A Design-Based Approach to Developing a Mobile Learning System

Martina Holenko Dlab, Natasa Hoic-Bozic, Ivica Boticki

Abstract**—**This paper presents technologically innovative and scalable mobile learning solution within the SCOLLAm project ("Opening up education through Seamless and COLLAborative mobile learning on tablet computers"). The main research method applied during the development of the SCOLLAm mobile learning system is design-based research. It assumes iterative refinement of the system guided by collaboration between researches and practitioners. Following the identification of requirements, a multiplatform mobile learning system *SCOLLAm [in]Form* was developed. Several experiments were designed and conducted in the first and second grade of elementary school. *SCOLLAm [in]Form system* was used to design learning activities for math classes during which students practice calculation. System refinements were based on experience and interaction data gathered during class observations. In addition to implemented improvements, the data were used to outline possible improvements and deficiencies of the system that should be addressed in the next phase of the *SCOLLAm [in]Form* development.

Keywords**—**Adaptation, collaborative learning, educational technology, mobile learning, tablet computers.

I. Introduction

MOBILE devices are used in classrooms to improve teaching and learning processes. Using smartphones and tablet computers students access mobile learning systems in order to view prepared learning materials, communicate with their teacher and peers, and participate in various learning activities [1], [2]. The emergence and rapid development of mobile devices in the last 15 years, created a space for an entire new software market. Although in many ways similar to classic desktop applications, mobile applications have specifics that require a different development approach, all the way from user interface design and navigation to usage of the built-in hardware. At the same time, easy portability, touch screen, built-in camera and different sensors make mobile devices an ideal platform for many software applications.

When it comes to the mobile educational applications, these features have a potential of improving students' experience and motivation [3], which could lead to better learning results. The study by O'Bannon et al. [4] analyzed the perception of mobile phones in the class by American teachers. Although a majority of respondents was unsure about allowing students to use mobile phones in the classroom, they identified many features that could be useful in the learning process, and as a primary benefit emphasize the "anywhere/anytime learning opportunities".

Mobility provides chances for more effective and more autonomous learning, chances for personalization of learning process, and chances for social interactions and collaboration inside and outside the formal learning context [5]. To ensure effective learning, the introduction of mobile technologies should be complemented with the introduction of appropriate didactical models. At the same time, the development of mobile learning systems should be in line with the needs of the anticipated users. Today, mobile learning scenarios often take advantages of employing different collaborative learning strategies that encourage interaction amongst students. In the context of mobile computer-supported collaborative learning (mCSCL), mobile devices are used as infrastructure *through* which students collaborate. Students can also be gathered *around* the mobile device in order to collaborate [6].

Productive interaction that will result in collective knowledge creation should be additionally supported with adequate mCSCL system [5], [7]. Such systems enable delivery of learning materials, data collection, and artefact creation. They also include communication services (e.g. messages, chat, discussion) and collaborative activities tools. It is also important that mCSCL systems support teachers in designing learning scenarios and allow monitoring of students' progress.

This paper presents an approach to development of technologically innovative and scalable mobile learning system called *SCOLLAm [in]Form*. The *SCOLLAm [in]Form* system is being developed within the SCOLLAm project ("Opening up education through Seamless and COLLAborative mobile learning on tablet computers") which is one of the first scientific research projects closely related to mobile learning in Croatian schools [8].

The main research method applied during the development of the SCOLLAm mobile learning system is design-based research. *SCOLLAm [in]Form system* was used to design synchronous mCSCL activities for math learning in first and second grade of primary school. Designed activities were conducted during several cycles of testing. Based on gathered experience and interaction data, system refinements were made.

The paper is organized as follows. Section II gives background information regarding mobile computer-supported collaborative learning and the architecture of the *SCOLLAm [in]Form* system. Section III describes the conducted research.

M. Holenko Dlab is with the University of Rijeka, Department of Informatics, HR-51300 Rijeka, Croatia (corresponding author, phone: +38551584708; fax: +38551584749; e-mail: mholenko@inf.uniri.hr).

N. Hoic-Bozic is with the University of Rijeka, Department of Informatics, HR-51300 Rijeka, Croatia (e-mail: natasah@inf.uniri.hr).

