Towards an M-learning Requirements Catalog for the Development of Educational Applications for the Teaching of Programming

Anderson S. Marcolino, Ellen Barbosa
Institute of Science and Computational Mathematics (ICMC-USP)
Avenida Trabalhador São–Carlense, 400, São Paulo, Brazil.
Email: andersonmarcolino@gmail.com, francine@icmc.usp.br

***Abstract*—The increasing adoption of ICT-based modalities to learn is a reality in several domains. However, the adoption of these modalities and their consequent benefits have not been properly exploited in domains such as the teaching of programming. This research aims at proposing a mobile learning requirements catalog capable of: (i) identify requirements to allow the development of mobile applications for teaching of programming with reuse-based Software Engineering approaches; and (ii) connect such requirements with educational theories and programming problems. The main goal is to create the necessary knowledge base to understand the domain engineering of this area. In order to initially evaluate our requirement catalog, a case study is briefly discussed. Positive evidences on the usefulness of the catalog have been achieved. In future work, the catalog will be included as part of the domain analysis phase in a reuse-based software engineering technique for the creation of m-learning applications for the teaching of programming.**

I. Introduction

The reduction in costs of information and communication technologies (ICT) and their widespread in social, economic and educational sectors have contributed to the appearance of new learning modalities, as electronic learning (e-learning), digital television based learning (t-learning) and mobile learning (m-learning) [1], [2], [3].

Although such modalities have provided benefits some domains, as teaching of programming, have not explore them [4]. Most of educational software in this domain addresses specific problems and do not present a good level of adaptation to the learners' needs. Also, there is little research on the adoption of mobile resources to better consider the learners' abilities in programming [5], and on the development of solutions considering reuse-based Software Engineering approaches [6].

This research aims at establishing an m-learning requirements catalog capable of: (i) addressing functional and nonfunctional requirements to the development of mobile applications for teaching of programming with reused-based Software Engineering approaches; and (ii) connect such requirements with educational theories in order to mitigate communication problems through the design and development process of educational applications, and with programming problems. In order to preliminary evaluate our catalog, a case study was conducted. The study allowed to identify positive initial results on the usefulness and adoption of the set of requirements.

This paper is organized as follows. Section II summarizes the related work. Section III presents the background. Section IV discusses the process of creation of the catalog, its characteristics, contributions and the preliminary case study results. Section V concludes with a summary and a discussion of future works.

II. Related Work

Georgieva et al [7] proposed a general classification of m-learning systems. Parsons and Cranshaw [8] specified a framework composed of a set of requirements for m-learning environments for general domains. Kearney et al [9] presented a pedagogical perspective of m-learning, highlighting features in a socio-cultural perspective. Duarte Filho and Barbosa [10] described a generic requirements catalog for m-learning environments. Jalil et al [11] identified pedagogical requirements for m-learning.

In general, those studies discuss specific classifications and sets of requirements based on the analyses of their purposes and features. However, none of them deals with m-learning requirements in the programming domain and most of them specified the requirements in a coarse-grained way. Finally, few present educational theories together with their requirements for extra explanations about the educational process covered on each desired feature.

In our study, we have investigated and identified requirements for the teaching of programming domain. Each requirement was analyzed and related with the programming problem that it handles before being included in our catalog. Educational theories were also included for each requirement, since they may shed some light on the development process of educational software, easing the communication process among developers and stakeholders.

III. Background

The adoption of ICT has provided the arising of different learning modalities, specially, e-learning, m-learning and

t-learning, each one with specificities and limitations. E-learning and t-learning generally use fixed technologies, such as desktops and televisions respectively, together with local network infrastructures to support online teaching and learning activities [2], [3]. M-leaning, on the other hand, changes the need of staying fixed in places to learn, being possible to learn anytime and anywhere through the mobility of devices and wireless network [12].

Regardless of the adopted modality of learning, even with the several benefits in their adoption, there still are some domains that do not have adequately exploited these benefits, such as the teaching of programming [5].

The teaching of programming has been adopted not only in undergraduate education. Many initiatives have been proposed to increase the adoption of this discipline in primary and secondary education [4]. However, teaching of programming presents many limitations that must be dealt to allow a more effective learning process. Thus, Souza et al [13] established six categories of programming problems: (P1) problems in learning of programming, (P2) application of programming concepts, (P3) understanding of programs, (P4) refactoring and factoring programs, (P5) motivation, and (P6) teachers' difficulties.

