ReqML-Catalog: The Road to a Requirements Catalog for Mobile Learning Applications

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***Abstract*—Mobile learning has emerged as a new and promising learning modality, providing more interactivity and flexibility to learners, tutors and teachers in carrying out educational activities and practices. However, in spite of the benefits, the existing applications still have several issues and challenges to be addressed, such as the quality evaluation of the resulting mobile learning applications. Aiming to bridge this gap, in our work we have defined a set of requirements for mobile learning applications, by means of a mobile learning catalog proposal, entitled ReqML-Catalog. The current catalog is an evolution of other previous versions with several improvements. It was firstly established from the results of systematic literature reviews previously conducted and also based on the knowledge of domain specialists. In order to improve and evolve the catalog, more domain specialists and already established models were considered aiming to standardize the terms used. In general, users were enthusiastic and positive about the ReqML-Catalog and its importance, indicating positive evidence on its use. The adoption of ReqML-Catalog can assist in the design and evaluation of mobile learning applications, definition of reliable software tests that show the applications' limitations and drawbacks and elaboration of requirements for the applications. Using ReqML-Catalog, it is also possible to compare different mobile learning applications, verifying which catalog items are included in each one.**

I. Introduction

Issues related to teaching and learning have been increasingly discussed and studied by the scientific community. Particularly, computational learning applications have shown increasing importance, playing a key role in educational activities, both in academia and in industry [1]–[3]. These applications provided, among several innovative educational practices, a new modality of teaching, known as mobile learning (m-learning) [4]–[6].

Mobile learning is characterized by the ability of providing strong interaction among learners and teachers, enabling them to contribute, participate and access the learning environment through mobile devices (mobile phones, tablets, laptops, among others).

In addition to the benefits mentioned, mobile devices have many technologies that can support m-learning. Among these, we can mention: (i) sensors; (ii) accelerometer; (iii) GPS (Global Positioning System); (iv) camera; and (v) touch screen [7]. These technologies enable mobile learning applications to exploit these resources, engaging learners and stimulating the interaction among teachers and learners [8], [9].

Despite the benefits provided in the context of teaching and learning, m-learning presents some problems and challenges (organizational, cultural and technological) in its use [10]–[12]. One of these problems is that the existing methods for evaluating software quality are still very generic and do not address specific aspects of mobile learning applications. Actually, there is no complete and well-defined set of requirements for mobile learning applications.

Motivated by this scenario, in this work we aim to define a set of requirements for mobile learning applications, called ReqML-Catalog. In order to discuss the contribution of ReqML-Catalog to the development of m-learning applications, we also present some research projects in which the catalog has been used as a supporting mechanism to assist in: (i) the design and evaluation of mobile learning applications; (ii) the definition of reliable software tests that reveals errors; and (iii) the elaboration of requirements for the applications. Besides that, a survey was carried out to complement the ReqML-Catalog evaluation.

The remainder of this paper is organized as follows. Section II presents related work. Section III describes ReqML-Catalog. Section IV discusses ReqML-Catalog application in several research projects. Section V discusses the survey conducted to evaluate ReqML-Catalog. Finally, our conclusions and perspectives for future work are presented in Section VI.

II. Related Work

The establishment of a well-defined set of criteria, characteristics and specific requirements for the development of mobile learning environments is a critical issue to be addressed to guarantee the effective adoption of such systems [13].

In this context, one of the research initiatives in terms of the development of m-learning applications can be found in Duarte Filho and Barbosa's work [14]. In short, the authors proposed a requirements catalog for m-learning environments. The catalog was established from the results of a systematic review conducted in this domain. In order to facilitate the understanding and the maintenance of the catalog, a three-level hierarchical structure (criteria, requirements and description) was adopted. Additionally, based on the knowledge of domain

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specialists, the requirements were prioritized in order to reflect the main experiences and needs in the m-learning setting.

It is important to point out that the requirements catalog is not only for developers of m-learning environments but also for those who evaluate and use such systems. Duarte Filho and Barbosa [14] also suggest that the requirements defined may serve as a basis for: (i) the specification of a quality model for m-learning environments; and (ii) the establishment of a reference architecture for m-learning environments.

