

# Mobile learning applications for the elderly: eliciting requirements based on pedagogical and accessibility guidelines

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**Abstract**—In this research full paper we present a set of requirements for an m-learning application for the elderly. Currently, the elderly population has been growing considerably. This fact leads to the country and society adapt and create new opportunities for this audience, since they can present changes and challenges of aging. One of this challenges involves the educational area. Education can take place formally or informally, with face-to-face or distance classes and, in this context, emerges the concept of mobile learning (or m-learning). This modality of learning has generated great expectations for educators and learners, since it has benefits related to the flexibility of learning, especially regarding the adaptation with respect to space and time of use. Based on this potential for flexibility and adaptation, one of the main goals of m-learning is to democratize access to education. Thus, m-learning applications must be adequate and structured to serve the general population, including the elderly. Considering this audience, it is necessary to develop accessible and pedagogically appropriate m-learning applications, since these users may have different skills in comparison with younger students. Elderly people may have their physical, sensory, perception and cognitive abilities compromised due to the aging process and, therefore, m-learning applications must be developed based on these needs. In this paper we present the requirements elicitation process for a m-learning app, focused on elderly users. The requirements were created based on works that involve eliciting requirements for m-learning in general, pedagogical pattern language for this type of domain and pedagogical and accessibility guidelines for m-learning app focused on the elderly. At the very end, such requirements will support the development of a crossword mobile application to the elderly, which should contribute to the learning process of such audience.

**Index Terms**—mobile learning applications, elderly, accessibility requirements, pedagogical requirements.

## I. INTRODUCTION

Currently, technologies are in a constant process of transformation, updating and innovation. For example, cell phones, have now new features and functionality, giving rise to smart-phones. In addition to cell phones, other mobile devices, such as tablets, have gained more evidence, bringing new possibilities for users. Information and Communication Technologies (ICT) can improve people's lives in different ways and contexts, being even more important in education area. In this scenario, mobile learning (m-learning) has been generating great expectations in this context.

In short, applications in this domain have the following characteristics: mobility, access, immediacy, situated cognition,

ubiquity, convenience, convenience and contextuality [1]–[3]. Besides, they allow learning anytime and anywhere. Mobile learning enables flexibility and adaptation to the user, as well as the democratization of access to education. In this perspective, it is essential m-learning apps can be used by different types of users, such as the elderly [4].

Aging is natural in human life and is not considered a state, but a process of progressive and distinct degradation [5]. Each person ages in a different way, which can vary according to the level at which he/she is (biological, psychological or sociological), speed and severity, making it impossible to date the beginning of this process [6].

According to Neri [7] there are three different patterns in the aging process that can rarely be seen in their pure state, they are:

- i. Normal aging: it concerns the occurrence of typical and inevitable changes in aging. This aging pattern is characterized by a gradual decline in cognitive functions, which can hinder the learning process and include forgetfulness. [8].
- ii. Pathological aging: it is marked by the presence of diseases, dysfunctionalities and discontinuity of development. All individuals have pathological potential that may or may not manifest, depending on their psychic conditions, risk factors and the influence of the environment. [9].
- iii. Great aging: it is referenced for the excellent quality of life, being a sociocultural ideal. It is manifested by a low risk of illness and disability, good physical and mental health and a high active engagement in life.

As presented in items (i) and (ii), some changes and challenges can occur in elderly people due to the aging process and are related to physical, sensory and cognitive aspects, as can be seen in Table I, adapted from Whitbourne [10] study. Aging process brings new social, educational and computational challenges [6].

M-learning apps must be developed based on specific requirements. Some studies propose a set of requirements for this type of application domain [11], [12]. However, to serve the elderly, it is necessary to include jointly accessibility and pedagogical requirements considering their characteristics and needs.

