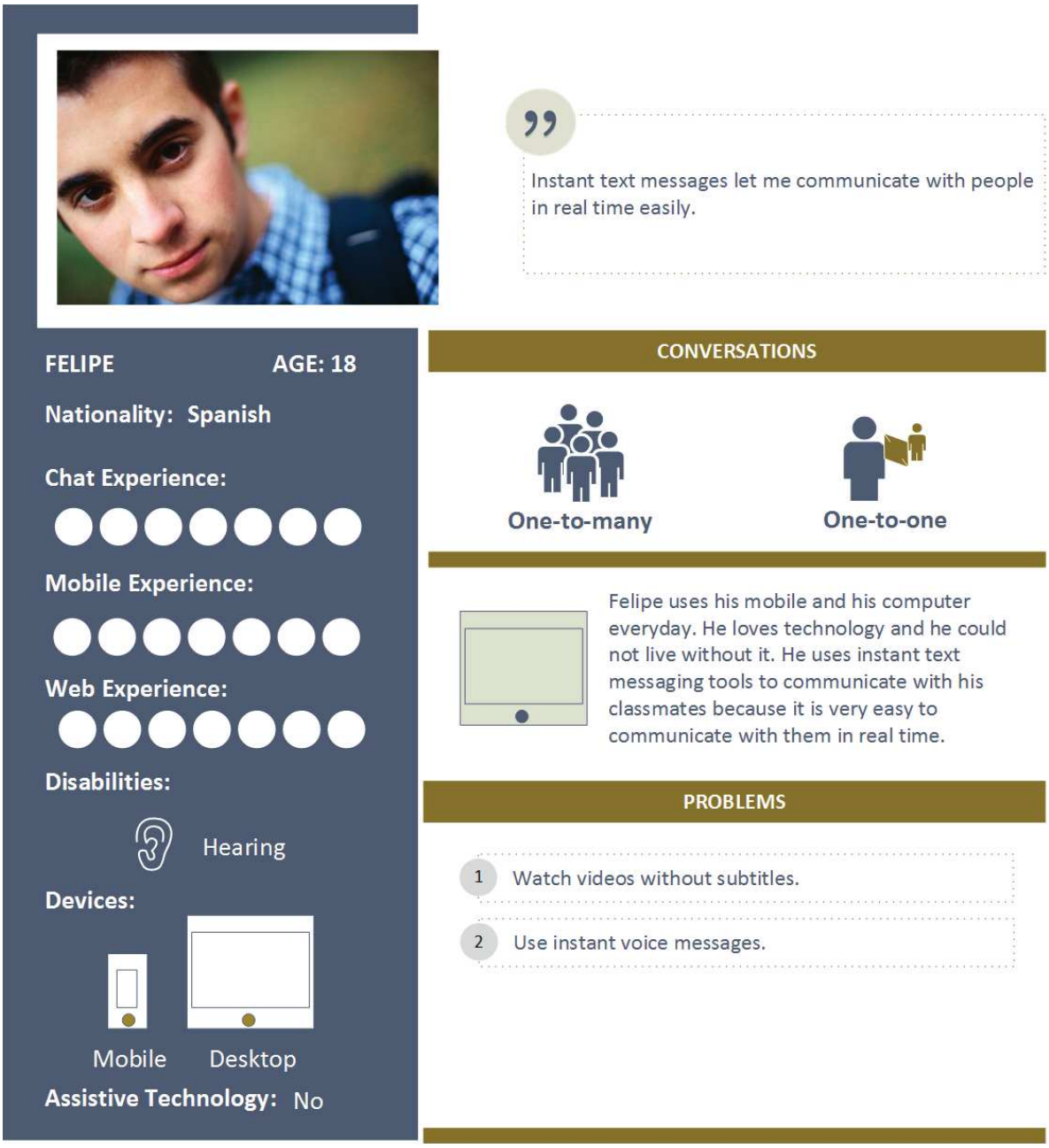

Figure B.3: Persona Felipe

Nowadays, retired people start to learn what they could not learn when they were young. They assist to classes and they have to adapt to the new ways of learning through virtual environments. However, sometimes they could experience some impairments because of their age such as: loss of vision, loss of hearing or loss of point precision. The *Persona* Antonio represents to this group of people - see Figure B.4.

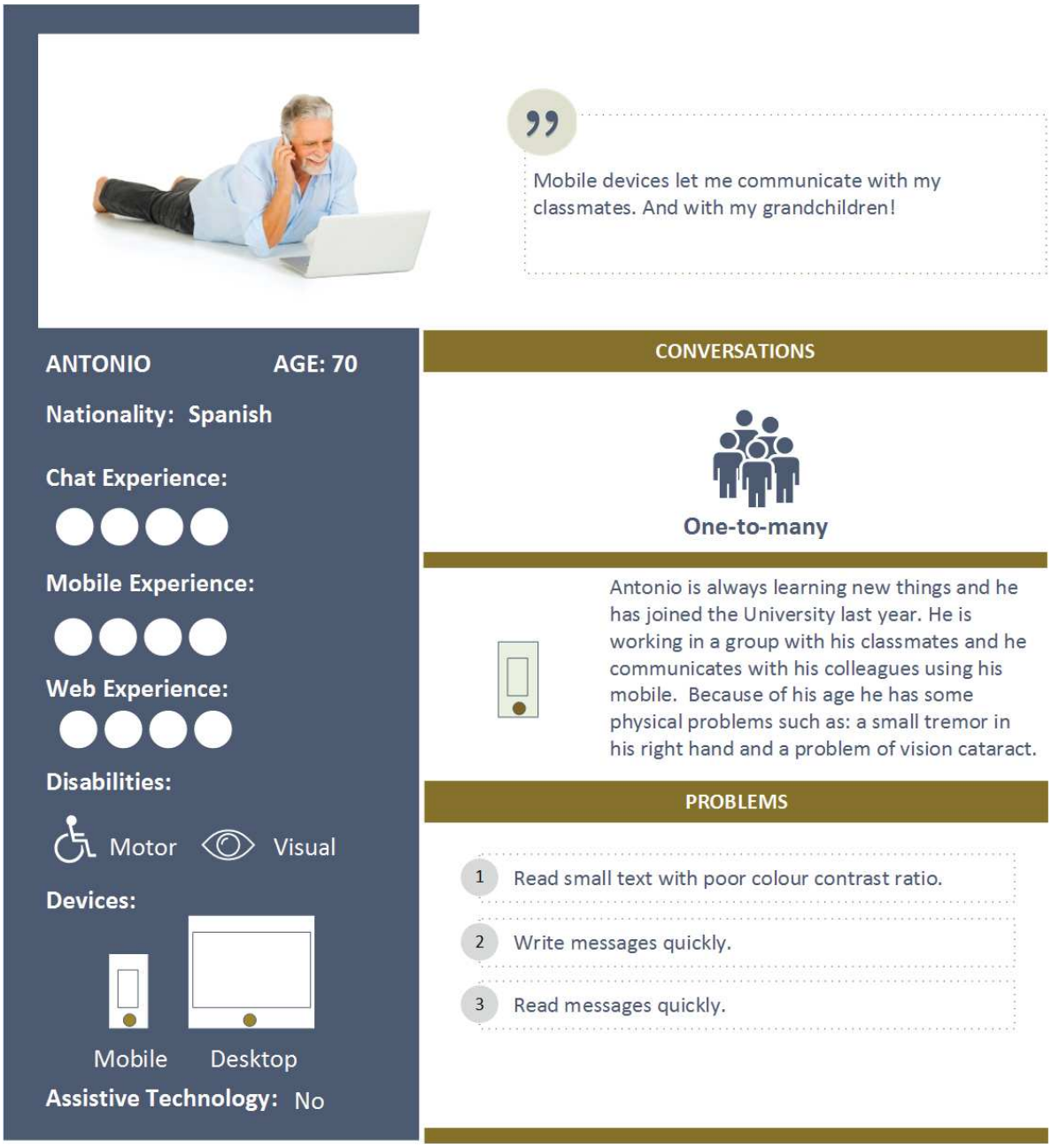

Figure B.4: Persona Antonio

People with cognitive disabilities can study and communicate with their teachers and colleges using new technologies. Some researches have demonstrated that users with cognitive disabilities could learn easily because of they use tables and MDs more intuitively. Thus, users with cognitive disabilities could use chats in m-learning environments to learn. The *Persona* David represents this group of people in the Figure B.5

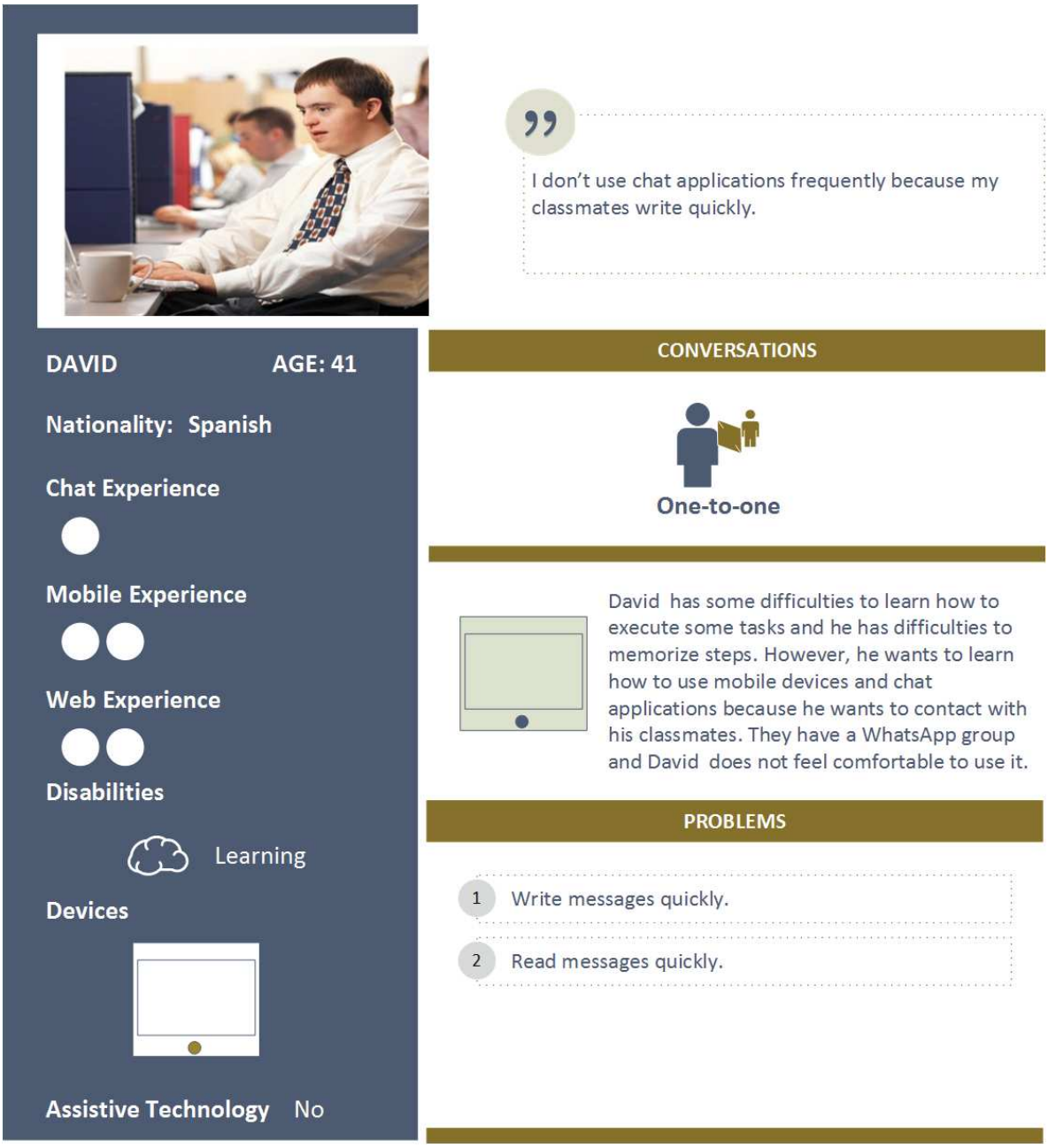

Figure B.5: Persona David

Appendix C

Scenarios

This Appendix shows the main barriers that the previous *Personas* created could face when they use the chats in MDs. Each scenario is described in detail as well as the actors, objective, settings, task description, problems and similar actors.