Based on the catalog proposed by Duarte Filho and Barbosa [14], it was possible to identify the needs, expectations and constraints not only in the domain of mobile learning environments, but also in their subdomains. In this sense, the work of FalvoJr et al. [15], [16] has proposed some adaptations in Duarte Filho and Barbosa's catalog for the design of a Software Product Line (SPL) for m-learning applications under the Android platform.

In general, the catalog has shown good adaptability in different domains, both in the educational and mobility contexts. For this reason, its requirements were used as the basis for SPL domain engineering. Thus, the features model and the SPL adoption strategy [17] had a great influence on the catalog, which has shown to be promising in the field of mobile educational applications [15], [16].

Additionally, the catalog proposed by Duarte Filho and Barbosa [14] was also used in the work proposed by Soad et al. [18], which aimed to establish a set of quality characteristics related to m-learning applications. One of the results of this work was a catalog of quality characteristics for m-learning applications, containing the characteristics and requirements relevant to this context. This result was used as the basis for the development of ReqML-Catalog.

III. ReqML-Catalog: An overview

A large number of mobile devices has been used worldwide, rising the possibility of adoption for teaching and learning. As consequence, several requirements need to be met to allow this usage.

Accordingly, research is necessary for the systematic identification of the educational requirements, especially considering that the global adoption of ubiquitous devices motivates users to adopt mobile platforms to learn. However, some concerns arise, as the distractions related to other applications present on the users' device and the users' expectations to find the same features from other applications in learning apps.

To the best of our knowledge, there was no complete and well defined set of requirements for mobile learning applications so far. Aiming to bridge this gap, our work intend to be a step forward in this direction, by means of a mobile learning catalog proposal, entitled ReqML-Catalog.

In this perspective, the related works previously mentioned [14]–[16], [18] allowed the identification of functional and non-functional requirements for the development of m-learning applications, improving the initial requirement catalogs presented in this study. It was firstly established from the results of systematic literature reviews previously conducted and also based on the knowledge of domain specialists. In order to improve and evolve the catalog, more domain specialists and already established models were considered aiming to standardize the terms used.

As Figure 1 shows, ReqML-Catalog[1] adopts a three-level hierarchical structure, in which the main criteria, characteristics and requirements of m-learning applications are defined and detailed.

The characteristics related to the pedagogical category address the issues related to teaching and learning, being defined as follows:

- **Learning:** ability of the application to provide features that contribute to learning.
  - Learning limitations: ability to help the identification of knowledge gaps.
  - Learning style: identification of different learner's learning profiles (auditory, visual and kinesthetic).
  - Teaching and learning processes: well defined teaching and learning processes used.
  - Knowledge effectiveness: ability to evaluate the user's effective knowledge acquisition.
  - Knowledge at the right time: content offered at the correct stage of learning, for the avoidance of a very advanced content that depends on non-gained knowledge.
  - Educational activities: different types of activities related to education, that enable, for instance, knowledge acquisition, guidance from a tutor, instructions that guide the user during learning.
  - Adaptation to the context: ability to adapt to the user's context taking into account age, gender, education, physical conditions of the environment, among other context factors.
  - Motivation: stimuli through which the user acts in relation to knowledge acquisition.
  - Engagement: functional commitment to roles and responsibilities for the achievement of a goal associated with emotional involvement for the development of such activities.
  - Creativity: ability to solve tasks and develop ideas differently from the normal pattern for the establishment of a certain purpose.
  - Progress monitoring: use of a set of information on day-to-day teaching and learning and summative assessments for an overview of the learner's progress.
- **Content:** ability of the application to deliver manageable and quality content.
  - Quality of content: quality content related to situations and problems of learner's interest which is free of misspellings and contains no invasive, negative or discriminating messages.
  - Target audience: society sector with some common characteristics (age, gender, profession, interests, etc.) to which the application is devoted.