TABLE I  
CHALLENGES AND CHANGES OF AGING - (ADAPTED FROM WHITBOURNE [10])

Physical
- Appearance (Skin and Hair)
- Body building
- Mobility (muscles, bones, articulation)
- Body control system (endocrine system and immune system)
- Nervous system (central nervous system, sleep, nervous and temperature control)
Sensory and Perception
- Vision
- Hearing
- Balance
- Smell and taste
- Somatosensory system
Cognitive
- Information processing
- Memory
- Language and communication

This paper aims to present the requirements elicitation process for a m-learning application, focusing on elderly users. To achieve this goal, three studies were considered: (i) ReqML-Catalog– general requirements catalog for m-learning app [12]; (ii) MLearning-PL– pedagogical pattern language to assist in the definition of m-learning apps [13]; (iii) M-Learning Guidelines for the Elderly (MLGE) – set of pedagogical and accessibility guidelines focused on the elderly.

The remainder of this paper is organized as follows. Section II summarizes some research works that helped in the requirements elicitation process. In Section III, the organization and development of pedagogical and accessibility guidelines are presented. Section IV shows the requirements obtained based on the requirements catalog, pedagogical pattern language and MGLE. Finally, Section VI summarizes our conclusions and perspectives for future work.

## II. BACKGROUND

Sommerville [14] stated that the requirements for a system are the descriptions of what the system should do – the services that it provides and the constraints on its operation. These requirements reflect the needs of customers for a system that serves a certain purpose such as controlling a device, placing an order, or finding information.

Requirements engineering provides appropriate mechanisms for the understanding of customers’ demands, analyzing needs, assessing feasibility, negotiating a reasonable solution, specifying the solution unambiguously, validating the specification, and managing the requirements as they are transformed into an operational system [15].

An important and hard task in this process is requirements elicitation (also called requirements gathering), which combines elements of problem solving, elaboration, negotiation, and specification. At first, the gathering of information on the desired software from customers, user and stakeholders seems a simple task. However, several problems may arise during this process such as: problems of scope, problems of understanding; problems of volatility. As a solution to help

overcome these problems, we must approach requirements gathering in an organized manner [15].

Although the requirements elicitation is performed in an organized manner, analysts are susceptible to errors. When errors related to requirements document are found during the development process or after the system is up and running, there may be high rework costs involved. Repairing requirements issues can be much more costly than repairing design or coding errors, since changing requirements may involve changes in design or implementation.

In a related perspective, when dealing with domain-specific software, we must be concerned about domain requirements, that is, requirements that are related to the application domain of the system and not to specific users’ needs [14]. The problem with domain requirements is that software engineers may not understand the characteristics of the domain in which the system operates. They often cannot tell whether or not a domain requirement has been missed out or conflicts with other requirements.

Therefore, it is important that the specialist’s knowledge is considered in the requirements engineering team. Regarding m-learning applications, the team can encompass education professionals, teachers and tutors. However, tacit knowledge is not trivial to be captured and transferred; therefore, a support mechanism can be beneficial in this process.

### A. Requirements Catalog

Considering the aforementioned scenario, Soad et al. [12] proposed ReqML-Catalog, a requirements catalog focusing on mobile learning applications. The creation of ReqML-Catalog was motivated by a scenario in which the number of works related to the definition of requirements for m-learning applications was still incipient.

The catalog is divided into 12 requirements subcategories which were defined by means of a systematic literature review and knowledge of domain experts.

The *Pedagogical* category is divided in three subcategories: *Learning* (it concerns the resources provided by the app that contribute to student learning.), *Content* (is related to offering content quality and manageable) and *Interactivity* (it is related to the resources provided by the app, in a way that facilitates the interaction between user and application). This category is the most important for our research. The *Social* category is divided in *Socioeconomic* and *Sociocultural*. Lastly, the *Technical* category is subdivided into *Functional Suitability*, *Performance Efficiency*, *Compatibility*, *Usability*, *Reliability*, *Security* and *Portability*.