C.1. Discussion

The create conversation scenario, Table C.1, specifies the main problems that the persona Antonio can experience when he wants to create a conversation with a student.

Actors:	Antonio.
Objective:	Create a conversation.
Settings:	Antonio is sitting at home and wants to chat with Rosa.
Task Description:	Antonio decides to chat with Rosa. He loges into the chat and looks for Rosa. The chat shows all the users that are connected, idle or disconnected; However, he is not able to distinguish if Rosa is connected or not because it is used the color green to show if she is connected or not.
Problems:	Unable to distinguish which users are connected or not. (Content problem)
Similar actors:	–

Table C.1: Scenario: Create Conversation; Persona: Antonio

Another scenario represents the interaction of users when they send messages through the chat, Table C.2. Rosa and Antonio send messages between them through the mobile chat to solve doubts about their homework.

Actors:	Rosa and Antonio.
Objective:	Send chat sentences.
Settings:	Rosa and Antonio are chatting in different places. As Rosa is really good at new technologies, she is able to write really fast. However, Antonio is not able to write really fast because of his temblor and his tactile keyboard.
Task Description:	Rosa and Antonio are chatting with the MD. Rosa sends a message to Antonio. "Do you know how to solve the exercice number six?". Antonio starts to reply it. Rosa sends another message. "I have talked with Tim about it and he does not know neither". Antonio continues replying to the first message. Rosa replies the 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 and feels really uncomfortable because of this. Rosa is sending messages even if Antonio has not answered any of them previously and Antonio receives more than one sentence at the same time. Antonio feels uncomfortable and leaves the chat.
Problems:	Unable to follow the flow and the rhythm of the conversation (Interaction problem)
Similar actors:	Shannon experiences the same problems because of the language and her experience in the IT language. David because of his speech and learning problems.

Table C.2: Scenario: Send Sentences; Personas: Rosa and Antonio

Another important feature in chats for MDs is the send of images when the students are studying through them. The scenario send chat sentences and images, Table C.3, shows the interaction between two users who are chatting between them and send an image too.

Actors:	Rosa and Shannon.
Objective:	Send chat sentences and an image.
Settings:	Rosa and Shannon are chatting in different places. Rosa cannot download huge amounts of information because she has wasted all her mobile limit connection.
Task Description:	Rosa and Shannon are chatting about the last class. Rosa does not understand one of the problems and Shannon decides to send an image which shows the results of the problem. She takes a photo with her mobile and send it to Rosa. However, Rosa is not able to see the image because she cannot download it; she has reached the limit connection and she has to pay more to download it.
Problems:	Unable to see the image (Content problem)
Similar actors:	Antonio has the same problems because of his vision impairments.

Table C.3: Scenario: Send Sentences and Images; Personas: Rosa and Shannon

Specially in learning environments, students create groups of students to discuss and to share documents related to their classes. Thus, it is important to guess how the students could feel when someone is added to the conversation. The scenario Add an Interlocutor, Table C.4 shows how the students' difficulties when someone adds a new interlocutor.

Actors:	Rosa, Antonio and Felipe.
Objective:	Add Interlocutor to the conversation.
Settings:	Rosa is sitting at home chatting with Antonio and wants to add another interlocutor to the conversation: Felipe.
Task Description:	Antonio is chatting with Rosa and Rosa decides to chat with Felipe at the same time. She presses the button Add Interlocutor and the system shows all the users, Rosa selects Felipe and after that she creates the conversation with the user. The system shows the conversation with all of them. Felipe starts to write sentences and Rosa too. They are really fast to answer. However, Antonio is not able to answer it quickly and does not feel comfortable.
Problems:	Unable to distinguish which users are connected or not. [The problem is similar to the problem of create conversation because of this it is not specified again] (Content problem) The user is not able to follow the rhythm of the conversation (Interaction problem)
Similar actors:	Shannon experienced the same problems because of the language and her experience in the IT language.

Table C.4: Scenario: Add Interlocutor; Personas: Rosa, Antonio and Felipe

After chatting with someone, users would like to close the conversation and to do other things or to chat with someone else. The process to close the conversation needs to be analysed too. The scenario Leave Conversation, Table C.5 shows how a user leaves the conversation.

Actors:	Rosa
Objective:	Leave the conversation.
Settings:	Rosa is sitting at home chatting with Antonio and wants to leave the conversation.
Task Description:	Rosa is chatting with Antonio and Rosa decides to leave the chat. She presses the button Leave and the system closes the chat.
Problems:	N/a
Similar actors:	N/a

Table C.5: Scenario: Leave Conversation; Personas: Rosa

Students could like to reread previous conversations in order to take notes of them or to analyse them to study. The scenario Show Previous Conversations, Table C.6.

Finally, the scenario WrittenLanguage, Table C.7, represents a group of scenarios in which users can change a feature. In this case the feature changed the language used to write; however, it is similar to the features: change learning needs, specify geographical location of the learner, learning needs, type of device being used, connection speed, electrical capabilities, learning group.

Actors:	Rosa
Objective:	Show previous conversations.
Settings:	Rosa is chatting at home and wants to check previous conversations with Antonio.
Task Description:	Rosa is chatting at home and wants to check previous conversations with Antonio. So, she presses the button to show all the users and selects Antonio. After that, she presses the button Show previous conversations and the system shows all the conversations that Rosa has had with Antonio.
Problems:	N/a
Similar actors:	N/a

Table C.6: Scenario: Show previous conversations; Personas: Rosa

Actors:	Rosa
Objective:	Written Language.
Settings:	Rosa pretends to define the written language that she uses when she chats with someone to correct her mistakes automatically.
Task Description:	Rosa pretends to define the written language that she uses when she chats with someone to correct her mistakes automatically. So, she selects the feature Change language and the system shows the languages available. Rosa selects Spanish and automatically the system corrects the grammatical mistakes that she has when she writes.
Problems:	N/a
Similar actors:	N/a

Table C.7: Scenario: Written Language; Personas: Rosa

Appendix D

Questions of the interviews for people with disabilities

This Appendix shows the questions asked to the participants of the method Interviews (Chapter 3). These questions were created in Spanish because the population target was Spanish people. However, as the document is written in English, the questions showed in this Appendix are translated from Spanish to English.

D.1. Chat's Accessibility Questionnaire

Aim of the research

This study is part of the Ph.D. "Accessible Chat for Computer Supported Collaborative Learning Environment in Mobile Devices" which is being developed by me in the LaBDA Group of the Carlos III University of Madrid. The main aim of this study is to obtain the main accessibility barriers that people with disabilities experience when they use chats in MDs.

The obtained information will not be used to obtain any profit, the data will be used for the statistic study exclusively and to publish it as part of the Ph.D.

Some general information

- Age:
- Sex (Male/Female):
- Job:
- Studies:
- Disability:

Mobile device Expertise

- How often do you use mobile devices? (Every day, two or three days per week, once a week, rarely or never):
- Which is your mobile device (Brand and Model)?:
- Which is the keyboard that you use (Tactile, physical keyboard..)?:
- Do you use any assistive technology (Screen reader, screen magnifier..)?:

Internet Expertise

- How often do you surf on the internet in desktop? (Every day, two or three days per week, once a week, rarely or never):
- How often do you surf on the internet in mobile devices? (Every day, two or three days per week, once a week, rarely or never):

Chat Expertise

- How often do you chat in desktop? (Every day, two or three days per week, once a week, rarely or never):
- How often do you chat in mobile devices? (Every day, two or three days per week, once a week, rarely or never):
- Which chats have you used before (Messenger, Gtalk, Whatsapp, Social Network's chats)?:

Chat Expertise in learning environments

- Have you used chats in learning environments?:
  - Do you consider that chats are useful for learning?
  - What would you do with a chat?
- What would you use chats in learning for?:

Chat accessibility barriers

- Have you experienced any problem when you use chats?:
  - Are you able to distinguish the colors or the shapes to identify users?
  - Are you able to comprehend the icons used in the conversation?
  - Are you able to follow the *Flow and Rhythm* of the conversation?
  - Do you consider that the buttons are really small to be pressed?
  - Are you able to write quickly?
- Have you experienced any problem when you use chats in group conversations?:
  - Do you understand the messages of each person? and your messages?:
  - Are you able to read the messages and answer them when you need it?:

Opinion about the new functionality

Some users have problems when they use the chat because they are not able to follow the *Flow and Rhythm*. It means that they are not able to understand the conversation and they could be lost if the conversation runs quickly and they are not able to answer messages in the appropriate moment. As a result, they are not able sometimes to participate in conversations with users who write more quickly. The project proposes a solution to this problem, a new functionality which allows users stopping the reception of new messages until they consider that it is necessary.

Imagine this situation: You are sending messages with another user, the other user writes many messages at the same time and you could feel overwhelmed because of this. Then, you decide to stop the reception of new messages. Now, considering it, we ask you the next questions:

- Would you use this new functionality?
- If you used it, what would you like that the system did after you stopped the reception of new messages?
  - the other user would be able to send all the messages that this person wants and you would receive all of them together when you would renew the conversation
  - the other user would be able to send all the messages that this person wants and you would receive all of them one by one later
  - the other user would send one more message and you would receive it later
  - the other user would not be able to send any more messages
  - the other user would write a message but he would not be allowed to send
- Do you consider that this new functionality could be useful in one-to-one conversations? 0 is not useful and 4 is really useful
- Do you consider that this new functionality could be useful in one-to-many conversations? (0 is not useful and 4 is really useful)
- Would you be ashamed if you used it? (0 not ashamed and 4 ashamed)
- Would you prefer not to inform other users? (Yes/No)
- Would you mind if another person use this functionality?

Appendix E

Questionnaires for people with disabilities

This Appendix shows the questions asked to the participants of the method Questionnaires for people with disabilities (Chapter 3). These questions were created in Spanish because the population target was Spanish people. However, as the document is written in English, the questions showed in this Appendix are translated from Spanish to English.

E.1. Chat's Accessibility Questionnaire

This questionnaire mix the questionnaire spread through the people with disabilities to obtain their accessibility problems and the question related to the new functionality because the general questions related to the age, disability or chats' use were the same.

Aim of the Study

Dear evaluator,

This study is part of the Ph.D. "Accessible Chat for Computer Supported Collaborative Learning Environment in Mobile Devices" which is being developed by Rocío Calvo in the LaBDA Group of the Carlos III University of Madrid. The main aim of this study is to obtain the main accessibility barriers that people with disabilities experience when they use chats in MDs.The obtained information will not be used to obtain any profit, the data will be used for the statistic study exclusively and to publish it as part of the Ph.D.

If you would like to have more information about the Ph.D. please contact with Rocío Calvo through the email: mrcalvo@inf.uc3m.es.

Thank you for your collaboration.