[1] reqml.labes.icmc.usp.br

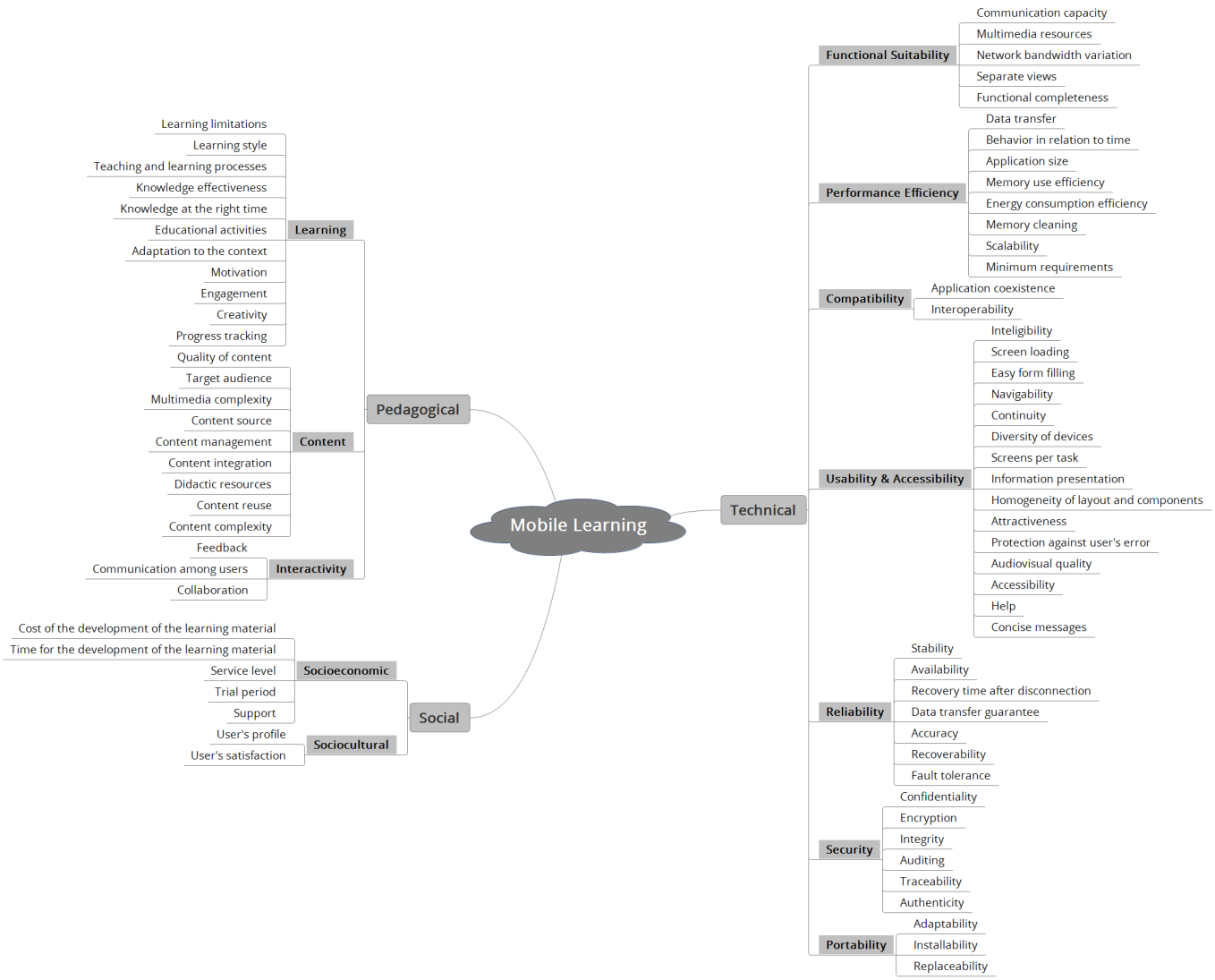

Fig. 1. ReqML-Catalog

- Multimedia complexity: definition of a limit of multimedia elements that do not distract the user.
- Content source: all available content must be provided by a reliable source.
- Content management: control, management and monitoring of the content offered.
- Content integration: integration of contents, for a defined flow among them.
- Didactic resources: didactic resources that assist the learning process.
- Content reuse: ability to reuse content.
- Content complexity: gradual adaptation of the content complexity according to the user's level, so that a complex content does not become an obstacle to users' understanding.