### B. Pedagogical Pattern Language

Although several initiatives have been developed for mobile learning, it still lacks standardization and supporting mechanisms that guide the requirements elicitation phase. Thus, pattern languages are significant methods aimed at describing recognized tacit knowledge, making them great candidate as a supporting mechanism [15]. Patterns provide the possibility

to capture domain knowledge and experience, allowing reapplication when there is a new problem [15]. In this sense, pedagogical patterns aim to capture specialized knowledge in teaching and learning practices [16].

Pedagogical patterns can be an important supporting mechanism to describe best practices, good designs, and capture of expert’s knowledge and experience so that other can reuse this experience regarding the practice of teaching and learning. In this sense, Fioravanti et al. [13] proposed MLearning-PL, a pedagogical pattern language for mobile learning applications, which aims to improve student motivation and commitment to the use of educational mobile applications, considering different learning styles and an effective knowledge acquisition.

Novice educators are the main audience of MLearning-PL, since such professionals play the role of requirements analyst in a project that involves m-learning app.

### III. MLGE: AN OVERVIEW

Although the aforementioned artifacts aim to bridge the gap in requirements elicitation of mobile learning applications, another important issue to be considered is the users and their experience with such applications.

To the best of our knowledge, no initiatives for the use of guidelines to address accessibility and pedagogical issues in the context of mobile learning applications for the elderly have been developed. Therefore, MLGE (Mobile Learning Guidelines for the Elderly) is a step forward towards bridging such a gap.

MLGE<sup>1</sup> is in the development phase and followed the method of elaborating guidelines presented by Rusu et al. [17]. This method consists of six phases: exploration, description, correlation, explanation, validation and refinement. The MLGE structure was developed based on Rocha and Baranauskas [18] and is organized as follows:

- **Guideline:** Guideline name.
- **Description:** Brief description of the guideline.
- **Example:** Practical example of using the guideline.
- **Support:** Possible user limitations that the guideline attend.
- **Category:** Category based on requirements catalog [12].
- **Source:** Source from which this guideline was based.

MLGE is a pedagogical and accessibility guideline for m-learning app. This guidelines are important because the aging process can bring limitations to people, such as: cognition, vision, hearing, memory, information processing, language and communication, mobility, among others. Currently, there are consolidated accessibility guidelines (WCAG 2.1., for example) for software development and improve access for people with some kind of limitation. However, these guidelines do not regard cognitive, language and learning disabilities [19]. These points are necessary for the process of developing m-Learning applications, especially those specific to the elderly user.

So, MLGE is divided in two main sets: pedagogical and accessibility. Pedagogical guidelines were organized according to the study of ReqML-Catalog (Principles: Learning, Content and Interactivity) and were developed based on some preliminary studies we have conducted:

1. Interview with experts: Pedagogues or teachers of the elderly (6 participants).
2. Questionnaire with experts: professionals with experience in the education of the elderly - teachers, pedagogues, gerontologists and others (33 participants).

Both studies aimed to verify pedagogical practices and educational methods used by professionals who work in the teaching of elderly people. The data from the interviews and surveys supported the construction of the pedagogical guidelines.

An example of a pedagogical guideline is the following:

- **Guideline:** User profile guides activities and content.
- **Description:** Based on the student’s profile and experiences, provide personalized content and activities that are consistent with their life context.
- **Example:** The application can ask personal and objective questions in order to know and personalize the classes based on the needs of the students.
- **Support:** Cognitive ability (Information processing and language, and communication).
- **Category:** Teaching and learning processes.
- **Source:** Interview and questionnaire with experts.

The accessibility guidelines were based on the Web Content Accessibility Guidelines (WCAG 2.1.). WCAG 2.1. is considered the international standard and being organized according to the following principles: perceptible, operable, understandable and robust [19].

The main differences between WCAG 2.1. and MLGE accessibility guidelines are: structure and organization, focus on the elderly and on native m-learning app. For this reason, not all WCAG guidelines can be found in the MLGE or vice versa.

TABLE II  
EXAMPLE WCAG 2.1. AND MLGE GUIDELINES.