Some general information:

1. Please select an age range that fits you. Age:

☐Under 18 ☐18-24 ☐25-34 ☐35-44 ☐45-55 ☐55-64 ☐65+

2. Please specify your gender. Gender:

☐Male ☐Female

3. Do you have any disability? If you do not have any, please select None. Problems:

☐Blindness ☐Partial Vision ☐Colour Blindness ☐Deaf ☐Hearing impairments ☐Motor impairment ☐Learning problems ☐Other

4. Which device(s) do you currently use? Devices used:

☐Nexus ☐Samsung ☐HTC ☐Motorola ☐iPhone ☐I do not know ☐Other

5. Which is the model that you use? (If you do not know it, it is not necessary to specify it) Model:

6. Specify the kind of mobile device that you use. Kind of mobile device:

☐Tactile (Touch screen) ☐With physical keyboard (The mobile device has a physic keyboard with buttons) ☐Tactile with additional keyboard (An additional keyboard is added to the mobile device) ☐I do not know

7. Do you use any assistive technology? Assistive Technologies:

☐VoiceOver ☐TalkBack ☐Zoom ☐Assistive Touch ☐Hearing Aid ☐Other

8. How often do you use the chat in a computer to communicate with someone else in the last three months?How often?:

☐Every day ☐Two or three times per week ☐Once a week ☐Rarely ☐Never

9. How often do you use the chat in a mobile device to communicate with someone else in the last three months? How often?:

☐Every day ☐Two or three times per week ☐Once a week ☐Rarely ☐Never

10. Which of the following chat applications have you used? Chats:

☐Messenger ☐Gtalk (Hangouts) ☐Whatsapp ☐Social Networks' Chats (E.g: Facebook or Tuenti) ☐Line ☐Other

Accessibility Barriers:

11. Have you had any of the next problems when you have used previous chat applications? Problems:

☐I cannot identify the colours or shapes of the users.
☐I cannot understand some icons.
☐I cannot follow the flow and rhythm of the conversation because I write slower than the other people.
☐The icons are tiny.
☐I cannot write quickly.
☐There are images without alternative text.
☐Other

Questions Related to the New Functionality

Some users have problems when they use the chat because they are not able to follow the flow and rhythm. It means that they are not able to understand the conversation and they could be lost if the conversation runs quickly and they are not able to answer messages in the appropriate moment. As a result, they are not able sometimes to participate in conversations with users who write more quickly. The project proposes a solution to this problem, a new functionality which allows users stopping the reception of new messages until they consider that it is necessary.

Imagine this situation: You are sending messages with another user, the other user writes many messages at the same time and you could feel overwhelmed because of this. Then, you decide to stop the reception of new messages. Now, considering it, we ask you the next questions:

12. What would you prefer that the system did after pressing the button to stop the reception of new messages? The system informs the other user about the new situation and ... :

☐the other user would be able to send all the messages that this person wants and you would receive all of them together when you would renew the conversation
☐the other user would send one more message and you would receive it later
☐the other user would not be able to send any more messages
☐the other user would not be able to send any more messages
☐the other user would write a message but he would not be allowed to send it
☐other

13. Do you consider that this new functionality could be useful? Is it useful?: 0 is not useful and 4 is really useful

14. Would you be ashamed if you used it?

Ashamed?: 0 no ashamed and 4 ashamed

15. Would you preferred that the other user would not be informed when you stopped the reception of new messages? Inform to other users?

☐Yes ☐No

16. Do you consider that any functionality should be improved? Improvements:

Appendix F

Questionnaires for people without disabilities

This Appendix shows the questions asked to the participants of the method Questionnaires for people without disabilities and elderly people(Chapter 3 and Chapter 5 respectively). These questions were created in Spanish because the population target was Spanish people. However, as the document is written in English, questions were translated from Spanish to English.

F.1. Chat's Accessibility Survey

This questionnaire mix the questionnaire spread through the people without disabilities to obtain their accessibility problems and the question related to the new functionality because the general questions related to the age, mobile device or chats' use were the same.

Aim of the Study

This study is part of the Ph.D. "Accessible Chat for Computer Supported Collaborative Learning Environment in Mobile Devices" which is being developed by Rocío Calvo in the LaBDA Group of the Carlos III University of Madrid. The main aim of this study is to obtain the main accessibility barriers that people with disabilities experience when they use chats in MDs as well as to obtain the main goal of this study is to check if one of the new functionalities that we propose to add to the chat could be useful for people with disabilities or without experience and if this new functionality does not bother other users.

The obtained information will not be used to obtain any profit, the data will be used for the statistic study exclusively and to publish it as part of the Ph.D.

If you would like to have more information about the Ph.D. please contact with Rocío Calvo through the email: mrcalvo@inf.uc3m.es. Thank you for your collaboration.

Some general information:

1. Please select an age range that fits you. Age:

☐Under 18 ☐18-24 ☐25-34 ☐35-44 ☐45-55 ☐55-64 ☐65+

2. Please specify your gender. Gender:

☐Male ☐Female

3. Which device(s) do you currently use? Devices used:

☐Nexus ☐Samsung ☐HTC ☐Motorola ☐iPhone ☐I do not know ☐Other

4. Which is the model that you use? (If you do not know it, it is not necessary to specify it) Model:

5. Specify the kind of mobile device that you use. Kind of mobile device:

☐Tactile (Touch screen)
☐With physical keyboard (The mobile device has a physic keyboard with buttons)
☐Tactile with additional keyboard (An additional keyboard is added to the mobile device)
☐I do not know

6. How often do you use the chat in a computer to communicate with someone else in the last three months? How often?:

☐Every day ☐Two or three times per week ☐Once a week ☐Rarely ☐Never

7. How often do you use the chat in a mobile device to communicate with someone else in the last three months? How often?:

☐Every day ☐Two or three times per week ☐Once a week ☐Rarely ☐Never

8. Which of the following chats have you used? Chats:

☐Messenger ☐Gtalk (Hangouts) ☐Whatsapp ☐Social Networks' Chats (E.g: Facebook or Tuenti) ☐Line ☐Other

Accessibility Barriers:

9. Have you had any of the next problems when you have used previous chats? Problems:

☐I cannot identify the colours or shapes of the users.
☐I cannot understand some icons.
☐I cannot follow the flow and rhythm of the conversation because I write slower than the other people.
☐The icons are tiny.
☐I cannot write quickly.
☐There are images without alternative text.
☐Other

Questions Related to the New Functionality

Some users have problems when they use the chat because they are not able to follow the flow and rhythm. It means that they are not able to understand the conversation and they could be lost if the conversation runs quickly and they are not able to answer messages in the appropriate moment. As a result, they are not able sometimes to participate in conversations with users who write more quickly. The project proposes a solution to this problem, a new functionality which allows users stopping the reception of new messages when they need it.

Imagine this situation: You are sending messages to your friend, your friend feels overwhelmed because you are sending many messages at the same time. Then, the user decides to stop the reception of new messages. Now, considering it, we ask you the next questions:

10. What would you prefer that the system did after your friend presses the button to stop the reception of new messages? The system informs me about the new situation and ... :

☐I would like to continue writing messages.
☐I would like to send one more message and you would receive it later.
☐I would like to not send any more messages.
☐Other.

11. After your friend has stopped the reception of new messages. Would you prefer that the system informs you about this new situation? Would you like to be informed?

☐Yes. I would like knowing it ☐No. Absolutely not.

12. Would you like that the system informs you when your friend has renewed the conversation? Would you like to be informed?

☐Yes. I would like knowing it ☐No. Absolutely not.

13. Would you be disappointed if your friend stopped the conversation? Would you be disappointed?

☐Yes ☐No

14.If you have selected Yes in the question number 13. Why would you be disappointed? Would you be disappointed?

15. Do you expect that the method to stop the chat would delay the conversation?Would it delay the conversation?

☐Yes a lot ☐Yes a little ☐Indifferent ☐No. It would not ☐No. absolutely

16.If you have answered "Yes a lot." or "Yes a little." in the question number 15. Why do you think that it would delay the conversation? Why?

17. If you would be overwhelmed because you were receiving many messages at the same time. Would you use this new functionality? Would you use this new functionality?

☐Yes ☐No

18. If you have answered "Yes" in the question number 17. When would you use this new functionality? When would you use it?

19. How would this new functionality be useful?Useful?:

☐Yes a lot ☐Yes a little ☐Indifferent ☐No. It would not ☐No. absolutely

20. Do you consider that any functionality should be improved? Improvements:

Appendix G

Questionnaires for Semistructured Interview in Real Situation

The questionnaires used to take out the semi-structured interviews are identified in this appendix. It is significant to mention that these questionnaires were the same for the one-to-one and one-to-many evaluations, but in the one-to-many evaluations in that location were not taken all of them to the participants because they did not use all the functionalities to test.

As the research was conducted in Spain the questions considered the recycling system that is available in Spain in 2014. Thus, some of the rules could not be the same in other countries and as a result, the answer's questions could be different.

Demographic questions

Some general information:

Gender: 1) Male; 2) Female
Profession:
Level of studies:
Age:
Disability: 1) Yes 2) No

Kind of disability:

Mobile device expertise

1. How often do you use mobile devices?:
1) Every day; 2) Two or three times per week; 3) Once a week; 4) Rarely; 5)Never

2. Kind of Keyboard: 1) Tactile (Touch screen); 2) With physical keyboard (The mobile device has a physic keyboard with buttons); 3) Tactile with additional keyboard (An additional keyboard is added to the mobile device); 4) I do not know

3. Which is your mobile device?:

4. Do you use any assistive technology?:
1) VoiceOver; 2) TalkBack; 3) Zoom; 4) Assistive Touch; 5) Hearing Aid; 6) Other

Chats expertise

1. Have you used chats previously?: 1) Yes 2) No

2. How often do you use the chat in a computer to communicate with someone else in the last three months? :
1) Every day; 2) Two or three times per week; 3) Once a week; 4) Rarely; 5)Never

3. How often do you use the chat in a mobile device to communicate with someone else in the last three months?:
1) Every day; 2) Two or three times per week; 3) Once a week; 4) Rarely; 5)Never

4. Which of the following chats have you used?:
1) Messenger; 2) Gtalk (Hangouts); 3) Whatsapp; 4) Social Networks' Chats (E.g: Facebook or Tuenti); 5) Line; 6) Other

Previous Chat Experiences

When you were chatting with other chats, did you have problems to follow the conversation in:

Individual conversations[Specify from one (Many) to five (None) the level of difficulty that you experienced]

Group conversations[Specify from one (Many) to five (None) the level of difficulty that you experienced]

When you were chatting with other chats, did you have problems to read the sent messages when you receive many messages at the same time in:

Individual conversations[Specify from one (Many) to five (None) the level of difficulty that you experienced]

Group conversations[Specify from one (Many) to five (None) the level of difficulty that you experienced]

When you were chatting with other chats, did you have problems to write messages quickly in:

Individual conversations[Specify from one (Many) to five (None) the level of difficulty that you experienced]

Group conversations[Specify from one (Many) to five (None) the level of difficulty that you experienced]

Moodle's Chat:

After using the Moodle's chat, we desire to know if you had understood the conversation. To know it, answer the following questions.

Which is the three R's rule?
1) Reduce Reuse and Recycle; 2) Reduce Reuse and Challenge; 3)Reduce Challenge and Recycle

Which object cannot be throw into the glass bin?
1) Bottle of glass; 2)A can of glass; 3)A glass

How difficult was executing the task? [Specify from one (None) to five (Many) the level of difficulty that you experienced]

When I was the person who used the Moodle's chat..

Were you bored or interested in the conversation when I wrote really slow? Why?
1) Very bored; 2)Bored; 3)Neutral; 4)Interested; 5)Really interested

Were you annoyed or pleased with the velocity of the messages? Why?
1) Very annoyed; 2)Annoyed; 3)Neutral; 4)Pleased; 5)Really pleased.

Were you Unrelieved or Relieved because you did not know why I sent messages really slowly? Why?
1) Very Unrelieved; 2)Unrelieved; 3)Neutral; 4)Relieved; 5)Really Relieved.

When you were the person who used the Moodle's chat..

Were you Unrelieved or Relieved because you though that you were loosing part of the conversation when you did not press the button? Why?

1) Very Unrelieved; 2)Unrelieved; 3)Neutral; 4)Relieved; 5)Really Relieved.

Were you confused or confident when you pressed the button to refresh the screen and you received all the messages at the same time? Why?

1) Very Confused; 2)Confused; 3)Neutral; 4)Confident; 5)Really confident.

Were you disappointed or happy because you had to press the button? Why?

1) Very disappointed; 2)Disappointed; 3)Neutral; 4)Happy; 5)Really happy.

New Chat's Chat:

After using the New Chat, we desire to know if you had understood the conversation. To know it, answer the following questions.

Which object cannot be throw into the paper bin?
1) A newspaper; 2) A journal; 3) Dirty kitchen paper.