- **Interactivity:** ability of the application to provide features that help users interact with each other and with the application.
  - Feedback: ability to enable reciprocal feedback between students and teachers.
  - Communication among users: communication among users (learners, tutors and/or teachers) through blogs, forums, groups, and other media.
  - Collaboration: collaboration in activities for the interaction among learners, tutors and teachers through wiki, games, microblogs, forums and groups.

In the other hand, the characteristics related to the social category address economic and cultural issues of the application and are defined as follows:

- **Socioeconomic:** ability of the application to provide viability in the use of the application, making a relation of cost and benefit.
  - Cost of the development of the learning material: reduction in the learning material creation costs,

since they directly influence the application costs and user's investment.
  - Time for the development of the learning material: adoption of mechanisms that facilitate the creation of learning materials for reductions in the development time.
  - Service level: Establishment of service levels for a safer use of applications and their continuity: (i) continuity plan: recovery strategies and procedures of m-learning environments for the avoidance of interruption of learning practices; (ii) service-level agreement: agreement based on number of participants and materials and application functionalities; and (iii) cost-benefit: viability achieved by low development, acquisition and maintenance costs.
  - Trial period: availability of a trial period of the application or permission to access the basic functionality to allow the user to try the application before the acquisition.
  - Support: support to users regarding the services offered by the application.
- **Sociocultural:** ability of the application to adapt to the sociocultural context of the user, considering characteristics such as age, level of education, certain cultural group, among others.
  - User's profile: application configurability for treating different possible limitations according to age, gender, religion, race, and other user's characteristics.
  - User's satisfaction: satisfaction of user's expectations for the avoidance of abandonment and discomfort during the use of the application.

Finally, the characteristics related to the technical category address issues that contribute to the operation and use of the application. These characteristics are defined as follows:

- **Functional Suitability:** ability of the application to provide functions that address implicit and explicit needs regarding the application.
  - Communication capacity: ability of data transmission between devices.
  - Multimedia resources: ability to support different types of media, such as video, text, audio, among others.
  - Network bandwidth variation: ability to adapt to bandwidth variation of the network.
  - Separate views: supply of different views according to the user's profile (e.g.: teacher, student)
  - Functional completeness: ability to provide all features expected by users.
- **Performance Efficiency:** ability of the application to provide good performance in relation to the amount of resources used under established conditions, that is, refers to the optimization of the use of available resources.
  - Data transfer: ability of data minimization for improving transfer time of connections and number of data transfered.
  - Behavior in relation to time: user's waiting time for the full loading of the requested information.
  - Application size: amount of space required for the application to be used in the device.
  - Memory use efficiency: use of techniques that optimize the use of the device's memory.
  - Energy consumption efficiency: efficient use of energy, given the limitations of the devices' batteries.
  - Memory cleaning: non storage of unnecessary data in the device, e. g. files no longer used by the application.
  - Scalability: ability to handle a growing amount of work.
  - Minimum requirements: compliance with the minimum requirements, so that the application is used with no loss of performance.
- **Compatibility:** ability of the application to exchange information or perform operations with other applications, sharing the same hardware and software environment.
  - Application coexistence: ability to execute multiple instances simultaneously without affecting other applications.
  - Interoperability: ability of expansion of an application through communication with other applications.
- **Usability:** ability of the application to be used by specific users in a specific context, offering ways that the application can be understood, learned, used, and attractive to the user.
  - Inteligibility: easy understanding of the key concepts of the use software and its use influenced by time and user's cognitive efforts towards learning the application use.
  - Screen loading: amount of information and elements on a screen.
  - Easy form filling: ability to facilitate the filling of data by user. The number of fields for data entry in the application is taken into consideration. Screen and keyboard limitations hamper the entry of data.
  - Navigability: easy access to content and activities.
  - Continuity: application flow which avoids navigation constraints.
  - Diversity of devices: variety of devices, which improves exclusive usability according to the device used (example: Android x iOS back button).
  - Screens per task: number of screens used in a task.
  - Information presentation: limitation of information according to the screen display area.
  - Homogeneity of layout and components: standardization of the appearance of components through the keeping of their characteristics for all application screens and standardization of the components due to the several types of components that provide the same functionality.
  - Attractiveness: attractive and motivating application to the users.