WCAG 2.1.
<p><b>Guideline 1.1.</b> Text Alternatives Provide text alternatives for any non-text content so that can be changed into other forms people need, such as large print, braille, speech, symbols or simpler language.</p> <p><b>Success Criterion 1.1.1.</b> Non-text Content.</p>
MLGE
<p><b>Guideline:</b> Text Alternatives <b>Description:</b> Provide text alternatives for any non-text content so that can be changed into other forms people need, such as large print, braille, speech, symbols or simpler language. <b>Example:</b> Images or icons may have text alternatives. <b>Support:</b> Cognitive ability (Information processing), Vision (blindness or low vision) and Hearing (deafness or low hearing). <b>Source:</b> Adapted from WCAG 2.1.</p>

To the requirements elicitation phase of this work, a set with the main guidelines of the MLGE m-learning domain

<sup>1</sup>Access Link: <https://bit.ly/mlgeguideline>

was selected, as presented next.

#### IV. REQUIREMENTS ELICITATION AS USER STORIES

Traditional requirements describe how the software should act, being the intent of the system the main focus. Requirements documents go into great detail on how an area of software should work. They typically serve the purpose of guiding how the software team will build something.

However, we are also concerned with the user experience while using a mobile learning application. In this context, we can mention user stories, which are short descriptions of functionality told from the user's perspective. The focus is on *why* and *how* the user interacts with the software, being essentially a high-level definition of what the software should be capable of doing.

Therefore, while requirements documents go into a lot of detail and take a fair amount of time to write, user stories are plain and simple. In this sense, we chose the user stories format and used the three aforementioned artifacts as supporting mechanisms: ReqML-Catalog, MLearning-PL and MLGE.

In this perspective, we used one of the key Scrum [20] artifacts, the Product Backlog. Product Backlog is a prioritized list of everything needed to build or increment the product. Our Product Backlog was tailored to fit our needs and contains the following fields:

- **ID:** Identification number.
- **User story:** Short description of functionality told from the user's perspective.
- **Rationale:** Describes the origin of each feature: ReqML-Catalog, MLearning-PL or MLGE prototype.
- **Issues addressed:** Describes which possible user limitations the requirement can assist: vision, physical ability, hearing and/or cognitive ability.

Tables III and IV show excerpts of our Product Backlog.

#### V. CROSSWORD LEARNING: AN M-LEARNING APP FOR THE ELDERLY

The requirements previously obtained have been used as an input for the development of the m-learning app Crossword Learning. This is a crossword mobile learning application which focuses on elderly users. The application aims to present various concepts to the student that may involve content from History, Geography, Languages, Mathematics, Computer Science and others. The content can be inserted by a teacher or an administrator.

Crossword Learning has a reward system that assigns points to players / students, making them progress to more complex levels according to their performance. In addition, users have access to their scores and statistical data and can, through an internal social network of friends, share their results.

The following features and functionality can be highlighted:

- 1) content presented through video, text or audio;
- 2) possibility of creating an internal social network;
- 3) sharing of results and main activities;
- 4) monitoring the level of learning.

Despite working with gamification concepts, the main idea of the application is to assist in the learning process of the elderly user.

The Crossword Learning prototype has already been evaluated [21] and redesigned. Figure 1 shows some of Crossword Learning screens.

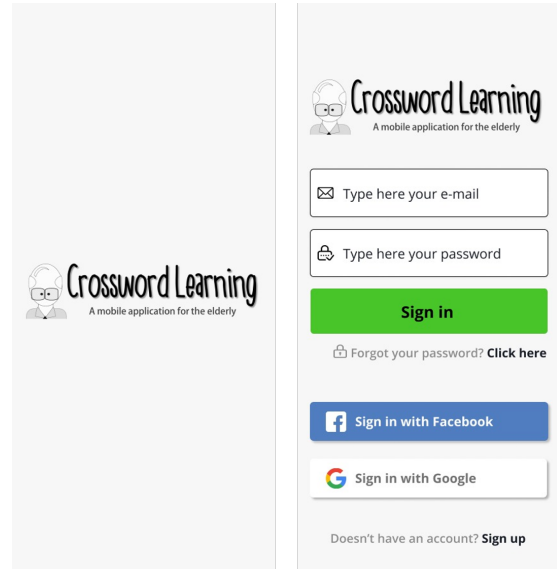


Fig. 1. Crossword Learning application screens

Currently, the application is under development, being implemented using the React Native framework. The Crossword Learning app will assist in the evaluation of the MLGE guidelines.