Which object cannot be throw into the plastic bin?

1) A tin; 2) Aluminium; 3) A CD or DVD

How difficult was executing the task? [Specify from one (None) to five (Many) the level of difficulty that you experienced]

When I was the person who used the New chat..

Were you bored or interested in the conversation when I wrote really slow? Why?

1) Very bored; 2)Bored; 3)Neutral; 4)Interested; 5)Really interested.

Were you annoyed or pleased with the velocity of the messages? Why?

1) Very annoyed; 2)Annoyed; 3)Neutral; 4)Pleased; 5)Really pleased.

Were you Unrelieved or Relieved because you did not know why I stopped the reception of messages? Why?

1) Very Unrelieved; 2)Unrelieved; 3)Neutral; 4)Relieved; 5)Really Relieved.

When you were the person who used the New's chat..

Were you Unrelieved or Relieved because you though that you were loosing part of the conversation when you did not press the button? Why?

1) Very Unrelieved; 2)Unrelieved; 3)Neutral; 4)Relieved; 5)Really Relieved.

Were you confused or confident when you pressed the button to receive the messages on the screen and you received all the messages at the same time? Why?

1) Very confused; 2)Confused; 3)Neutral; 4)Confident; 5)Really confident.

Were you disappointed or happy because you had to press the button? Why?

1) Very disappointed; 2)Disappointed; 3)Neutral; 4)Happy; 5)Really happy.

Comparing both chats:

- When I was the person who used the chat (Moodle's and New Chat), which one do you prefer?Why?
- When I was the person who used the chat (Moodle's and New Chat), which one do you prefer? Why?
- Which one do you used in group or individual conversations? Why?
- Which one do you used in e-learning environments? Why?

Appendix H

Requirements Specification for Accessible Chat Applications in m-learning environments

This chapter specifies the list of requirements that have been elicited, specified and validated during the research.

The elicited requirements are categorised and designed in order to provide a better understanding of them. As it was explained in previous sections, these categories are: (1) Login; (2) Personalisation; (3) Contacts; (4) Conversations; (5) Messages; (6) Exchange files. Next sections specify the requirements related to each category.

H.1. Login

The requirements do not specify how a user could create an account in a system because it is outbound of the research. However, the requirements describe how the access to the system should be created and it is included in the *Login* requirements.

Privacy is really important nowadays and chat applications need to consider accessibility too. Chat applications need to be secure and its access should be controlled using a user name and password. Some users might consider it it very complex because they have to remember this login details. As a result, it is important to make it as simple as possible. The following table, Table H.1 includes solutions for the users' problems obtained in previous studies and details the requirement which considers it.

Problem	**Req.**	**Solution**
Privacy	L-1	Username and password are used to log into the system.
Forget information	L-1	Provide mechanisms to reset passwords.
Write quickly	L-1	Provide mechanisms which help users typing as less information as possible when they log into the system.
User's errors	L-1	Prevent user errors as much as possible.

Table H.1: Login: Problems Solved

Some people have problems to remember their passwords and others can have just forgot them. Users could be allowed to save their login details in their device and to recover their password or user name. Another problem that users have is related to the password input text

fields. These input text fields hide the information typed on them. Users should be allowed to hide or show their passwords when they are typing their passwords. The Table H.2 shows the requirement which specifies how help users access to the system using user name and password.

Code:	L-1
Requirement:	Login
Priority:	High
Classification:	Login
Description:	Protect the access to the system and help users to log into the system.
Recommendation:	(1) **User information:** the user can sign into the system with a password and username. (**Imp.:** *User's protection*) (2) **User errors:** Control, avoid and guide users to solve input errors. For example: sending empty fields or wrong password (***Imp.:*** *Reduce, avoid and check errors*) (3) **User name:** Save at least the last user name accessed to the system. (***Imp.:*** *Reduce memory and Reduce input text*) (4) **Forgot user name and password:** Allow users to recover their forgot passwords and user names. (***Imp.:*** *Reduce memory and Reduce, avoid and check errors*) (5)**Automatic sign in:** Provide mechanism to sign in automatically. (***Imp.:*** *Reduce memory and Reduce input text*) (6) **Hide or show passwords:** Allow hiding or showing passwords when the user does not remember it (***Imp.:*** *Reduce, avoid and check errors*)
Based on:	WCAG_2.0_2.1.1, WCAG_2.0_2.4.3, WCAG_2.0_3.3.1, WCAG_2.0_3.3.1, MWABP_6, ISO_29140_2_6.2.1

Table H.2: Login (L-1): Login

A sequence diagram - see Figure H.1 - represents this requirement. The behaviour of the system when the user introduces the user name and password wrongly [alt: User¡¿Ok or Password ¡¿Ok] and when the user recovers password is shown [ForgotPassword()]. This diagram specifies the system's behaviour in these situations exclusively.

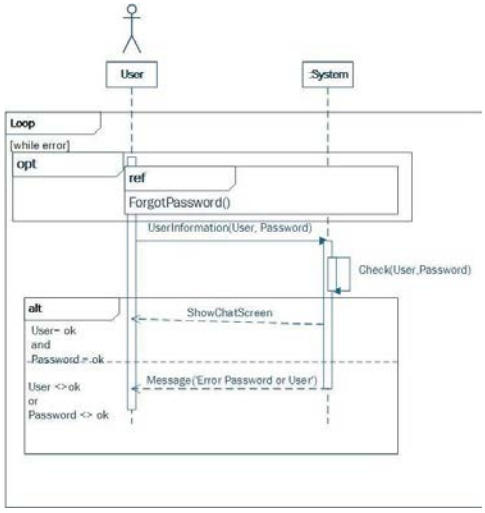

Figure H.1: Sequence Diagram: L-1. Control access to the system

H.2. Personalisation

Users have their own necessities. Chats should allow users configuring the interface to adapt it better to their necessities. Next table, Table H.3, shows the main solutions to the problems identified previously and the requirement which solves it.

Problem	**Req.**	**Solution**
Unknown language	P-1	Allow users to select the language used in their messages and in the system's interface.
Too much text	P-2	The information shown on the screen could be customised by users.
Modify user's name	P-2	User's name can be customised.
Awkward messages	P-3	Control messages sent by other users.

Table H.3: Personalisation: Problems Solved

Students could configure the system's language and specify the language they are using to write their messages. Table H.4 specifies this requirement.

Code:	P-1
Requirement:	System and Messages' language
Priority:	Medium
Classification:	Personalisation
Description:	Allow users to customise the message's language the interface
Recommendation:	1. **Interface's language:** allow changing the language of the chat applications interface. (**Imp:** *Language identification)* 2. **Messages language:** allow managing the language that the student uses to communicate within the chat application (**Imp:** *Language identification)*
Based on:	WCAG_2.0_3.1.1, MWBP_1.0_57,UDL_2.0_1.1, UDL_2.0_7.1, UDL_2.0_7.1, ISO_29140_2_6.3.3

Table H.4: Personalisation (P-1): User Language

Figure H.2 shows the sequence diagram, which represents the previous requirement. Students select the language from the list of languages available in the system.

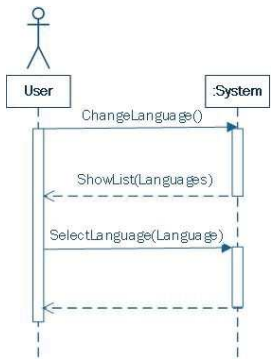

Figure H.2: Sequence Diagram: P-1. Change System's Language

Basing on existing chat applications, students should be able to specify personal information such as: their email or their telephone number. However, this information was not considered in the requirements because it was not detected any accessibility problem related to this information. In contrast, other problems related to the nickname or profile images were detected in the configuration phase - see table H.5. The nickname could be specified by the user but this nickname should not include special characters such as: # or $ because screen reader users might not be able to understand them. However, if users need to include these characters, users could modify their contact's names. Besides, it is important that each user includes an image in order to be recognised easier by other people. This feature is important for people, who need more time to read text information and prefer visual information.

Code:	P-2
Requirement:	User information
Priority:	Medium
Classification:	Personalisation
Description:	Allow users modify their personal information.
Recommendation:	1. **Nickname:** this identifies the user. **Advice**: It could be better if this nickname do not include special characters. (**Imp:** *Understand words and acronyms)* 2. **Image:** the user's image must be specified by users in order to be recognised by users. (**Imp:** *Less information)*
Based on:	WCAG_2.0_1.1.1, WCAG_2.0_3.1.5, MWBP_1.0_18, MWBP_1.0_36, UDL_2.0_1.3, UDL_2.0_2.1, IMS_v2_1, ISO_9241_171_8.2.1-8.2.5, ISO_9241_171_8.3.1-8.3.5, US_508_1194_22a, ISO_29140_2_6.3.3, CVAA_b2_i, CVAA_b2_ii

Table H.5: Personalisation (P-2): User information

Each student can modify their status. After analysing existing chat applications, the most common statuses are: Idle, Disconnected, Busy or Connected. Students could create other statuses as well as additional description for each status to explicate its meaning. Next Table H.6 shows this requirement in detail.

Code:	P-3
Requirement:	User status
Priority:	High
Classification:	Personalisation
Description:	Each student can specify their status.
Recommendation:	1. **Available statuses:** Provide statuses such as: Idle, Disconnected, Busy or Connected. Students should be able to personalise and create other statuses. (**Imp:** *Avoid interruptions and Specify the status of the conversation and user)* 2. **Inform when other student is writing:** Inform other students when other people is writing in a specific conversation. (**Imp:** *Specify the status of the conversation and user)* 3. **Personalise student status:** Allow specifying a status by default but students could modify this status. (**Imp:** *Avoid interruptions; Specify the status of the conversation and user)* 4. **Clarify status:** Students could add an additional message to their status to describe it more accurately. (**Imp:** *Avoid interruptions; Specify the status of the conversation and user)*
Based on:	WCAG_2.0_2.2.4, UDL_2.0_1.1, UDL_2.0_1.3, UDL_2.0_7.1, UDL_2.0_7.2, UDL_2.0_8.3, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2

Table H.6: Personalisation (P-3): User status

H.3. Contacts

Students have lists of contacts that they can contact with. Some students might have problems to manage their list of contacts. Considering the problems obtained in previous studies, some requirements are defined to solve these problems. The Table H.7 shows the main problems that people identified and how these problems could be solved.

Problem	**Req.**	**Solution**
Search contacts	C-1	Students can search and manage their list of contacts.
Identify their contacts	C-2	Allow students to name, describe, and classify their contacts in order to identify them better.
Colours and Colour Contrast Ratio	C-3	Students can personalise colours used to identify participants and the status of each participant.
Too much text	C-2	Use images to identify students as well as text.
Incomprehensible icons and Understand statuses	C-2	Do not use just colours or shapes to identify the status of each student.
Students' protection	C-4	Allow students to control the reception of messages.

Table H.7: Contacts: Problems Solved

List of contacts might include many students. Chat applications should include features to manage this list. Table H.8, shows the requirement which specifies the system's behaviour.

Code:	C-1
Requirement:	Search contacts
Priority:	Medium
Classification:	Contacts
Description:	Provide ways to help students find other students easily and quickly.
Recommendation:	1. **Search:** include a mechanism to find a contact easily. 2. **Categories:** categories are used to organise the list of contacts. Students could organise their contacts according to a predefined or customised list of categories. 3. **Sort by:** more than one way is available to order the list of contacts - e.g. sort by: name or status. (**Imp:** *Access information easily)*
Based on:	WCAG_2.0_1.3.1, WCAG_2.0_2.4.5, WCAG_2.0_2.4.6, UDL_2.0_3.3, ISO_29140_2_2.6.3

Table H.8: Contacts (C-1): Search contacts

Students might need different formats to access to the content; so, they could personalise their list of contacts format - see Table H.9. Some students - e.g. with visual impairments - prefer images while other students - e.g. with blindness - prefer short text.