  - Protection against user's error: user's protection against mistakes (example: inclusion of validations in open input fields).
  - Audiovisual quality: use of quality media for the promotion of learning.
  - Accessibility: accessibility mechanisms used by people with special needs.
  - Help: help to users regarding use of the application.
  - Concise messages: accurate and easy-to-understand application operational messages that speed up communication.
- **Reliability:** ability of the application to deliver consistently-expected behavior over a long period of time.
  - Stability: absence of defects in the application.
  - Availability: availability and accessibility anytime and anywhere.
  - Recovery time after disconnection: connection reestablishment after disconnection. The operation is maintained, despite unexpected interruptions.
  - Data transfer guarantee: data transfer, despite the occurrence of disconnections. The application must ensure data will not be lost, although the transfer is not possible.
  - Accuracy: supply of accurate and error-free results.
  - Recoverability: automatic or user-option saving of Backup points in case of low battery.
  - Fault tolerance: reaction to an anomalous situation, ie, the application continues to run despite possible failures.
- **Security:** ability of the application to protect information and data, protecting unauthorized access and ensuring their access according to the different levels of authorization.
  - Confidentiality: secure and private access for authorized users and applications.
  - Encryption: use of encryption in sensitive data transferred and stored by the application (e.g. passwords or user documents).
  - Integrity: use of different user's profiles, which restricts the access to certain features of the application.
  - Auditing: record of each action in the application, which assists in the non-denial of action if the user denies it.
  - Traceability: storage of records of events occurred in the application for the tracking of the user-made paths.
  - Authenticity: guarantee of user's actions authenticity.
- **Portability:** ability of the application to be transferred from one hardware or software to another.
  - Adaptability: ability of application to adapt to different types of mobile devices.
  - Installability: ability of application to be installed and uninstalled in different mobile devices with no errors.
  - Replaceability: quick and automatic update and configuration.

The definition of ReqML-Catalog was an important step, as this set of characteristics can help several m-learning related researches. In order to demonstrate the various possibilities of using the catalog, the next section presents three researches that use ReqML-Catalog as a reference.

IV. ReqML-Catalog in practice

In order to discuss the contribution of ReqML-Catalog to the development of m-learning applications, in this section we summarize some research projects in which ReqML-Catalog has been used.

A. Quality Evaluation Method for Mobile Learning Applications

One of the challenges of m-learning is the quality evaluation of applications. Currently, software quality evaluation methods are generic and do not consider specifications of mobile learning applications.

Quality aspects, particularly, represent an important aspect to be addressed, mainly due to the growing popularity of m-learning applications in different sectors of society. In this emerging scenario, quality is not only related to technical aspects. There is also a need to address educational, sociocultural, and socioeconomic issues related to the daily activities of learners and teachers [10].

Based on this need a quality evaluation method for m-learning applications was proposed in Soad et al. work [19]. Although the results of the preliminary validation of the method were positive, the quality model used had to be updated, to make the method more comprehensive. In this way, it would be possible to gather more information about the quality of the applications, besides allowing a better organization of the characteristics. For this reason, a new quality model was created for the method using ReqML-Catalog as a reference.

The quality evaluation method is composed of three main components:

- Quality model: defines a set of quality characteristics that are related to each other, providing the basis for the quality evaluation;
- Metrics: defines the means of data collection for the evaluation;
- Judgment criteria: defines how the application will be judged based on the metrics collected.

In this case, ReqML-Catalog was used to updated the quality model of the method. ReqML-Catalog provided the guidelines that allowed the method to evaluate new characteristics related to m-learning applications. In this way, the ReqML-Catalog allowed the creation of a more comprehensive quality evaluation method than the previous.

B. Pedagogical Pattern Language for Mobile Learning Applications

As previously mentioned, despite the benefits and facilities that m-learning applications provide, there are problems and

challenges to be addressed. These problems and challenges are not limited to technical aspects, also including pedagogical aspects, such as keeping the learner motivated to avoid dropouts, treating different learning styles (visual, logical, social, etc.), guiding the learner in self-learning, among others.

In this scenario, patterns and pattern languages are important mechanisms to support the whole process of software development. A pattern is an abstract solution to a recurring problem in a given context [20]; a pattern language is a structured collection of patterns that rely on each other to transform requirements and constraints on an architecture [21]. Similarly, pedagogical patterns and pattern languages try to capture expert knowledge regarding the practice of teaching and learning [22].