#### VI. CONCLUSIONS AND FUTURE WORK

In this paper we presented a set of requirements for an m-learning application for the elderly. To achieve this goal, the following artifacts were used: ReqML-Catalog, MLearning-PL and pedagogical and accessibility guidelines for m-learning app focused on the elderly (MLGE).

We aim to use such requirements as an input for the development of a crossword mobile learning application for the elderly, named Crossword Learning. Other applications in the same domain should also be developed based on the requirements established. The goal is to help the analysts in adopting pedagogical and accessibility guidelines in the process of developing m-learning applications, allowing elderly users (in this context) to use such applications without major difficulties.

As future work, we point out the need of conducting evaluations and experiments with MGLE guidelines and requirements. In addition, it is expected that the Crossword Learning application will assist in this evaluation process and allow other applications to be developed following its structure.

TABLE III  
PRODUCT BACKLOG - PART I.

ID	User Story	Rationale	Addressed Issues
1	As a User, I want interactive activities so that I remain active in the app.	MLearning-PL: Be Active; MLGE: Encourage Participation; ReqML-Catalog: Collaboration and Communication among users.	Cognitive ability (Information processing, difficulty concentrating and easily distracted).
2	As a User, I want to be rewarded for my accomplishments so that I feel excited and motivated.	MLearning-PL: Give Them a Treat; ReqML-Catalog: Motivation and Engagement.	Cognitive ability (Information processing, difficulty concentrating and easily distracted).
3	As a User, I want to see my evolution (percentage) so that I realize how my knowledge and skills have grown	MLearning-PL: Keep Them Posted; MLGE: Continuous Feedback and Evaluation; ReqML-Catalog: Feedback.	Cognitive ability (Information processing, difficulty concentrating and easily distracted).
4	As a User, I want to receive messages showing which stages I have completed so that I feel accomplished and motivated.	MLearning-PL: Keep Them Posted; MLGE - Continuous Feedback and Evaluation; ReqML-Catalog: Feedback.	Cognitive ability (Information processing, difficulty concentrating and easily distracted).
5	As a User, I want to be praised publicly for my accomplishments (ranking) so that I keep focused on maintaining or improving my position in the ranking.	MLearning-PL- Gold, Silver and Bronze Medal, Mobile Rivalry	Cognitive ability (Information processing, difficulty concentrating and easily distracted).
6	As a User, I want to have fun during the learning process (game elements) so that learning is not a duty.	MLearning-PL- Let's Play; MLGE: Encourage participation; ReqML-Catalog: Collaboration, Motivation and Engagement.	Cognitive ability (Information processing, difficulty concentrating, easily distracted and memory).
7	As a User, I want the topics to be as small as possible so that I can finish it more quickly, proceed to the next one and to help with my memory.	MLearning-PL: Little by Little; MLGE: Objective Content; ReqML-Catalog: Content complexity and Content Management.	Cognitive ability (Information processing, difficulty concentrating, easily distracted and memory).
8	As a User, I want to be notified when close to reaching the next goal so that I can accelerate toward it.	MLearning-PL: Sprint Booster; ReqML-Catalog: Engagement.	Cognitive ability (Information processing, difficulty concentrating, easily distracted and memory).
9	As a User, I want the app to firstly and repeatedly show me the most important ideas so that I can understand it more easily and to help with my memory and Information processing.	MLearning-PL: As Soon as Possible; MLGE: Repeat Content Presentation; ReqML-Catalog: Motivation and Knowledge effectiveness.	Cognitive ability (Information processing and memory).
10	As a User, I want the app to match my abilities and interests (different levels and subjects) so that I can keep motivated.	MLearning-PL: Respect the Differences; MLGE: User profile guides activities and content; ReqML-Catalog: Teaching and learning processes.	Cognitive ability (Information processing and language and communication).
11	As a User, I want the app to show the same content in different types of media so that I will not get bored and attend my specific characteristics and Information processing.	MLearning-PL: Suitable for You; MLGE: Content in different media; ReqML-Catalog: Content complexity.	Cognitive ability (Information processing; language and communication and memory).
12	As a user, I want to feel comfortable with the theme or subject addressed and then advance in my knowledge.	MLGE: User-friendly content; ReqML-Catalog: Knowledge effectiveness, Motivation and Learning style.	Cognitive ability (Information processing; language and communication and memory).
13	As a user, I want comprehension activities to be available to assist in my learning process, my memory and to learn in my time.	MLGE: Comprehension Activities; ReqML-Catalog: Motivation and Educational activities.	Cognitive ability (Information processing; language and communication and memory).
14	As a user, I want activities to be available at different levels of difficulty (Easy, Medium and Hard) so that I feel more motivated and prepared.	MLGE: Content and activities with different levels of difficulty; ReqML-Catalog: Content complexity.	Cognitive ability (Information processing and language and communication).
15	As a user, I want my progress to be assessed throughout my teaching and learning process.	MLGE: Diagnostic Evaluation; ReqML-Catalog: Progress monitoring.	Cognitive ability (Information processing; language and communication and memory).
16	As a user, I want to switch expository and hands-on activities so that the learner will not feel tired.	MLearning-PL: Switch Thinking; MLGE: Expository and Hands-on Activities; ReqML-Catalog: Content management.	Cognitive ability (Information processing; language and communication and memory).
17	As a user, I want the content and classes to be traditional, gradually involving challenging and differentiated activities or content to make me feel more comfortable.	MLGE: Traditionalism and Innovation; ReqML-Catalog: ReqML-Catalog: Content management and Complexity Content.	Cognitive ability (Information processing, difficulty concentrating, easily distracted; language and communication and memory).
18	As a user, I want to be able to communicate with other students forming a small social network for communication and sharing information to make me feel closer to others and welcomed.	MLGE: Interaction With Other Users; ReqML-Catalog: Communication among users and Collaboration.	Cognitive ability (Language and communication)