Considering the software solutions and applications to mitigate problems in teaching of programming domain [5], we can notice some nuances: (i) there are many features in common, mainly those used for online interactions and activities; and (ii) there are also variabilities among the observed features, especially those related to the use of specific hardware in the modalities. These set of variabilities and commonalities, together with the needs to develop m-learning applications for teaching of programming, increases the needs to investigate the adoption of different features from m-learning modality to build new applications with a reuse-based Software Engineering approach, increasing production of educational software and applications. Moreover, each specific feature can be analyzed and adapted for its use in other modalities transversely, being explored to attenuate problems in teaching of programming. Taking this opportunity, our catalog comes to bring a deeper understanding of the Domain Engineering for the teaching of programming, creating a referential baseline to allow the investigation of the reuse process in this domain.

IV. M-learning Requirements Catalog

A. Methodology and Conception

The catalog was based on four steps, namely:

1) Identification of studies that describe functionalities and features from educational software and applications of different modalities for the teaching of programming, identified in a SM [5];
2) Extraction and grouping of all possible requirements (functional or nonfunctional).
3) Categorization of the requirements into sets in order to expressing common features among them; and
4) Assessments:
   - 4.1 Assessment of requirements based on pre-existing m-learning general–purpose catalogs (Section II), ISO/IEC 25010 – International Standard for Software Product Quality [14] and ISO/IEC 15288 – System Life Cycle Processes [15];
   - 4.2 Assessment of requirements comparing them with existing m-learning applications;
   - 4.3 Assessment of common requirements in the design of an m-learning general–purpose application (case study) and;
   - 4.4 Qualitative assessment of the whole catalog by experts (Future works - Section V).

The 81 software and applications identified in the SM [5] were used in the extraction of the initial m-learning requirements (Step 1). Only those dated from 2011 until 2015 were considered, which resulted in 33 studies.

With the 33 final studies, 498 requirements were extracted and grouped in a smaller number, resulting in 225 requirements (Step 2). This step also includes the process of analysis of the requirements from other modalities, identifying if they can be adapted for m-learning. The analysis in other m-learning catalogs and current industry technologies was also considered.

Similarly, the 225 requirements were analyzed and compared in a new interaction, which resulted in 83 requirements (Step 3) classified into nine categories. Each requirement received a set of keywords, related programming problems and educational theories.

The set of requirements was then subjected to assessments. Firstly, they were compared with other catalogs [7], [8], [9], [10], [16], [11] and ISO/IEC 25010 [14] for software product quality. The activity ended with the inclusion of 14 other requirements which were mainly nonfunctional (Step 4.1). Secondly, m-learning solutions were selected from main mobile application stores for the identification of the presence of our requirements (Step 4.2). Thirdly, a case study was conducted to apply our catalog to design an m-learning general-purpose application (Step 4.3), assessed from a preliminary practice perspective.

The case study was conducted similarly to Jalil et al work [11] and the adopted method consists of a brainstorm with one professor from Software Engineering area and three programmers, collecting their needs for proposing a design of a mobile application using our catalog. Based on the collected features we identified that our m-learning catalog covered all the identified functionalities in the brainstorming in a satisfactory level. Furthermore, we collected contributions from the developers team that allowed us to improve the requirements descriptions.

Finally, the last assessment with experts has been conducted to improve and finalize the catalog (Step 4.4), available in: http://caed.icmc.usp.br/mlearning/.

The catalog comprises nine categories of requirements, of which each includes: (1) an identification code of the

category, (2) category keywords, (3) subcategories, (4) description of the requirement, (5) an explanation on the requirement and all requirements, (6) the educational modality of origin, (7) m-learning adaption considerations (when necessary), (8) relationship among the requirements, (9) the code of one of the six programming problem categories including a general category, (10) educational theories ids (when possible), and (11) bibliography reference ids.

B. The Catalog

Our catalog is composed of nine categories with a total of 97 requirements. Most requirements were extracted from e-learning solutions and other software that supports teaching of programming. Table I shows a summary of each category and examples of their requirements.