Aiming to support the requirements elicitation and analysis phases of mobile learning applications projects, a pedagogical pattern language was proposed. In this context, the pedagogical subset of ReqML-Catalog characteristics was used to categorize the pedagogical patterns within the pattern language.

C. Development of Mobile Learning Applications for the Teaching of Programming

Regarding the development of educational software, the inclusion of pedagogical and didactic issues for attending specific courses, as the teaching of programming, has required the adoption of different methods and approaches. Learning how to program is not a trivial task and many problems can emerge in this domain.

Different reuse-based approaches have been adopted to improve and mitigate problems in the development of educational solutions, e.g., Software Product Line (SPL). SPL concerns the sharing features within a family of products, addressing business, architecture, processes and organizational aspects and also provides mechanisms for the evolution of products, since new features may arise from stakeholders' needs [23].

In this context, the creation of new products requires technical support, which hinders and constrains the SPL adoption for development of m-learning applications. Aiming to support the SPL establishment, Marcolino and Barbosa [24] defined an m-learning requirements catalog for the development of m-learning applications for the teaching of programming. This catalog is a specialization of ReqML-Catalog and comprises all its characteristics, besides the specific characteristics related to the teaching of programming.

V. Evaluation

Even though the application of ReqML-Catalog in several research projects can already be considered an evaluation and indicates its value to the community, a survey was also carried out to complement the catalog evaluation.

The questionnaire consisted of 17 questions, shown in Table I. It was sent via email to the evaluators.

From the total of 18 evaluators, all of them are graduated. Some are master and PhD students and others are already academic professors, but all of them research Computer Science Education. According to Figure 2, 61.1% of the evaluators has at least 4 years of experience with educational activities and 77.8% has already participated in the development of educational software, as Figure 3 shows.

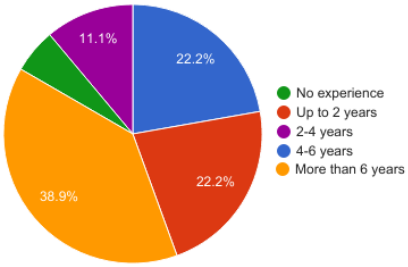

Fig. 2. Experience with educational activities

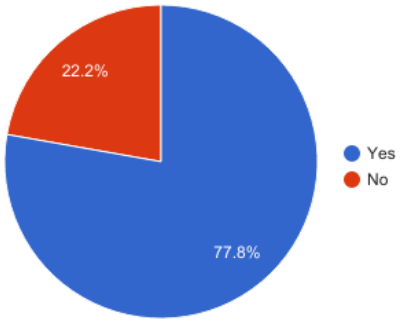

Fig. 3. Participation in the development of Educational Software

When asked if ReqML-Catalog is well structured, Figure 4 shows that 88,8% agree or strongly agree that it is. As we later asked the reasons why the evaluator didn't think the catalog was well structured, we had 2 comments pointing out some minor problems of typos, but it is worth mentioning those were already solved. In addition, users mentioned that the last level of the hierarchy has many characteristics. Although the participant indicates this as a problem, the idea of the catalog is to cover all the characteristics related to m-learning, for this reason, the number of characteristics represents what was identified during the research.

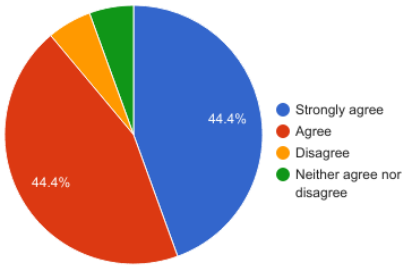

Fig. 4. Is ReqML-Catalog well structured?

Concerning the definition of the requirements, 88.9% agrees or strongly agrees that the technical requirements are clear and well defined, as shown in Figure 5.