I. Boticki is with the University of Zagreb, Faculty of Electrical Engineering and Computing, HR-10000 Zagreb, Croatia (e-mail: ivica.boticki@fer.hr).

Section IV discusses research results and gives guidelines for further work, while Section V concludes the paper.

II. Background

A. Mobile Learning Systems Development

Development of mobile learning systems comes with a great variety of challenges [9]: technical challenges, research challenges, pedagogical challenges, and policy challenges.

It is important to make sure that the developed mobile learning system can be used on various platforms. At the moment there are three main smartphone and tablet computer platforms on the market: Google Android, Apple iOS and Microsoft Windows, with the former two holding more than 95% of the market [10]. With that in mind, every software project which aims to cover broad audience, should be developed in at least two versions, Android and iOS. With focus on user experience or application speed, the best approach is to develop separate applications, one for each operating system [11], but that requires a dedicated developer or development team for each platform, and continuous coordination between them, which significantly raises the price of development and maintenance. Another solution is to use one of the existing cross-platform development frameworks, like Xamarin, Cordova, Titanium and React [12]. Each of these tools has some advantages and disadvantages, and it is on the developer to decide which tool suits the needs of the project best.

Another technical challenge is to provide adequate support to mobile learning activities, especially in the case of synchronous collaborative learning. Such activities assume real-time interaction so the system should deal with numerous communication and coordination issues such as reliability, automatic reconnection, and detection of communication interruptions. It should also allow an easy setup of groups for sharing messages on one or more mobile devices [9], [13].

The development process of learning systems in general should include researchers and practitioners. Therefore, design-based research can be considered as appropriate method for development of mobile learning systems. It is an increasingly used method for innovative solutions development in the context of educational research. Design-based research aims to build a stronger connection between educational research and real-world problems, emphasizing a need for collaboration of practitioners and researchers [14].

The potential of mobile learning system is depending on the pedagogical approaches chosen by researchers or practitioners to enhance learning and frameworks for its proper integration defined by policy makers (on the school, national or international level) [9]. In order to support the process of gaining new knowledge, skills and experience, mobile learning scenarios should allow learners to continually collect and store multimedia information and encourage reflection. Students should get chance to construct knowledge with their peers during collaborative learning activities [15]. It is also necessary to take into account the need for adaptation to spatial and temporal context. This refers to the ability of the system to adapt based on students' actions and the state of students' surroundings [5]. Possibilities for personalization according to the characteristics of individual students should also be considered. Very often, such an adaptation process includes presentation of learning content based on student's preferences [8], but can also refer to other aspects of mobile learning (e.g. adaptive group formation in case of collaborative learning [2]).

B. Architecture of the SCOLLAm[in]Form System

As a part of the SCOLLAm project, a mobile learning application called *SCOLLAm [in]Form* was developed. It is a multiplatform application with the client-server architecture, developed using the cross-platform tool Xamarin, and written mostly in C#. *SCOLLAm [in]Form* is an evolution of several previous mobile learning applications, developed by the team members in the recent years. The most recent of them, SamEx [16], is a basis on which the multi-platform [in]Form was built upon. Since Xamarin uses C#, the re-usage of parts of the existing SamEx codebase was possible. In addition to the mobile application, the *SCOLLAm [in]Form* system consists of several server modules and two web additional Web applications – *[in]Form Author* and SCOLLAm Web Administration interface for teachers.

At the current stage of development, the *SCOLLAm [in]Form* consists of several interconnected modules, built around central database (Fig. 1): a digital lessons authoring tool named *[in]Form Author*, a digital lesson viewer/player named *[in]Form Player*, Q&A module, group task/collaboration module with shared canvas, and several other auxiliary modules. These components represent core part of the *SCOLLAm [in]Form* application and their main purpose is briefly described in the reminder of this section.

[in]Form Author – Digital lessons authoring tool - One of the most important parts of the system is a digital lessons authoring tool that enable teachers to plan mobile learning experiences for their students [16]. *[in]Form Author* is a tool similar to the presentation editor, where slide-based digital lessons can be created. Each slide consists of multimedia content, enhanced by user-defined actions, rich content, variables, etc. Lessons are saved in JSON format, in a central database, and retrieved as needed by the *[in]Form* application.

Digital lessons player – This module plays digital lessons created by the *[in]Form Author*. The lessons are run inside the main *[in]Form* application, and interact with other parts of the system, send data to the logging service, etc.