Column "Category" (Table I) provides the name of the category, column "#Req." indicates the number of requirements included in that category and column "#Prog. Req." specifies the number of requirements included in the category that deals specifically with the programming domain. Columns "Summary" and "Example(s) of Requirements" provide a succinct description of the category and some examples of requirements, respectively. All requirements can be consulted online fro the identification of the items previously mentioned.

The domain of the requirements is the teaching of programming and one of the aims of the catalog is research on improvements in the domain with the development of m-learning applications. Each requirement was provided with a set of programming problems that can be mitigated when the related requirement is selected and used to develop an application taking into account the description of the primary study where each one was extracted[1].

Among the 97 requirements, 34 deal with the learning of programming problem (Category P1). For a better explanation of complexes programming structures and concepts. The main category of requirements that focuses on this problem is the **Contents** since it encompasses the features which define mechanisms that allows to teach the main concepts in this domain.

35 requirements deal with problems related to the application of programming concepts (Category P2), with an emphasis on the category of **Programming Mechanisms**, which is focuses on the application of different resources, features and tools for a more complete experience in programming through mobile devices, allowing to learners to apply the acquired knowledge though the content.

35 requirements focus on the category that specifies problems related to the understanding of programming concepts (Category P3). They provide ways for the fixing of the programming content. One of the main categories that deals with such issues is the **Learning activities** category, since they are related to the application of programming concepts, and require the understanding of excerpts of source codes in the proposed activities. The use of additional concepts, such as software testing are highlighted, as it can facilitate the learners' understanding of the behavior of the program.

28 requirements address the problems in the factoring and refactoring of programs (Category P4). Originated in other programming problems, mainly in the learning of programming concepts. The main sets of requirements that deal with such problems are **Contents** and **Programming Mechanisms**. They address with features that include specificities for the programming environments that, if were not adapted for m-learning (due the screen size, battery use, interaction ways, etc.), may demotivated learners to learning with mobile applications.

32 requirements deal with problems related to the learners' motivation (Category P5). They encompass strategies that explore different multimedia resources and their combinations with mobile devices hardware resources for creating unique experiences that motivate learners. The highlighted category of requirements that cares about this problem is the **Learning activities** category. It emphasizes how mechanisms that include different features can motivate the learning process, mainly when learners are solving the proposed learning activities, engaging them to finish their activities, with minimal distraction.

39 requirements (the major part) deal with professors' difficulties (Category P6). The problem encompasses limitations for professors of high workload, assisting and correcting the activities, besides to giving feedback for learners' interactions, answering doubts and exercises, etc. The main category that addresses these problems is **Support to Teaching and Learning**. It includes features that provide facilities to achieve the educational goal, reducing the workload of the professors and giving to them more time and ways to analyse the performance of learners, to support them in the decision making and to allow the adoption of new strategies to improve the learning, and consequently, changing the application accordingly with their (or learners') need.

Additionally with the programming problems and educational theories, which support pedagogical and didactic issues, our catalog includes extra explanations and comments about the need in the adaptation of features that comes from other modalities, such as e-learning solutions. Among the main concerns about the necessity of the adaptation of the requirements for our m-learning catalog, we can mention: (i) reduction the graphical elements in the screens for mobile devices; (ii) implementations of mechanisms for interaction with the content and activities even with no Internet connection; (iii) implementations and support for different input devices; (iv) implementation of more personal and configurable content and activities; and (v) concerns on the limitation of hardware resources,

[1]The complete list of of the 37 primary studies references from the requirements were extracted is available at http://caed.icmc.usp.br/mlearning/?page=refer_requer

TABLE I
SUMMARY OF THE M-LEARNING REQUIREMENT CATALOG.