TABLE I
SURVEY QUESTIONS

Question	Type
Name	-
Evaluator degree	Multiple choice
Experience with educational activities	Multiple choice
Profession	Open
Research area	Open
Have you participated directly or indirectly in the development of educational software? Explain the activities performed.	Open
Is ReqML-Catalog well structured?	Likert scale
If the answer to the previous question indicates disagreement, point out which improvements can be made to the catalog.	Open
Are the technical requirements clear and well defined?	Likert scale
Are the pedagogical requirements clear and well defined?	Likert scale
Are the social requirements clear and well defined?	Likert scale
For the 3 previous questions: If there are any requirements that are clear and well defined, point out which ones and what needs to be improved.	Open
Are there any requirements that are inappropriately classified? If yes, please indicate the inappropriate requirement(s), the reason for the inadequacy and which classification you consider correct.	Open
Do you know technical, pedagogical or social requirements that are not included in the catalog and are relevant in the context of mobile learning applications? If you do, list these requirements and/or indicate the reference of the material to which you refer.	Open
Do you believe that ReqML-Catalog can be used to assist in the design and evaluation of mobile learning applications?	Likert scale
If the answer to the previous question indicates disagreement, justify the reason.	Open
Suggestions, strengths and weaknesses	Open

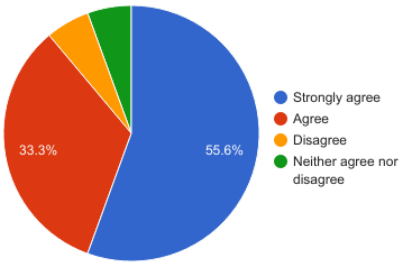

Fig. 5. Clear and well defined technical requirements

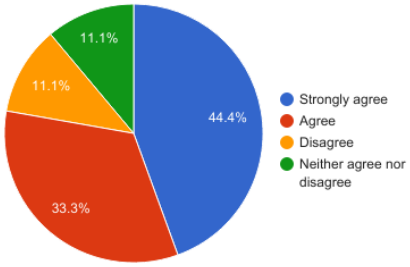

Fig. 7. Clear and well defined social requirements

When asked about the pedagogical requirements, 83.3% of the evaluators agrees or strongly agrees they are clear and defined (Figure 6). Finally, 77.7% thinks the social requirements are clear well defined (Figure 7). Regarding social requirements, although the result is still good, it shows a decrease compared to the other types of requirements, which may indicate the need to improve the descriptions of social requirements, thereby increasing their understanding.

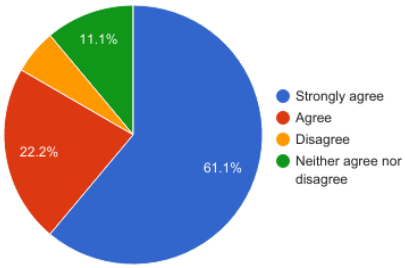

Fig. 6. Clear and well defined pedagogical requirements

Finally, Figure 8 shows that when we asked if they believe that ReqML-Catalog can be used to assist in the design and evaluation of mobile learning applications, 88.9% agrees or strongly agrees with it. It is important to note that the remaining 11.1% (value of two participants) answered 3, that is, none of the participants considered the catalog as something that can not aid in the design and evaluation of m-learning applications.

The problems indicated by these participants refer to the need of more detailed information about the catalog, that is, there was a lack of a more in-depth understanding of the catalog. Another problem mentioned was the size of the catalog, due its size it can hinder the requirements validation during the application development, for instance. A problem pointed out by one participant was the scope of the catalog, but even though it was considered a problem, we understand it as an advantage, since ReqML-Catalog's goal is to comprise all requirements related to m-learning applications.

Based on evaluators' experience with educational activities and their background in educational software development, we took these two factors into account to further analyze the answers. Table II summarizes the results in three different perspectives.

Most of the answers "Strongly agree" were given by evaluators with more than 6 years of expertise, followed by evaluators with 2-4 years of experience. These answers bring

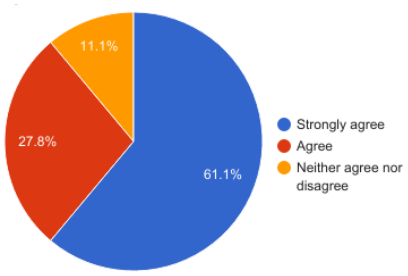

Fig. 8. Acceptance of ReqML-Catalog to assist in the design and evaluation of mobile learning applications

TABLE II
RELATION OF EVALUATORS' EXPERIENCE WITH THE SURVEY'S ANSWERS.