Code:	C-2
Requirement:	Contact identification
Priority:	Medium
Classification:	Contacts
Description:	Students are allowed to personalise how their list of contacts.
Recommendation:	Provide mechanisms to identify each contact in the list of contacts. 1. **Personalise contacts' profile picture:** Students could change the picture profile of its contacts. (**Imp:** *Less information, Avoid unnecessary images and Reduce Memory)* 2. **Personalise contacts' nicknames:** Students could modify students' nicknames to make them easier to read and shorter. (**Imp:** *Simple language and Reduce Memory)* 3. **Colour:** Students are identified by a colour. Students could modify the colour assigned to each participant. (**Imp:** *Control font style and Reduce Memory)*
Based on:	WCAG_2.0_1.3.3, WCAG_2.0_1.4.1, WCAG_2.0_1.4.3, MWBP_1.0_26, MWABP_32, UDL_2.0_1.1, UDL_2.0_1.3, UDL_2.0_7.1, UDL_2.0_7.2, ISO_29140_2_6.3.3, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2

Table H.9: Contacts (C-2): Contact identification

Students could specify their current statuses to avoid interruptions. They could select the

status from a list of statuses or they could customise them. Usually, these statuses are identified with colours or shapes exclusively but some users could have difficulties to differentiate them. The following table, Table H.10, shows the requirement which specifies this in detail.

Code:	C-3
Requirement:	Customise statuses
Priority:	Medium
Classification:	Contacts
Description:	Allow students to customise how to represent statuses.
Recommendation:	Students could specify if contacts' statuses are represented using text, shapes and/or colours. Each student could customise it. By default, do not use colours or shapes exclusively to identify the status of the student. Provide the information conveyed with colour through another visual cue. For example, use a "Red circle" represents busy contacts and use a "Yellow triangle" to represent idle contacts. (**Imp:** *Less information and Do not identify information with colours or shapes exclusively)*
Based on:	WCAG_2.0_1.3.3, WCAG_2.0_1.4.1, WCAG_2.0_1.4.3, MWBP_1.0_26, MWBP_1.0_27, MWBP_1.0_28, MWBP_1.0_53, UDL_2.0_1.1, UDL_2.0_1.3, UDL_2.0_7.1, UDL_2.0_7.2, UDL_2.0_8.3, FUNKANU_40, FUNKANU_47, US_508_1194_22c, CVAA_b1_ii,CVAA_b2_ii, ISO_9241_171_8.2.1-8.2.5, ISO_9241_171_10.3.1, ISO_9241_171_10.4.1,

Table H.10: Contacts (C-3): Status identification

Some contacts or students might be rude and could send unwanted/awkward messages to other students. In order to preserve students rights, these students could block the reception of messages from other students - see Table H.11.

Code:	C-4
Requirement:	Block students
Priority:	Medium
Classification:	Contacts
Description:	Block the reception of messages for specific student.
Recommendation:	Students could block other contacts who disturb them. The blocked users could not send any message to the student who has blocked him. (**Imp:** *Users protection*)

Table H.11: Contacts (C-4): Block users

H.4. Conversations

Chat applications allow students to communicate in conversations. These conversations include two or more participants (Students or Teachers) which discuss a specific topic. In these conversations, students and teachers exchange their knowledge and their doubts quickly.

Considering previous studies, students experience problems when they communicate with other students and teachers using the chat application. To solve these problems a list of

requirements has been specified. The following table, Table H.12, shows the Problem, the related Requirement and the Solution for this problem.

Problem	**Req.**	**Solution**
Follow the Flow and Rhythm	G-1, G-7	Provide mechanisms to help users Follow the Flow and Rhythm of the conversation.
Write quickly	G-1, G-7	Idem to "Follow the Flow and Rhythm" problem
Too much text information	G-6	Students could manage the Look and Feel of each message in order to just show the information needed.
Unaware of new messages	G-7	Students should be informed when new messages are received.
Many messages on the screen	G-5	The number of messages shown on the screen should be controlled by each user.
Many participants at the same time	G-1, G-4, G-5, G-6, G-9	Provide mechanisms to control speaker designations, control the number of participants per conversation as well as the number of messages and the chronological order of the messages.
Unable to understand conversations	G-2	Provide a list of concepts and abbreviations to help students understand and follow the conversation.
Many unimportant messages	G-10	Allow students to mark and tag important messages in order to retrieve them later easily.
Receive awkward messages	G-11	Allow students to specify when they do not want to receive more messages from a specific contact.
Asynchronous chats	G-12	Provide mechanisms to arrange tutoring dates where students and teachers could collaborate together.

Table H.12: Conversation: Problems Solved

The number of participants per conversation could influence in the student‘s learning and communication. The person (Student or teacher), who created the conversation, could add more participants to the conversation. The rest of participants should confirm if they want to add this person to the conversation or not. In addition, current participants could leave the conversation at any time. In this case, other participants should be advised about this new situation. Finally, students could block a participant and they would not receive more messages from this person. Next sections specify each requirement in detail and if the requirement is difficult to understand, a UML diagram is included to specify its behaviour.

The use of chat applications in m-learning environments is very useful for students and teachers to communicate easily and quickly. One of the most important features of these applications is to provide the possibility of creating group conversations to exchange knowledge. The next requirement, Table H.13, does not make any improvement related to the problems found in previous studies. However, this requirement is included in each analysed chat application for m-learning environments.

Code:	G-1
Requirement:	Group conversations
Priority:	High
Classification:	Conversation
Description:	Allow students create group conversations.
Recommendation:	Provide a mechanism to create group conversations with one or more students and one or more teachers. These group conversations will: 1. **Exchange information:** Allow students to exchange files and messages in these groups. 2. **Conversation information:** Provide a name, description and image for each conversation. 3. **Permissions:** The user who creates the conversation has all the permissions to administrate the conversation. However, this user can specify permissions for other users.
Based on:	UDL_2.0_8.3, ISO_29140_2_6.3.6

Table H.13: Conversations (G-1): Group conversations

These group conversations could include two or more participants (students and/or teachers) and additional participants could be added if the other participants every participant accept it. In addition, if new participants are added to the conversation, they might have access to previous messages if confirmed. Table H.14 explains in detail this requirement.

Code:	G-2
Requirement:	Add new participants
Priority:	High
Classification:	Conversation
Description:	Students could add new participants to the conversation if other participants agree it and these new participants could have access to previous messages if agreed.
Recommendation:	When new participants are added to the conversation the following adjustments are true: 1. Every student confirms the addition of this participant to the conversation. (***Imp:*** *Less information and Reduce input text*) 2. Users could specify if previous messages are available for new participants or not. (***Imp:*** *Important Information*)
Based on:	ISO_29140_2_6.3.7, UDL_2.0_1.1, UDL_2.0_3.1, UDL_2.0_7.1, UDL_2.0_7.2

Table H.14: Conversations (G-2): Add new participants

Next figure, Figure H.3 , shows the sequence diagram which represents the G-2 guideline. This diagram shows how the User1 adds a user to the conversation which is being carried out by the User1 and User2. Then, the User2 receives a request to add a new user to the conversation. User2 can confirm the addition of the new user to the conversation or not.

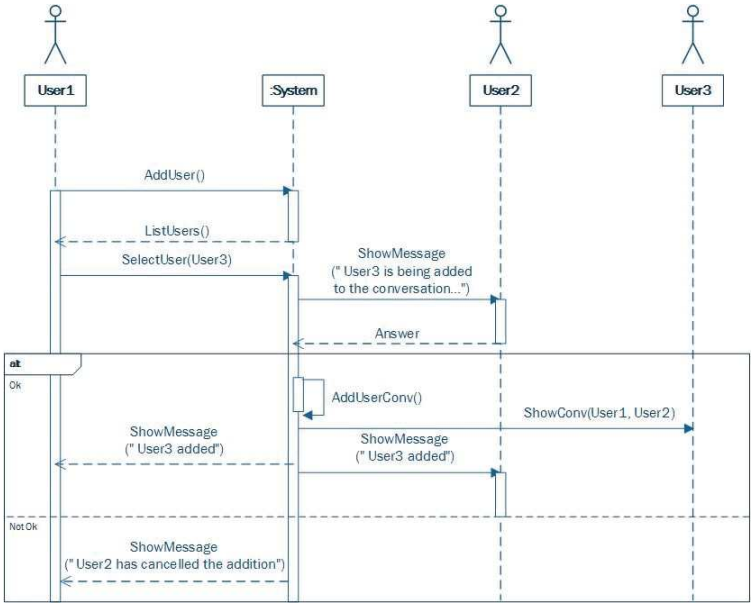

Figure H.3: Sequence Diagram: G-2. Add new participants

In these conversations, different topics could be addressed. Depending on the topic, it could be difficult for some students to understand the conversation. They could have difficulties if the topic is new, if the topic is difficult or due to other circumstances. Because of this, it is useful to provide a glossary of terms which helps students to understand the most complex words addressed in the conversation. Table H.15 explains this requirement in detail.

Code:	G-3
Requirement:	Glossary of terms
Priority:	Medium
Classification:	Conversation
Description:	Provide a glossary of terms.
Recommendation:	Students could create a glossary of terms to explain difficult expressions or words, which are referenced in a particular conversation.(***Imp:*** *Less information and Reduce input text*)
Based on:	ISO_29140_2_6.3.7, UDL_2.0_1.1, UDL_2.0_3.1, UDL_2.0_7.1, UDL_2.0_7.2

Table H.15: Conversations (G-3): Glossary of terms

Some students might prefer to see recent messages at the top because they focus their sight at the top of the screen. In contrast, other students might prefer the classical behaviour and see the most recent messages at the bottom. Students should have this option and could be able to modify it according to their preferences - see Table H.16.

Code:	G-4
Requirement:	Message order configuration.
Priority:	Medium
Classification:	Conversation
Description:	Allow students to show messages in chronological or inverse order.
Recommendation:	Messages are ordered by time to represent a sequence. This order could be configured by the student:(***Imp:****Important information*) ▪ **Chronological order**: Show oldest messages at the top. ▪ **Inverse order**: Show oldest messages at the bottom.
Additional Req:	*Allow manage the preferences*
Based on:	WCAG_2.0_1.3.1, WCAG_2.0_1.3.2, WCAG_2.0_2.4.3, MWBP_1.0_31, MWBP_1.0_43, MWBP_1.0_58, MWABP_32, UDL_2.0_1.1, UDL_2.0_7.1, UDL_2.0_7.2, ISO_29140_2_6.3.3, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2, US_508_1194_2d

Table H.16: Conversations (G-4): Message order configuration.

Message's information could be personalised to show the most useful information. Students could specify: date's format; message look and feel; and senders information - see Table H.17.

Code:	G-5
Requirement:	Configure the information shown per message.
Priority:	High
Classification:	Conversation
Description:	Users can configure the information shown per message
Recommendation:	Each student could configure the information shown per message. All the following are true: 1. **Date time format**: Students can specify if they prefer to see the day and time; only the time; or only the date of the sent messages. (***Imp.****:Less information and Simple language*) 2. **Senders information**: Configure how Senders are identified. E.g. Image profile or nickname. (***Imp.****:Less information, Avoid unnecessary images and Simple language*)
Additional Req:	*Allow manage the preferences*
Based on:	WCAG_2.0_1.3.3, WCAG_2.0_1.4.1, WCAG_2.0_1.4.3, MWBP_1.0_19, MWBP_1.0_26, MWBP_1.0_27, MWBP_1.0_36, MWABP_32,UDL_2.0_1.1, UDL_2.0_1.3, UDL_2.0_7.1, UDL_2.0_7.2, ISO_29140_2_6.3.3, FUNKANU_27, FUNKANU_47, US_508_1194_22c ,CVAA_b1_iii,CVAA_b2_ii, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2, ISO_9241_171_10.2.1

Table H.17: Conversations (G-5): Configure the information shown per message.

The message's layout could be personalised - see Table H.18. This helps students to understand and read the messages better.