TABLE IV  
PRODUCT BACKLOG - PART II.

ID	User Story	Rationale	Addressed Issues
19	As a user, I would like to access all the content, without relying on the images to understand it.	MLGE: Text Alternatives and Images of Text (No Exception).	Cognitive ability (Information processing) and Vision.
20	As a user, I want the application have the option of contrast and text resizing to facilitate my viewing.	MLGE: Resize Text and Contrast.	Vision (reduced contrast sensitivity and low vision).
21	As a user, I want to have enough time to access the content and do my activities helping with my learning process and information processing.	MLGE: Enough Time.	Cognitive ability (Information processing).
22	As a user, I want to be able to stay focused and view all the items on the screen, without animations or flashes that could cause me disturbances.	MLGE: Seizures and Physical Reactions.	Vision (color perception and light sensitivity).
23	As a user, I want to navigate, find content and determine where they are easily and without external help.	MLGE: Navigable; ReqML-Catalog: Navigability.	Cognitive ability (Information processing) and physical abilities (fat finger and decreased movements).
24	As a user, I want to use text, speech and gestures to insert data into the application and facilitate my interaction.	MLGE: Input Modalities.	Cognitive ability (Information processing), physical abilities (fat finger and decreased movements), hearing (deafness or low hearing); vision (blindness or low vision).
25	As a user, I want the content to be readable, understandable and the application to work in a predictable way so that I feel more motivated and engaged.	MLGE: Readable and Predictable.	Cognitive ability (Information processing; language and communication).

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