Categories		Total of Evaluators	Well Structured	Technical Requirements	Pedagogical Requirements	Social Requirements	Acceptance of Catalog
# of "Strongly Agree" Answers by Experience with Educational Activities							
> 6 years		7	3	4	5	4	6
4-6 years		4	3	3	2	2	2
2-4 years		2	1	2	1	1	0
Up to 2 years		4	1	1	3	1	2
No experience		1	0	0	0	0	1
Total		**18**	**8**	**10**	**11**	**8**	**11**
# of "Strongly Agree" Answers by Participation in Educational Software Development							
Yes		13	5	7	8	5	7
No		5	3	3	3	3	4
Total		**18**	**8**	**10**	**11**	**8**	**11**
# of "Strongly Agree" Answers by Experience and Participation in Educational Software Development							
> 6 years	**Yes**	5	2	2	3	2	4
	No	2	1	2	2	2	2
4-6 years	**Yes**	3	3	2	1	2	1
	No	1	0	1	1	0	1
2-4 years	**Yes**	2	1	2	1	1	0
	No	0	0	0	0	0	0
Up to 2 years	**Yes**	3	0	0	0	0	1
	No	1	1	1	3	1	1
No experience	**Yes**	0	0	0	0	0	0
	No	1	0	0	0	0	1
Total		**18**	**8**	**10**	**11**	**8**	**11**

more reliability to the results, since they reflect the evaluators' expertise in educational activities and their knowledge in the area. We can also see that only "Well structured" and "Social requirements" categories were not considered eligible for "Strongly agree" answer by more than half of the evaluators.

Analyzing the "Strongly agree" answers by the evaluators' experience in educational software development, we can notice that out of 18 evaluators, 13 have experience in development and most of them strongly agreed with the evaluated categories, providing reliability to the achieved results. We can also see that most of the evaluators with no experience in development had a similar opinion, strongly agreeing with the evaluated categories.

Concerning "Strongly agree" answers based on the experience and work in development, we can highlight that most of the answers "Strongly agree" were provided by more experienced evaluators, which is, those with more than 6 years of expertise and with some background in educational software development, followed by the evaluators with 4-6 years of experience and that had also been involved somehow in development activities.

In general, the participants highlighted positive aspects: (i) the requirements (technical, pedagogical and social) are well structured; (ii) the context presented in the set of requirements is focused on mobile learning applications, acting as a guide and good practices for its development or evaluation; and (iii) ReqML-Catalog can be used in different contexts of mobile learning applications: evaluation, development, modeling, among others.

As negative aspects, the participants pointed out there is a large amount of sub-items in the last level of the hierarchy, hindering it comprehension. Thus, they suggested to: (i) insert more descriptions into the elements (third level of the hierarchy) to help in understanding; (ii) provide practical examples of the requirements; and (iii) provide further information about the catalog in order to ease its understanding and use.

Regarding the threats to validity of the survey, we highlight: (i) the reduced number of participants; and (ii) the amount of available information in the catalog, since the survey was estimated to be answered in about 15 minutes. In this context, in order to ensure greater validation to ReqML-Catalog, other experiments have been planned and will be conducted shortly.

VI. CONCLUSIONS AND FUTURE WORK

This paper presented a mobile learning requirements catalog, called ReqML-Catalog. We discussed its use as a supporting mechanism to assist in: (i) the design and evaluation of mobile learning applications; (ii) the definition of reliable software tests that reveals errors; and (iii) the elaboration of requirements for the applications. Using ReqML-Catalog, it is also possible to compare different mobile learning applications, verifying which catalog items are included in each one.

In general, users were enthusiastic and positive about the ReqML-Catalog and its importance, indicating positive evidences on its adoption.

As future work, we intend to identify characteristics that can be unified, in this way we will achieve a reduced version of the catalog. We also point out the need of conducting other experiments. This validation has already been planned and will involve the use of the catalog in the evaluation and comparison of different m-learning applications in different knowledge domains.

As a final remark, we highlight that knowledge about any domain emerges, evolves and consolidates over time. So, ReqML-Catalog must also be continually evolved, inserting these new types of knowledge in order to not deteriorate.

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