Code:	G-6
Requirement:	Configure message layout.
Priority:	High
Classification:	Conversation
Description:	Allow students to configure the messages layout.
Recommendation:	The message layout could be configured by the student (***Imp.****:Control font size*) All the following are true: 1. **Date time format**: Configure font style (E.g.: font type or colour) and the position (E.g.: before or after the message information). 2. **Message text**: Configure font size and colour of each message. 3. **Senders's identification:** Each sender could be identified by a sound and a colour; and this can be configured.
Additional Req:	*Allow manage the preferences*
Based on:	WCAG_2.0_1.3.3, WCAG_2.0_1.4.1, WCAG_2.0_1.4.3, MWBP_1.0_19, MWBP_1.0_26, MWBP_1.0_27, MWBP_1.0_36, MWABP_32,UDL_2.0_1.1, UDL_2.0_1.3, UDL_2.0_7.1, UDL_2.0_7.2, ISO_29140_2_6.3.3, FUNKANU_27, FUNKANU_47, US_508_1194_22c ,CVAA_b1_iii,CVAA_b2_ii, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2, ISO_9241_171_10.2.1

Table H.18: Conversations (G-6): Configure message layout.

Students can be confused if they receive many messages and their learning can be affected. As a result, students could control the number of messages shown - see Table H.19.

Code:	G-7
Requirement:	Control the number of messages shown on the screen.
Priority:	Medium
Classification:	Conversation
Description:	Allow students control the number of messages shown on the screen.
Recommendation:	1. **Number of messages**: Students can specify how many messages are shown on the screen. (***Imp.****:Less information*) 2. **Clear messages:** Students can clear the messages shown on the screen every time they need it. (***Imp.****:Less information*)
Additional Req:	*Allow manage the preferences*
Based on:	MWBP_1.0_7, MWBP_1.0_17, MWBP_1.0_18, MWBP_1.0_19, MWBP_1.0_20, MWBP_1.0_21, MWBAP_22, MWABP_32,UDL_2.0_1.1, UDL_2.0_2.2, UDL_2.0_3.3, UDL_2.0_7.1, ISO_29140_2_6.3.3, FUNKANU_16, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2, CVAA_b1_x

Table H.19: Conversations (G-7): Control the number of messages shown on the screen.

The reception of new messages could cause problems for some students because they might have note read previous messages yet and they can be overwhelmed. Students could: control the reception of new messages and specify when these messages are shown; and specify the time interval to show new messages. The following requirement - Table H.20 - details this.

Code:	G-8
Requirement:	Control reception of new messages.
Priority:	High
Classification:	Conversation
Description:	Configure the time interval to show more messages.
Recommendation:	A mechanism should be provided to control messages. At least one of the following is true: 1. **Refresh interval**: Configure time interval to show new messages and students should be informed when new messages are ready to be read. (***Imp.:****Auto-updating information*) 2. **Pause the reception of new messages:** Provide mechanisms to pause the reception of messages when necessary. For example: provide a button to allow users to pause the reception of new messages.(***Imp.:****Control moving elements*)
Additional Req:	*Allow manage preferences*
Based on:	WCAG_2.0_2.2.1, MWBP_1.0_14, UDL_2.0_1.1, UDL_2.0_4.1, UDL_2.0_7.1, UDL_2.0_7.2, ISO_29140_2_6.3.3, FUNKANU_41, US_508_1194_22p, CVAA_b1_viii, ISO_9241_171_8.2.7, ISO_9241_171_10.1.2

Table H.20: Conversations (G-8): Control reception of new messages.

Figure H.4 shows the system's behaviour when a user pauses the reception of new messages. The User2 selects the Pause option to pause the reception of new messages. The system informs other participants - User1 - about this situation. Then, the User2 will not receive more messages until they press the "Continue" button to receive new messages.

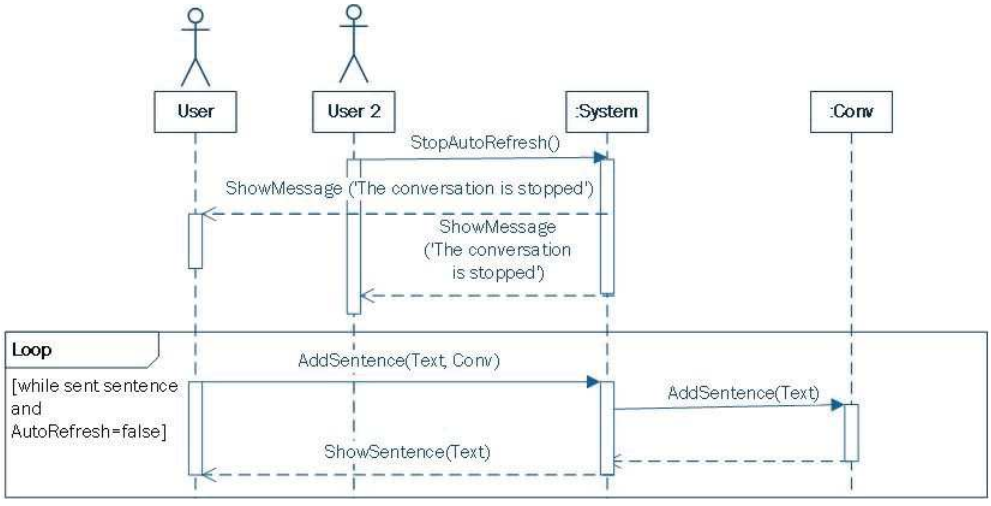

Figure H.4: Sequence Diagram: G-8. Control reception of new messages

Students might prefer to not change their status but they could prefer to silence a specific conversation and send automatic replies to specify this person is not available and will reply to the messages as soon as possible. Next Table H.21 details the requirement.

Code:	G-9
Requirement:	Mute conversation alerts.
Priority:	Medium
Classification:	Conversation
Description:	Allow students to mute conversations to not been disturbed.
Recommendation:	Students could mute specific conversations when they do not want to be disturbed. In this case, the user could specify an automatic reply which will be sent for the participants who tried to contact with them.
Additional Req:	*Allow manage the preferences*

Table H.21: Conversations (G-9): Mute Conversation Alerts.

Messages can be more or less important depending on the conversation or student. Students could consider some of these messages as essential for their learning process and they might need to retrieve these messages quickly in the future. As a result, it is important to provide a method which will allow students to tag important messages - see Table H.22.

Code:	G-10
Requirement:	Tag important messages.
Priority:	High
Classification:	Conversation
Description:	Manage most important messages in a conversation.
Recommendation:	Allow users to mark the most important messages of the conversation. Students can: manage, mark, retrieve and classify the most important messages in a conversation. (***Imp.****:Important information and Knowledge and learning*)
Based on:	UDL_2.0_3.2, UDL_2.0_6.3, ISO_9241_171_8.4.3

Table H.22: Conversations (G-10): Tag important messages.

A similar situation occurs with conversations. Some of them will be more important than others. Students should be allowed to manage and classify these conversations to retrieve them quickly and easily and to catalogue them - see Table H.23.

Code:	G-11
Requirement:	Manage conversations.
Priority:	High
Classification:	Conversation
Description:	Allow students to catalogue conversations .
Recommendation:	Users could catalogue and tag each conversation. Provide a list of default categories and allow creating new categories. (***Imp.****: Important information and Knowledge and learning*)
Based on:	UDL_2.0_6.3

Table H.23: Conversations (G-11): Manage conversations.

Figure H.5 shows the UML representation of this requirement. In this case, the User assigns a tag for a specific conversation. Then, the system creates this association and shows a message to User which confirms this association has been done correctly.

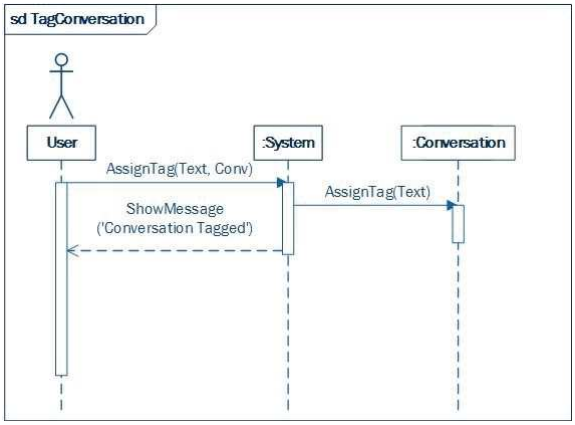

Figure H.5: Sequence Diagram: G-11. Manage conversations.

H.5. Messages

Students face problems when they send chat messages. These problems are related to different circumstances. For example, if messages are really long, students might have problems to understand and read them because they have to scroll up and down several times. Other students have problems to follow the *Flow and Rhythm* of the conversation. Besides, the use of complex language or the use of non-text information could cause problems for some students. These are some examples of problems faced by students. Table H.24 shows the problems solved in this section and the requirements which solve these problems.

Problem	**Req.**	**Solution**
Messages were too long	M-1	Specify Messages‘ maximum text size in order to help students understand the conversation easily.
Write quickly and Follow the Flow and Rhythm	M-1, M-7	Include predefined sentences which could be selected by students and allow students to forward messages to another contact.
Untagged emoticons	M-1	Emoticons should be tagged using a descriptive text.
Language is not understood	M-2, M-3	Specify messages language and allow students to translate it.
Different formats	M-2	Allow students to change output and input formats.
Spelling and autocorrection	M-4	Provide mechanisms to check the spelling for every word.
No tagged elements	M-5	Provide a description for every acronym and abbreviation.
Reception of messages	M-6	Specify the status of each message.
Unimportant information	M-8	Provide mechanisms to skip unimportant information and to allow students navigate quickly between messages.

Table H.24: Messages: Problems Solved

In m-learning chat conversations, accessible messages are exchanged between students and teachers. Table H.25 shows the requirement which describes the message‘s characteristics.

Code:	M-1
Requirement:	Send messages
Priority:	High
Classification:	Messages
Description:	Students and teachers could exchange messages.
Recommendation:	Allow students send these messages quickly and help them to type as less characters as possible. Provide the following mechanisms: 1. **Messages' size:** the messages size should be no longer than 150 characters in order to make it comprehensible and easy to read. (***Imp:*** *Less information*) 2. **Predefined sentences and words:** provide predefined messages which could be modified by the student according to his necessities. (***Imp:*** *Reduce input text*) 3. **Emoticons:** emoticons could be sent by students and teachers. These emoticons should be tagged with an alternative text. (***Imp:*** *Alternative non-text information*)
Based on:	WCAG_2.0_1.1.1, WCAG_2.0_1.3.1, MWBP_1.0_17, MWBP_1.0_18, MWBP_1.0_19, MWBP_1.0_36, MWBP_1.0_54, MWBP_1.0_55, MWBP_1.0_56, UDL_2.0_1.3, CVAA_b1_i, US_508_1194_22_a, US_508_1194_22_b

Table H.25: Messages (M-1): Send messages.

Figure H.6 specifies how students could send emoticons or predefined sentences. In this case, the User1 sends emoticons and a predefined sentence to the User2. Finally, the user types the message and sent it to the User2.

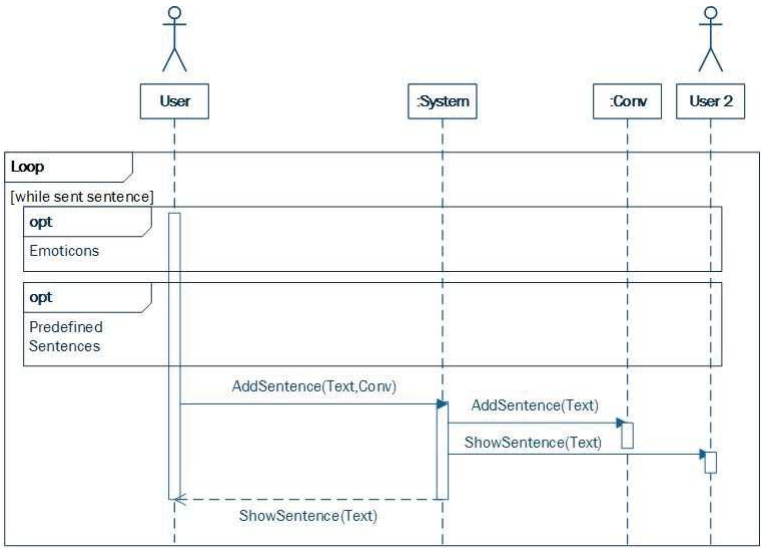

Figure H.6: Sequence Diagram: M-1. Send messages

Moreover, Figure H.7 shows how the User1 selects a predefined sentence from the list of sentences and sent it.