Category	#Req.	#Prog. Req.	Summary	Example(s) of Requirements
Feedback and Results	7	2	Feedback and results requirements are used to give returns in different learning interactions, including the results of the activities, the performance of learners, and returns of their interactions with the application. In the context of programming, the feedback is essential, since based on the returns the learners can correct their errors and learn with them.	RFFR006 - The application shall provide feedback for the different programming mechanisms. RFFR007 - The application shall provide feedback through test cases.
Monitoring and Learning Performance	4	-	Monitoring and learning performance requirements are related to the monitoring of all learners' interactions in the application, including their learning activities for the identification of their performance. In the programming context, time and number of errors during compilation, are examples of registers monitored.	RFPM3 - The application shall stop recording the learners' time in educational interactions when they interrupt the activities or the interaction not occured after a configurable period.
Learning Activities	10	7	Learning activities requirements provide ways and strategies which encompassing since the creation to delivery of the activities. In the context of programming, activities with different types of interactions, mainly the ones that use the resources from the mobile devices are encouraged.	RFAC007 - The application shall provide mechanisms to monitor and block possible cheats in source code activities.
Contents	6	1	Contents requirments, such as learning activities, provide ways for the adoption of content adaptation for the mobile platform. Specifically for programming content, content that enables interactions is more engaged and indicated, since it can use mobile devices sensors and resources for motivating learners.	RFCRT005 - The application shall present the programming content with software testing.
Assessments	4	3	Assessment requirements are related to the assessment of the learning activities and the learners' performance. They encompass the assessment and correction of exercises, describing mechanisms for the automatic correction and analysis of what learners learned in the educational process. In programming, they provide ways for analyses and identification of limitations in the source code and giving autonomy to learners to identify their errors and correct them.	RFAT002 - The application shall provide the automatic assessment/correction of the programming activities. RFAT004 - The application shall allows the process of correction and assessment of the learners' activities manually by the instructors.
Support to Teaching and Learning	14	2	Support to teaching and learning requirements deals specifically with issues from educational context, administration and formation of class, teams, interactions among learners and professors, as well as educational roles that enabçe better conduction of learning and teaching process. In the context of programming, the encouragement of the sharing of projects and source codes, development of learners' programming skills by the adoption of different strategies (content and activities), etc, are discussed.	RFTL009 - The application shall support an agenda/schedule of the activities and progress of users. RFTL012 - The application shall allow to sharing projects and source codes from the learners.
Programming Mechanisms	11	11	Programming mechanisms requirements directly related to the programming learning process and encompass learning activities, content, presentation of material, tools that support the source code development and execution, errors and feedback process and formats that improve programming learning through mobile devices. In most of cases such requirements depend on other requirements however, this category concentrates the requirements that deal specifically with programming issues.	RFPG003 - The application shall provide a source code debugger. RFPG004 - The application shall enable the use of visual graphic elements for the teaching of programming.
Users	3	-	Users requirements are related to the features that are needs to allow the identification and allow or deny access for the users in the applications. They promote the monitoring of users' interactions and, when desired, their learning performance.	RFUS002 - The application shall enable the registration of users through a form and/or other authentication mechanisms, such as reuse of credentials from other mobile device applications.
Nonfunctional Requirements	38	-	The set of nonfunctional requirements deals mainly with quality issues for the construction of applications with minimal quality for a useful application and with their functionalities doing what is expected. Consequently, they are related with all several requirements of programming and with the other set of requirements.	RNF002 - The application shall provide different idioms. RNF007 - The application shall be always available for users anytime and anywhere.

such as battery life, memory (for older devices), need to be treated with more attention than with e-learning and desktop software.

V. CONCLUSIONS AND FUTURE WORKS

Mobile devices are common, and have potentially become a tool for teaching and learning. However, some educational domains, as the teaching of programming, have not been exploited regarding their benefits, as pointed out in a SM. This has motivated us to investigate features and create an m-learning requirements catalog to bring understanding about both m-learning and the teaching of programming domain, improving the conduction of the phase of Domain Engineering and enabling its adoption with Reuse-Based Software Engineering approaches.

The main contributions of our work are the requirements, their description and relation with problems of teaching of programming. Besides, the indication of educational theories may allow a reduction of problems of communication among educational stakeholders and developers teams. Another important consideration is the discussion of the adaptation of the requirements provided by other modalities of software to be used in m-learning applications. With few solutions in m-learning domain, the technological considerations are fundamental to make the adoption of functionalities from other modalities in this platform possible. Thus, these pieces of information are also considered in each requirement, when convenient.

The conducted assessment and the preliminary case study suggest that our catalog can also be adopted to create generic mobile applications.