Group task / Collaboration module – This module contains a list of tasks defined by teacher, which students have to solve by collaborating on a shared canvas. In addition to drawing, students can share their experiences (text or pictures) with other students.

Widgets – reusable modular learning contents that can be used as part of the digital lessons and be displayed in the digital lesson player. Widgets are built using web technologies such as HTML or JavaScript and can be reused in variety of learning scenarios.

Other modules – Other system modules include

World Academy of Science, Engineering and Technology
International Journal of Educational and Pedagogical Sciences
Vol:11, No:10, 2017

communication web services, data logging modules, push notifications modules, etc.

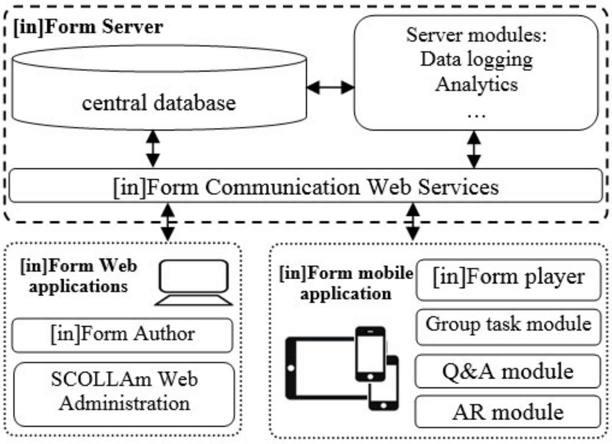


Fig. 1 SCOLLAm [in]Form Architecture

III. Research Design

A. Context and Participants

During the research, a widget for collaborative mathematics learning was developed. Using the developed mCSCL widget, teachers can deploy learning exercises with the set of tasks for practicing addition, subtraction, multiplication and division. By solving collaborative exercises, students have chance to discuss the steps of solving given problems in small groups and correct possible misconception. After students gain confidence by solving collaborative exercises, they can build speed and accuracy [17].

There are two main types of tasks that can be included in the collaborative exercises. Those are tasks in which students need to calculate a given expression (e.g. sum three two-digit numbers) and word problems in which students are expected to process the text, write an expression and then do the calculation (e.g. There are 12 boys and 11 girls in Ana's class. How many students are there in Ana's class in total?). Fig. 2 shows user interface of the *SCOLLAm in[Form]* system with word problem that was given as an example.

Participants included in the experiments during math lessons were students from one first grade class and two second grade classes of the Primary school Trnjanska, Zagreb, Croatia. The total number of students was 55, all of age 6-8 years. During the experiments, students were using internet-connected tablet computers (one device per one student) preloaded with the developed mCSCL widget.

During the conducted experiments students were working in pairs and triplets to solve tasks involving numbers up to one hundred (Fig. 3).

To determine the affordances of the system and possible improvements, interaction among students was observed via log-files, videos and class observation. Additionally, interviews with the teachers were conducted after the experiments. Based on all gathered data, the system has been updated in several cycles as described in the following section.

B. The Initial Version of mCSCL Widget

The initial version of mCSCL widget enabled the performance of role-based mCSCL activities in pairs and triplets.

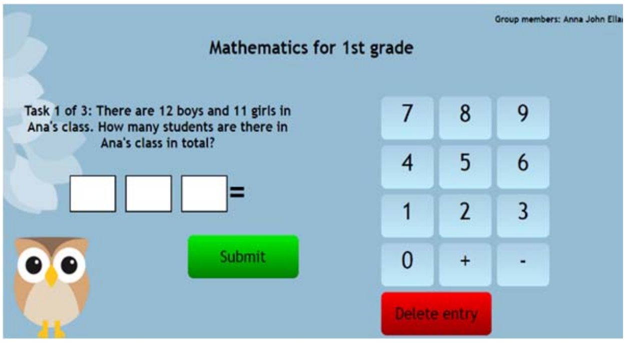


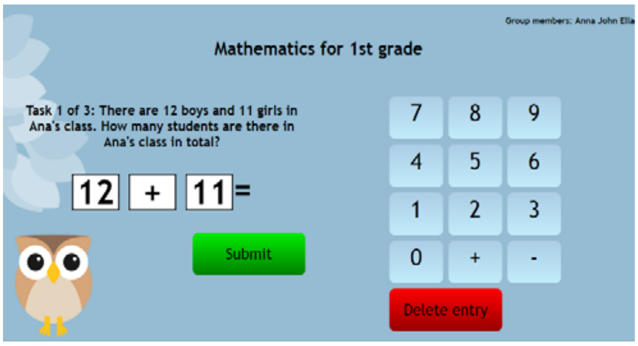
Fig. 2 Mathematical word problem in *SCOLLAm in[Form]* system