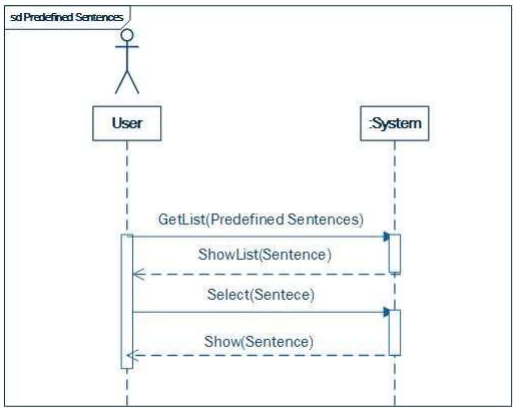

Figure H.7: Sequence Diagram: M-2. Predefined sentences

Depending on the conversation, students will send sentences in different languages. Students could specify the language they frequently use; in addition, the system should detect automatically the language used in the messages. Table H.26 specifies in detail this.

Code:	M-2
Requirement:	Language of sentences
Priority:	High
Classification:	Messages
Description:	Specify a default language of the sentences and recognise words written in other languages.
Recommendation:	Allow users to specify the language of the sentences that they write. The system should identify automatically the language of specific sentences which are not written in the predefined language. (***Imp:*** *Understand text*)
Based on:	WCAG_2.0_3.1.1, WCAG_2.0_3.1.2, MWBP_1.0_57,UDL_2.0_2.4, ISO_29140_2_6.2.6

Table H.26: Messages (M-2): Language of sentences.

Students might prefer reading information in a text or voice format. Besides, users might have difficulties to read information in other languages. Chat should allow users convert text to speech and speech to text the sent messages as well as to translate them - see Table H.27.

Code:	M-3
Requirement:	Convert messages
Priority:	Low
Classification:	Messages
Description:	Allow users converting messages into different formats.
Recommendation:	Support Text-to-speech or audio-to-text conversations. (***Imp:****Alternative text input and output*) and allow users to translate messages to other languages (***Imp:****Translate text*)
Based on:	UDL_2.0_1.1, UDL_2.0_2.3, UDL_2.0_2.4, UDL_2.0_5.2, ISO_29140_2_6.2.6, ISO_9241_171_9.1.4, ISO_9241_171_10.6.9

Table H.27: Messages (M-3): Convert messages.

This requirement can be represented in a UML format in order to explain the information better. Next, Figure H.8 shows the systems' behaviour when the User2 selects the option to convert the conversation from text to audio.

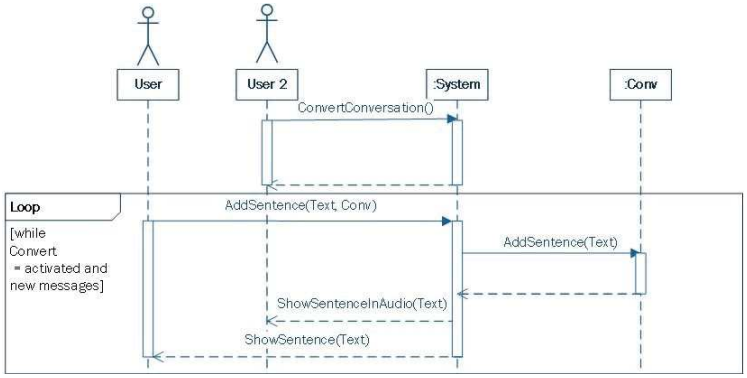

Figure H.8: Sequence Diagram: M-3. Convert messages

Students can make spelling mistakes. As the research is focused on learning environments, making mistakes could cause additional learning problems because these mistakes could be made by other students. These spelling features are useful for all students - see Table H.28.

Code:	M-4
Requirement:	Check spelling
Priority:	High
Classification:	Messages
Description:	Mark grammatical errors committed and provide suggestions.
Recommendation:	Provide ways to check spelling of the written messages and provide mechanisms to solve them (***Imp:****Reduce, avoid and check errors*)
Based on:	WCAG_2.0_3.3.1, WCAG_2.0_3.3.3, MWBP_1.0_50, UDL_2.0_5.2, FUNKANU_42, ISO_9241_171_9.1.5

Table H.28: Messages (M-4): Check spelling.

The UML diagram - see Figure H.9 - details this behaviour. If there is an error, the system marks it. Besides, if the word is written in another language, the system tags it.

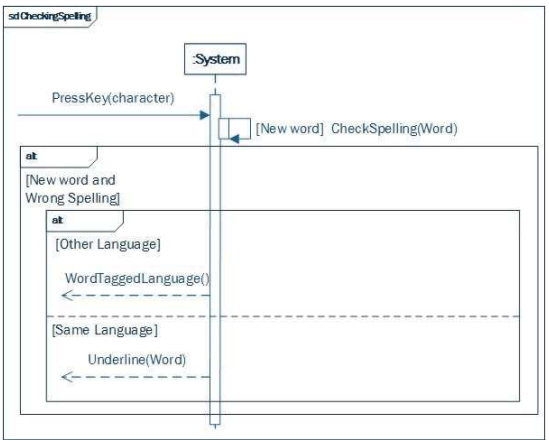

Figure H.9: Sequence Diagram: M-4. Check spelling

Messages might include abbreviations. This helps users to type information quickly because they do not have to type every single character. However, some students might have difficulties to understand these abbreviations because they are not enough descriptive or popular. As a result, these abbreviations should be tagged in order to provide additional information about their meaning - see Table H.29.

Code:	M-5
Requirement:	Tag abbreviations
Priority:	Medium
Classification:	Messages
Description:	Provide an additional description for the abbreviation used by the student.
Recommendation:	The system should have a dictionary of words and their abbreviations. These abbreviations will be tagged by the system considering the dictionary of words. Moreover, these words will be managed by students in order to add more words and relationships. (***Imp:*** *Reduce memory, Knowledge and learning and Understand text*)
Additional Req:	Manage preferences
Based on:	WCAG_2.0_3.1.4, FUNKANU_45

Table H.29: Messages (M-5): Tag abbreviations.

When students send messages to one of their colleges or teachers, the student wants to know if the other person has received the message or not as well as if the message has been read. This is especially important when the student needs a confirmation. The system needs to inform participants the message has been sent, received or read - see Table H.30.

Code:	M-6
Requirement:	Messages status
Priority:	Medium
Classification:	Messages
Description:	Students should be informed about the status of each message.
Recommendation:	Senders (people who has sent a message) and receptors (people who receive the message) should know if the message has been sent, received or read (***Imp:*** *Specify the status of the conversation and user*)
Additional Req:	Provide alerts in different ways and Allow manage alerts preferences
Based on:	WCAG_2.0_1.1.1, WCAG_2.0_1.2.1, WCAG_2.0_1.4.1, WCAG_2.0_1.4.2, WCAG_2.0_2.2.1, WCAG_2.0_2.2.2, MWBP_1.0_26, MWBP_1.0_27, MWBP_1.0_28, MWBP_1.0_36, MWBP_1.0_50, MWBAP_21, MWABP_32,UDL_2.0_1.1, UDL_2.0_1.2, UDL_2.0_1.3, UDL_2.0_2.1, UDL_2.0_7.1, UDL_2.0_7.2, UDL_2.0_7.3, UDL_2.0_8.4, ISO_29140_2_6.2.4, ISO_29140_2_6.3.3, IMS_v2_1, FUNKANU_39, FUNKANU_40, FUNKANU_47, FUNKANU_48, US_508_1194_22a, US_508_1194_22c, ,CVAA_b1_ii, CVAA_b2_i to CVAA_b2_ix, ISO_9241_171_8.2.1, ISO_9241_171_8.2.2, ISO_9241_171_10.2.1, ISO_9241_171_10.4.1, IMS_v2_5

Table H.30: Messages (M-6): Messages status.

Figure H.10 shows the systems behaviour when User sends a message to User2. When the message is received by User2, the system confirms User1 this message has been received.

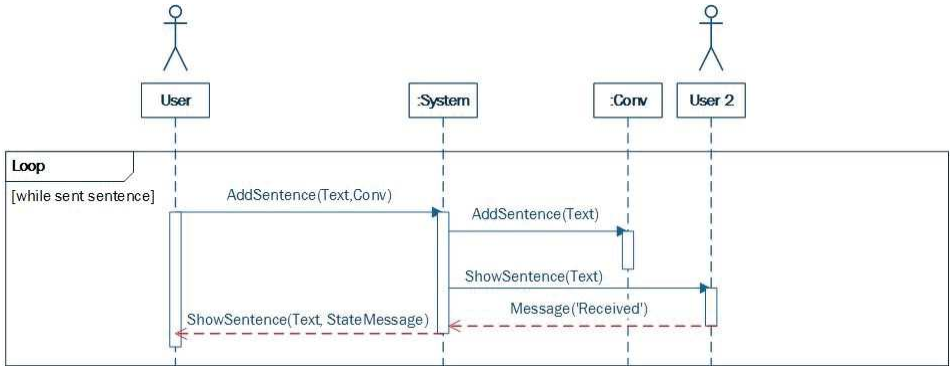

Figure H.10: Sequence Diagram: M-6. Messages‘ status

In some circumstances, students need to forward a specific message. A feature allow students forward messages to other students or teachers - see Table H.31. Otherwise, students will need to type this message and it will delay them. In addition, students who have problems to type information quickly, will have problems to send this information.

Code:	M-7
Requirement:	Forward messages
Priority:	Medium
Classification:	Messages
Description:	Allow students to forward messages.
Recommendation:	Students should be able to forward messages that they have received or sent previously. Moreover, students could modify these messages before sending them. (***Imp:****Reduce input text*)
Based on:	MWBP_1.0_54, MWBP_1.0_55

Table H.31: Messages (M-7): Forward messages.

Some conversations include many messages. Keyboard users and screen reader users will face problems because of this as they will not be able to scroll to the last message or to the first message quickly. Skip links should be provided to help students skip to the first message or to the last message - see Table H.32.

Code:	M-8
Requirement:	Skip messages
Priority:	High
Classification:	Messages
Description:	Allow students to skip messages.
Recommendation:	Students should be able to skip some messages. For example, provide students a mechanism to jump to the last or first message. (***Imp:****Quick navigation*)
Based on:	WCAG_2.0_2.4.1

Table H.32: Messages (M-8): Skip messages.

H.6. Learning

Chapter 3 describes a list of learning features for chat applications basing on UDL guidelines. Some of these guidelines were related to accessibility only and were included in previous subsections. In this section, learning features are included. The following table - Table H.33 - summarises the requirements covered in this section as well as the solved problem.

Problem/Feature	**Req.**	**Solution**
Learning feature	LE-1	Provide mechanisms to arrange tutoring dates where students and teachers could exchange knowledge.
Memory problem	LE-2	Allow students and teachers to set up tutoring reminders.
Learning feature	LE-3	Files could be exchanged in the chat application between students and teachers.
Learning feature	LE-4	Teachers should be allowed to control the messages shown to the students.

Table H.33: Learning: Problems Solved

Students might need assessments in their learning process. Teachers or students could arrange a tutoring date at a specific time and date in order to solve students‘ problems - see Table H.34 and Figure H.11. This source will be useful especially in on-line learning environments because users will need easy ways to communicate with their colleges and teachers.