As future work we aim at: (i) finishing the evaluation of the catalog by experts for improving the requirements, (ii) adopting the catalog in the conception of a feature model and (iii) implementing components that integrate an infrastructure for the instantiation of more configurable m-learning applications in real learning environments, investigating their effectiveness in this domain.

ACKNOWLEDGMENT

The authors acknowledge Brazilian funding agencies - FAPESP (Process 2014/03389-9), CAPES (Procad 071/2013) and CNPq for the financial support provided to this research.

References

[1] F. P. Galafassi, J. ao Carlos Gluz, and C. Galafassi, "A Interação e Apropriação Tecnológica de Pessoas com Deficiência Através de Ferramenta Multimídia Acessível," *Revista Brasileira de Informática na Educação*, vol. 21, pp. 41–52, 2013.

[2] A. Craig, J. Coldwell-Neilson, A. Goold, and J. Beekhuyzen, "A Review of E-learning Technologies–Opportunities for Teaching and Learning," in *Int. Conf. on Computer Supported Education (CSEDU)*, 2012, pp. 29–41.

[3] N. Rubens, D. Kaplan, and T. Okamoto, "E-Learning 3.0: Anyone, Anywhere, Anytime, and AI," in *New Horizons in Web Based Learning*. Springer, 2014, pp. 171–180.

[4] K. Harms, D. Cosgrove, S. Gray, and C. Kelleher, "Automatically Generating Tutorials to Enable Middle School Children to Learn Programming Independently," 2013, pp. 11–19.

[5] A. S. Marcolino and E. F. Barbosa, "Softwares Educacionais para o Ensino de Programação: Um Mapeamento Sistemático," *Simpósio Brasileiro de Informática na Educação*, vol. 1, pp. 190–199, 2015.

[6] ——, "Linhas de Produto de Software no Domínio Educacional: Um Mapeamento Sistemático," *Simpósio Brasileiro de Informática na Educação*, vol. 1, pp. 239–249, 2015.

[7] E. Georgieva, A. Smrikarov, and T. Georgiev, "A General Classification of Mobile Learning Systems," in *Int. Conf. on Computer Systems and Technologies CompSysTech*, vol. 8, 2005.

[8] D. Parsons, H. Ryu, and M. Cranshaw, "A design requirements framework for mobile learning environments," *Journal of Computers*, vol. 2, no. 4, pp. 1–8, 2007.

[9] M. Kearney, S. Schuck, K. Burden, and P. Aubusson, "Viewing mobile learning from a pedagogical perspective," *Research in learning technology*, vol. 20, 2012.

[10] N. F. Duarte Filho and E. F. Barbosa, "A Requirements Catalog for Mobile Learning Environments," in *Proceedings of the Annual ACM Symposium on Applied Computing*, New York, NY, USA, 2013, pp. 1266–1271.

[11] A. Jalil, M. Beer, and P. Crowther, "Pedagogical requirements for mobile learning: A review on mobilearn task model," *Journal of Interactive Media in Education*, vol. 2015, no. 1, 2015.

[12] M. Sarrab, "M-learning in Education: Omani Undergraduate Students Perspective," *Procedia - Social and Behavioral Sciences*, vol. 176, pp. 834 – 839, 2015, int. Educational Technology Conference IETC Chicago, IL, USA.

[13] D. M. Souza, M. H. S. Batista, and E. F. Barbosa, "Problemas e Dificuldades no Ensino de Programação: Um Mapeamento Sistemático," in *Revista Brasileira de Informática na Educação.*, 2015.

[14] ISO/IEC JTC/ 1/SC 7, "ISO/IEC 25010: Systems and software engineering - systems and software quality requirements and evaluation (square) - system and software quality models," Available in: http://goo.gl/tkpwPa., Tech. Rep., 2011.

[15] "ISO/IEC/IEEE Systems and Software Engineering - System Life Cycle Processes," *IEEE STD 15288-2008*, pp. c1–84, Jan 2008.

[16] A. Klaßen, M. Eibrink-Lunzenauer, and T. Gloggler, "Requirements for mobile learning applications in higher education," in *Multimedia (ISM), 2013 IEEE International Symposium on*. IEEE, 2013, pp. 492–497.