When working in pairs, students were supposed to solve a set of addition, subtraction, multiplication or division tasks (e.g. 25+47). At the beginning of the activity, students were randomly grouped by the system and each member was randomly assigned one of the two available roles: an editor or a checker role. An editor was supposed to solve each task and a checker had to determine whether the solution is right or wrong. After checker submitted his/her answer, both students received feedback message on the overall success. In case of correct solution, students were given a new task to solve. Otherwise, they were advised to discuss their solution and try again without revealing who made the mistake, editor, checker, or both.

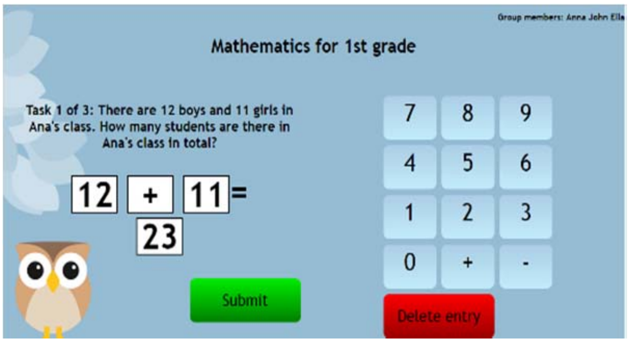
In case of activities for triplets, collaborative exercises contained word problems. Group members were assigned one of the three available roles: an author, an editor or a checker role. An author was supposed to process the text of the given problem and write its mathematical representation (expression). Then, an editor was supposed to do the calculation, and a checker was supposed to check the entire solution. For example, if the task was: "There are 12 boys and 11 girls in Ana's class. How many students are there in Ana's class in total?", the author was expected to submit "12+11", the editor was expected to submit "23", and the checker was expected to mark the solution as correct (OK) or incorrect (C), as illustrated in Fig. 4. After the checker submitted his/her answer, all group members received the feedback message on their solution. Again, in the case of a correct solution students were given the following task, while in the case of errors, students were advised to discuss and try again without indication as to who made the mistake, author, editor, or checker.

The main research question was: what are the differences in time needed to complete the mCSCL mathematics lessons for early primary school students in different roles (authors, editors or checkers)? The results showed differing times needed for students in each role to complete the assigned tasks. The author role takes the most time, while the checker role takes the least time. The analysis of correct answers showed that the authors made only 5% of the total errors, while the editors made the most mistakes.

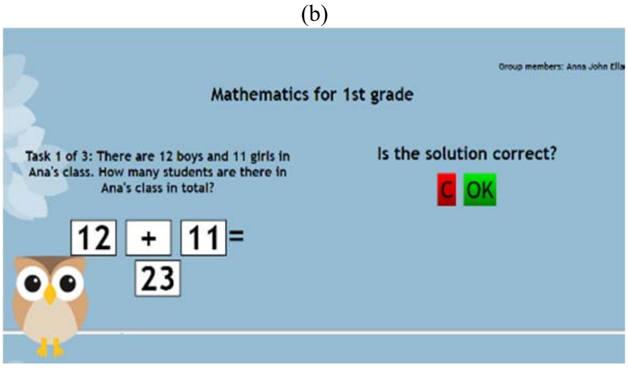
Fig. 3 Students solving mathematical tasks in pairs



(a)



(b)



(c)

Fig. 4 Solving a mathematical word problem in three different roles ((a) author, (b) editor and (c) checker roles)

The analysis showed that the checkers in many cases just agreed with the solution offered by author and editor, without thoroughly thinking it through and without noticing their mistakes. The implantation of a synchronous mCSCL module like this comes with a number of challenges that needed to be addressed as part of the design-based research and implementation phases. The main issues were the real-time synchronization of students working in group, whereby interruptions (such as no network signal) needed to be addressed. In addition to that, the logic of software needed to be considered carefully, as parallel software execution brings additional complexity to the design and software operation.