Code:	LE-1
Requirement:	Manage tutoring dates.
Priority:	High
Classification:	Learning
Description:	Specify tutoring dates to create cooperative learning groups.
Recommendation:	Allow users (teachers and students) to create tutoring dates. These online classes will be group conversations where students and teachers can exchange information about a specific topic. In addition, these classes should have associated descriptive information such as: Tutoring topic, Start hour, End hour or Date. The person who has created the tutoring dates should have all the privileges. However, this user could assign privileges to other users. (***Imp.:*** *Knowledge and learning*)
Based on:	UDL_2.0_8.2, UDL_2.0_8.3, UDL_2.0_8.2, UDL_2.0_8.3, ISO_29140_2_6.3.7

Table H.34: Learning (LE-1): Manage Tutoring Dates

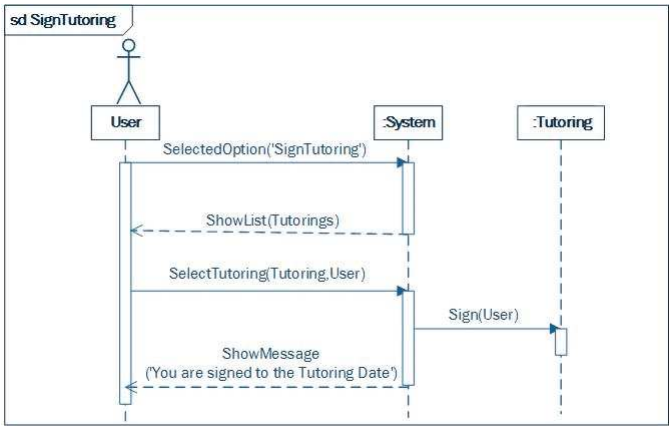

Figure H.11: Sequence Diagram: LE-1. Manage Tutoring Dates

Users should be allowed to set up reminders for incoming tutoring dates or when they have been assigned a tutoring date - see Table H.35 and Figure H.12.

Code:	LE-2
Requirement:	Set up reminders.
Priority:	High
Classification:	Learning
Description:	Allow students and teachers to set up tutoring reminders.
Recommendation:	Students and teachers could create reminders to the tutoring dates available. Students should be allowed to specify when they want to receive this notifications as well as how they want to receive these notifications. (***Imp.***: *Memory*)
Additional requirement:	*Provide alerts in different ways* and *Allow manage the preferences*
Based on:	WCAG_2.0_1.1.1, WCAG_2.0_1.3.3, WCAG_2.0_1.4.1, WCAG_2.0_1.4.2, WCAG_2.0_1.4.3, WCAG_2.0_2.2.2, UDL_2.0_1.1, UDL_2.0_1.2, UDL_2.0_1.3, UDL_2.0_3.4, UDL_2.0_7.1, UDL_2.0_7.2, UDL_2.0_7.3, UDL_2.0_8.4, UDL_2.0_9.1, FUNKANU_47, FUNKANU_48, US_508_1194_22a, CVAA_b2_i to CVAA_b2_ix

Table H.35: Learning (LE-2): Learning Guideline.

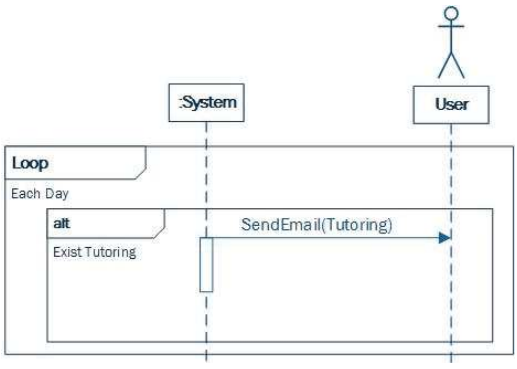

Figure H.12: Sequence Diagram: LE-2. Set up reminders

In learning environments, users need to exchange and share files because they might need to collaborate with each other. However, these files might not be accessible; specially, if they are non-text files. As a result, students should provide alternatives for these non-text content - see Table H.36.

Code:	LE-3
Requirement:	Exchanging files between users.
Priority:	High
Classification:	Learning
Description:	Allow students to exchange accessible files with their classmates and teachers.
Recommendation:	Files could be exchanged between teachers and students. When users exchange these files, they should be asked to provide textual alternatives for content which is not text. It means, if the file is an image, the user should specify a description for the image. If the file is a video, the user should provide subtitles. Users could not have subtitles for a video; then, the system should inform other users, who participate in the conversation, about the possibility of an inaccessible file. Besides, the user should be able to decide when the file is downloaded and the system does not download the file automatically. (***Imp.:*** *Knowledge and learning*)
Based on:	WCAG_2.0_1.1.1, WCAG_2.0_1.2.1, WCAG_2.0_1.2.2, WCAG_2.0_1.2.3, MWBP_1.0_11, MWBP_1.0_36, UDL_2.0_1.1, UDL_2.0_1.2, UDL_2.0_1.3, UDL_2.0_2.5, UDL_2.0_5.1, UDL_2.0_7.1, US_508_1194_22a, US_508_1194_22b, CVAA_b1_ii, , CVAA_b1_v, CVAA_b2_i to CVAA_b2_ix

Table H.36: Learning (LE-3): Exchanging files between users.

Messages sent in learning conversations might not be useful for students. Teachers could control the messages sent by students before these messages are received by other students - see Table H.37.

Code:	LE-4
Requirement:	Provide mechanisms to control the message shown to the students.
Priority:	Medium
Classification:	Learning
Description:	Teachers could modify and delete the messages sent by students.
Recommendation:	Teachers should be allowed to delete or modify messages sent by students in order to provide more accurate feedback and avoid possible problems related to nasty words or useless information. (***Imp.:*** *Knowledge and learning*)
Based on:	UDL_2.0_2.2, UDL_2.0_7.3

Table H.37: Learning (LE-4): Provide mechanisms to control the messages sent by students.

Appendix I

Questionnaires for Requirements Validation

I.1. Requirements Validation

This study aims to validate the requirements defined in this research in order to confirm if they are understood by developers and designers to create accessible chat m-learning applications.

Aim of the Study

Dear evaluator,

This study is part of the Ph.D. "Accessible Chat Applications for Computer Supported Collaborative Learning Environment in Mobile Devices" which is being developed by Rocío Calvo in the LaBDA Group of the Carlos III University of Madrid. The main aim of this study is to validate the requirements defined to create accessible chat applications for m-learning environments. The obtained information will not be used to obtain any profit, the data will be used for the statistic study exclusively and to publish it as part of the Ph.D.

If you would like to have more information about the Ph.D. please contact with Rocío Calvo through the email: mrcalvo@inf.uc3m.es.

Thank you for your collaboration.

Demographic information:

1. Please select an age range that fits you. Age:

☐Under 18 ☐18-24 ☐25-34 ☐35-44 ☐45-55 ☐55-64 ☐65+

2. Please specify your gender. Gender:

☐Male ☐Female ☐Prefer not to say

3. What is your role title?

4. How many years of experience do you have?

☐0-1 years ☐1-2 years ☐3-4 years ☐4-5 years ☐> 5 years

5. How familiar are you with accessibility?

☐Not at all familiar ☐Slightly familiar ☐Somewhat familiar ☐Moderately familiar ☐Extremely familiar

I.2. Instructions

A list of requirements - Section 1.2 Requirements - needed to create an accessible chat for m-learning environments is specified. You will help to validate these requirements and confirm they are easy to read and understandable.

Please read each requirement carefully and design a Mockup prototype in a piece of paper to design this requirement. For each requirement you will need to do the following:

1. All requirements (Step 1 to 7).
    - Read requirement
    - Design a paper prototype which represents the requirement
    - Answer a list of questions related to the requirement
    - Take a photo of your design (and send it)
2. Answer questions related to all requirements.

Example

Imagine you have to design the Login page of a chat application. In order to make it accessible, this page needs to include some specifications in order to make it accessible for people with disabilities. These specifications or requirements have been already obtained and you do not have to worry about them. They are detailed in the requirement given in each table, you just need to read it.

For example, considering the requirement Login 1 (L-1) - see below Table I.1. This table includes information about the requirement:

- **Code:** ID of the requirement.
- **Requirement:** Title of the requirement.
- **Description:** Summary of the purpose of the requirement.
- **Recommendation:** This section describes the requirement in detail; to help you design the requirement.

Steps to do: After understanding the structure of the requirement, the following steps have been done:

- **Read requirement**: Requirement has been read carefully and has been understood.
- **Design a paper prototype**: Considering the Login requirement, a paper prototype has been created using a pencil and paper - Figure 1.1.
- **Answer a list of questions related to the requirement** After reading the requirement and designing the prototype, I can answer questions about this prototype.

- **Take a photo of your design (and send it)** The picture has been taken and sent it once you have completed the study.

Code:	L-1
Requirement:	Login
Description:	Protect the access to the system and help users to log into the system.
Recommendation:	1. **User information:** the user can sign into the system with a password and user name. 2. **User errors:** Control, avoid and guide users to solve input errors. For example: sending empty fields or wrong password 3. **User name:** Save at least the last user name accessed to the system. 4. **Forgot user name and password:** Allow users to recover their forgot passwords and user names. 5. **Automatic sign in:** Provide mechanism to sign in automatically. 6. **Hide or show passwords:** Allow hiding or showing passwords when the user does not remember it

Table I.1: Login (L-1): Send messages.

The following image - Figure I.1 - shows the paper prototype for this result is the Mockup has been created to represent how the interaction of this requirement should be.

Figure I.1: Login - Paper Prototype example

There are 7 steps that you will need to complete. Please follow the next steps to create the Mockup and validate the requirements.

Questions Related to the Requirements

- **Requirements complete:** Is there any information missing from individual requirement descriptions?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Requirements consistent:** Do the descriptions of the requirement include contradictions?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Requirements comprehensible:** Can you understand the requirement?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Requirements ambiguous:** Are there different possible interpretations of the requirement?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Requirements ambiguous:** Could readers from different backgrounds make different interpretations of the requirement?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Requirements unambiguously identified:** Is the requirement unambiguously identified?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Requirements conformance to standards:** Does the requirement conform to defined standards?
  ☐Strongly disagree ☐Disagree ☐Neutral ☐Agree ☐Strongly agree
- **Other comments:** What would you like the most or the least from this requirement? Please explain below:

Glossary

Accessibility Web accessibility means that people with disabilities can use the Web. 26

Chat Chat applications or Instant Text Messaging application allow sending text messages, share photos and videos. 16–20, 28

Chat4LL Chat developed which includes the Pause Autorefresh functionality to control the reception of messages. 168

Disability If you have a physical or mental impairment that has a substantial and long-term negative effect on your ability to do normal daily activities. 29

Elderly This was considered 65 years or older as a definition of 'elderly' or older person. 79

Flow and Rhythm Ability to reply messages and maintain a conversation with other people using a chat application and without loosing part of the conversation. 136

Mobile Device A small computing device, typically, small enough to hold and operate in the hand and having an operating system capable of running mobile apps. 30–33

one-to-many Chat conversations with more than two participants. All can send and receive messages. 165

one-to-one Chat conversations with two participants. Both can send and receive messages. 165

Pause Autorefresh New functionality which allows people pause the reception of messages when they cannot follow the Flow and Rhythm of the conversation. 136

Renew The sent messages can be received again in the application. 158, 159

Senders People who send a message using a chat application. 263, 264

Acronyms

AT Assistive Technology. 26

CSCL Computer Supported Collaborative Learning. 16, 17, 20, 22, 30

ETSI European Telecommunications Standards Institute. 30

HCI Human Computer Interaction. 45

ICT Information and Communications Technology. 21, 26–30, 34, 43, 215

IM Instant Messaging. 38

IMS Instructional Management System project. 29, 30

LCMS Learning Content Management Systems. 38

m-CSCL Mobile Computer Supported Collaborative Learning. 17, 38

MD Mobile Device. 16–21, 216, 236

MWABP Mobile Web Application Best Practices. 30

MWBP Mobile Web Best Practices. 30

OS Operating System. 30

RE Requirement Engineering. 98

SE Software Engineering. 45

STF Specialist Task Forces. 30

UCD User Centered Design. 136, 218

UDL Universal Design Learning. 30

UI User Interface. 29

UML Unified Modeling Language. 111, 135

W3C World Wide Web Consortium. 26, 28, 30

WCAG Web Content Accessibility Guidelines. 37

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