Based on these results, the first cycle of improvements was carried out and a new version of the mCSCL widget was created.

C. First Cycle of Improvements

Since research results indicated that checker role is the least demanding and that students in that role are not sufficiently engaged, the checker role was left out from the exercises for triplets. So, in the case of collaborative exercises with word problems, students were solving tasks in pairs. An author was supposed to write the mathematical representation of the given problem and an editor was supposed to calculate it. At the end, the solution they offered was checked by the *[in]Form* system and in the case someone made a mistake, students were advised to discuss the solution and try again.

Additionally, in order to try to equalize the exercise complexity for all group members, alternation of roles was introduced. Instead of solving all the tasks within one exercise in the same role, students were alternately allocated to the editor and checker roles. The data showed that the desired goal was achieved.

Besides examining the average time needed to complete a task and analyzing the number of unsuccessful task completion attempts by task and role, it was examined how does student background data (academic achievements and engagement) relate to students' performance in different roles (authors, editors or checkers). The results showed that background data correlate with the students' performance data so information about students' academic achievements and engagement could be used to provide adaptation during mCSCL activities [17].

During this cycle, the *[in]Form* application was improved. A refresh button feature was added whereby students were able to quickly reload the current state of the distributed lesson, in case of network shortage or similar interruptions. The widget was restructured so that in case of complete application restart, students were able to continue the assignment exactly from the point where they left. Activity logs were also improved so that activity data could be analyzed in a more efficient manner.

D. Second Cycle of Improvements

Based on the results and observation from the previous phase, the new version of the mCSCL widget was developed. The role-based model was temporarily relinquished with the aim to achieve the greater involvement of students. Therefore, each group member was supposed to solve the whole task by himself/herself. The *[in]Form* system checked the offered solution and in the case of errors students were advised to discuss and try again without indication about who made a mistake. This way of group work allowed more time for individual problem solving and used group interaction for debriefing and agreement in key group interaction moments.

In addition to that, adaptive group formation was introduced. Instead of random grouping, students were divided into groups based on background data (academic achievements and engagement) at the beginning of each exercise. Created groups were homogeneous or heterogeneous, depending on the chosen criterion. Heterogeneous groups were used to enable students to learn from each other. On the other hand, homogeneous groups were used during drill exercises, when students possessed good knowledge of the topic but needed to perfect it.

From the technology development perspective, this software solution was much simpler primarily due to smaller number of synchronization issues and mechanisms.

IV. Discussion

Throughout monitoring, the interaction with students during learning activities as well as interviewing the teachers and students, researchers collected their satisfaction with the system. Teachers' observations indicate that in the next phase of the design-based research of the *SCOLLAm [in]Form* development, the core modules of the system should be complemented with two new components: *adaptation module* and *analytics module*. The *Adaptation module* will contain rules for adaptive group formation (to form groups according to the teacher's criterion) and adaptive activities sequencing (to provide students with the most suitable set of tasks). The *Analytics module* will be used to collect, store and analyze data regarding students' actions, achievements and preferences.

The introduction of adaptive group formation support provided the opportunity for adapting contents of a particular exercise to groups as wholes. This refers to combining the tasks of adequate weight in the exercise. In addition, the number of tasks included in the exercise should be balanced according to the students' background data and results from previous exercises.

While the adaptation module would be used to embed adaptation into students' activities, *[in]Form Author* should allow teachers to modify designed rules during the process of planning learning activities. The user interface and implemented functionalities should be tailored to teachers' digital competences in order to encourage them to use the system in everyday teaching.

Results of the presented research also indicate that further development of *SCOLLAm [in]Form* mobile learning system should include components that will support teachers in the planning and implementation of adaptive learning experiences. This is in the line with the contemporary approaches to technology enhanced learning which emphasize the need for adapting the learning process to students' characteristics.

V. Conclusion

Mobile learning systems should include appropriate components that will facilitate the implementation of designed learning activities, collection and storage of data about students, and enable the adaptation (personalization) process. In addition, it is necessary to implement modules that will support teachers in designing learning experiences for their students. Design-based research is a very useful approach for development of such learning environments because it is not always possible to immediately recognize all the needs of anticipated users as well as advantages or disadvantages of designed solutions.

Acknowledgment

This work has been in part supported by Croatian Science Foundation under the project UIP-2013-11-7908. The authors would like to thank the staff of Primary School Trnjanska - Ivančica Tajsl Dragičević, Kristina Vlah, Luci Plenković Omerso, Jasna Haraminčić, Petra Crnjević Trstenjak and Nada Šimić - for their enthusiastic partnership in the realization of the study presented in this paper.

References

[1] M. Sharples, "Mobile learning: research, practice and challenges," Distance Educ. China, vol. 3, no. 5, pp. 5–11, 2013.

[2] I. Boticki, C. K. Looi, and L. Wong, "Supporting mobile collaborative activities through scaffolded flexible grouping," J. Educ. Technol. Soc., vol. 14, no. 3, pp. 190–202, 2011.

[3] M. Wald, Y. Li, and E. Draffan, "Synote: Collaborative mobile learning for all," Procedia Comput. Sci., vol. 27, pp. 240–250, 2014.

[4] B. W. O'Bannon and K. M. Thomas, "Mobile phones in the classroom: Preservice teachers answer the call," Comput. Educ., vol. 85, pp. 110–122, Jul. 2015.

[5] S. Caballé, F. Xhafa, and L. Barolli, "Using mobile devices to support online collaborative learning," Mob. Inf. Syst., vol. 6, no. 1, pp. 24–47, 2010.

[6] M. Carapina and I. Boticki, "Technology trends in mobile computer supported collaborative learning in elementary education from 2009 to 2014," 11th Int. Conf. Mob. Learn., 2015.

[7] C. Cortez, M. Nussbaum, and R. Santelices, "Teaching science with mobile computer supported collaborative learning (MCSCL)," in 2nd IEEE International Proceedings of the Workshop on Wireless and Mobile Technologies in Education, 2004.

[8] T. Jagust, I. Mekterovic, and I. Boticki, "The experiences of setting up, developing and implementing a mobile learning project in Croatia: The SCOLLAm project," in 2015 IEEE Frontiers in Education Conference (FIE), 2015.

[9] F. Khaddage, W. Müller, and K. Flintoff, "Advancing mobile learning in formal and informal settings via mobile app technology: Where to from here, and how?," J. Educ. Technol., vol. 19, no. 3, pp. 16–26, 2016.

[10] "IDC Analyze the Future Press Release," 2015. (Online). Available: http://www.idc.com/getdoc.jsp?containerId=prUS25450615. (Accessed: 04-Jul-2015).

[11] A. Charland and B. Leroux, "Mobile application Development: Web vs. native," Commun. ACM, vol. 54, no. 5, pp. 49–53, 2011.

[12] M. Martinez and S. Lecomte, "Towards the Quality Improvement of Cross-Platform Mobile Applications," in IEEE/ACM 4th International Conference on Mobile Software Engineering and Systems (MOBILESoft), 2017, pp. 184–188.

[13] I. Boticki, N. Uzelac, and M. Holenko Dlab, "Enabling Synchronous Collaboration in Web Mobile Learning Applications," in Proceedings of International Mobile Learning Festival 2017: Mobile Learning, Emerging Learning Design and Learning 2.0, 2017, pp. 8–17.

[14] T. Amiel and T. Reeves, "Design-based research and educational

technology: Rethinking technology and the research agenda," J. Educ. Technol. Soc., vol. 11, no. 4, p. 29, 2008.
[15] A. Jalil, M. Beer, and P. Crowther, "Pedagogical Requirements for Mobile Learning: A Review on MOBIlearn Task Model," J. Interact. Media Educ., vol. 2015, no. 1, Aug. 2015.
[16] I. Boticki, J. Baksa, P. Seow, and C. Looi, "Usage of a mobile social learning platform with virtual badges in a primary school," Comput. Educ., vol. 86, pp. 120–136, 2015.
[17] M. Holenko Dlab, I. Boticki, N. Hoic-Bozic, and C.-K. Looi, "Adaptivity in Synchronous Mobile Collaborative Learning," in Proceedings of the International Conference on Education and New Learning Technologies - EDULEARN17, 2017, pp. 454–460.