

A tale of two mobile learning journeys with smartphones and tablets: the interplay of technology and implementation change

Mirna DOMANCIC, Jelena BAKSA, Tomislav JAGUST, & Ivica BOTICKI*

^a Faculty of electrical engineering and computing, University of Zagreb, Croatia

*ivica.boticki@fer.hr

Peter SEOW, Chee-Kit LOOI

National Institute of Education Singapore

Abstract: This paper describes two mobile learning journeys in the zoo using either smartphones or tablets, and a mobile learning application SamEx, all designed and implemented as part of a research study in a Singapore primary school. Out-of-school semi-formal learning activities such as zoo trips present standard curricular topics where students go out of their schools in order to explore topics of interest in a semi-controlled designed environment. Typically, students observe and connect their observations with prior knowledge or further extend their knowledge on the go or later with their teacher in the classroom. The initial study in 2013 included the whole Primary 3 (P3) level of students, 305 of them, while the subsequent study in 2015 included 321 students. Between the years technology shift was inevitable – the participating school switched from smartphone devices to tablet computers, where each child has a tablet with the option to connect to both a WiFi network and to a mobile broadband network. Furthermore, the changes in the design of the mobile learning SamEx application were carried out in collaboration with the teachers, through a design-based research process. SamEx allows for the collection, organization and storage of media collected by students typically as responses to questions and prompts set up by their teachers. The initial design was oriented towards individual students, to support their individual in-class and homework learning tasks and assignments. The main features added to the application incorporated additional teachers' needs in carrying out curricular topics including inquiry learning and collaborative learning. The paper explores the evolution of both technology and the implementation of the application in the period, and problematizes the notion of inevitable technology change, constant software maintenance and enhancement and the effect of these changes on learning activities and outcomes.

Keywords: mobile learning; e-learning; tablet computers in education; software design

1. Introduction

Mobile learning technologies stimulate student engagement while enabling authentic learning scenarios used as part of diverse educational programs around the globe (Chen, 2013). With the goal of providing a more sustained learning experience for their students, teachers in a Singapore primary school collaborated with a research team in 2012 in a Seamless Learning project in which the goal was the incorporation of mobile learning technologies into the science curriculum. An application named SamEx was developed and has been used as a part of the curriculum since then. The application is constantly improved through a process of iterative design with both teacher and student usage experiences in mind.

SamEx is an educational application for Android platform designed to allow students to post, store and share educational content with their colleagues and teachers either as responses to contextual prompts set up by their teachers or as student-initiated contributions. As a result of the two-year usage, the data on student involvement in form of media contributions, text answers, likes and comments is available for research analysis.

This paper focuses on the comparison of two mobile learning journeys using the data provided by SamEx application. The comparison is characterized by unavoidable technology improvement and insights provided by constant collaboration with the teachers. Analysis is conducted on the data collected from the Primary (Grade) 3 level students in the year 2013 and 2015. In 2013 the students had been using the smartphone SamEx application, while in 2015 the students were equipped with tablet computers running a redesigned and improved SamEx application. Analysis is based on the comparison of two student trips to the Singapore zoo, and characterized by a number of questions specifically designed by teachers for the students to answer on the spot by providing textual, picture, video or audio responses via the application.

Section II provides an overview of the state of the art mobile learning and pedagogical approaches to it. Section III follows with a detailed description of SamEx design. Sections IV and V describe the methodology used and present the results of the data analysis, while Section VI discusses interaction specifics.

2. State-of-the-art

The rapid development of mobile technologies has in recent years encouraged the emergence of a number of novel software applications, and also opened the possibility of transferring many existing applications from desktop PCs to mobile phones and tablets. Moreover, the ease of use, device portability, different connectivity options, built-in camera and various sensors made mobile platforms an ideal environment for many software applications. Used in the mobile educational applications, many of these features have potential of greatly improving user (learner) experience and motivation (Wald, Li, & Draffan, 2014), which could in the end, lead to better learning results. Similarly to Web learning platforms in the late '90s, mobile learning applications are "the hot educational topic" throughout the last ten years (Wald et al., 2014).

Although handheld devices, smartphones and tablet computers exist for a number of years now, the real revolution in the field happened in 2007 and 2008, when Apple iPhone and the first Google Android based phones were unveiled. These two, along with Microsoft Windows Phone, are the prevalent mobile and tablet computer platforms today. As soon as the technology stopped being a limiting factor, and tablet or smartphone devices started coming with enough processing power and memory for demanding applications, many studies started actively researching appropriate pedagogical approaches to mobile learning (Sharples, 2013).

Until recent years lectures were mainly designed so that teachers deliver knowledge to the students, who are mostly passive participants in the whole process (Chuang, 2014). Developments in e-learning, and especially m-learning, which is characterized by using mobile phones and unlike e-learning is available on any location, resulted in a more active involvement of students in the educational process.

There is a number of review papers on mobile learning written in the recent years, like (Sharples, 2013), (Wu et al., 2012), (Jacob & Issac, 2008), (Hokyoung & Parsons, 2007) and (Martin et al., 2011). Sharples (Sharples, 2013) gives an overview of the mobile learning field, accompanied with critical review of existing studies and general guidelines for development of future mobile learning applications, without information about specific technologies. Wu et al. (Wu et al., 2012) give a very comprehensive analysis of the field and existing mobile systems. Their study includes papers published until 2011, so a number of new trends and technologies are not included. Jacob and Issac (Jacob & Issac, 2008) made an analysis of learning practices and the accompanying exploitation of mobile devices. They state the advantages and disadvantages of a particular mobile device type in mobile education, as well as the usage of these devices amongst their students, with also no technology-specific information given. Parsons & Ryu (Hokyoung & Parsons, 2007) describe generic software architectures for mobile educational applications and conclude that the best (the "richest") platform for mobile learning seems to be the client-server architecture. Martin et al. (Martin et al., 2011) analyze the existing frameworks and middleware applications for mobile learning applications and focus only on these two aspects of mobile application programming, without a deep focus on available technologies.

3. SamEx

3.1 System Design

SamEx was designed to support self-directed and collaborative learning activities and provides a participatory platform for students to contribute, share, and give feedback. Students can use it to take a picture to collect data or post information they found to be useful for their learning. These postings are shared with other students who can review, give comments and evaluate by giving “Likes” to the contribution.

SamEx was developed for the Android, Windows 8.1 and Windows Phone 7 and 8 mobile operating systems in the Seamless Learning Curricular Innovation project in a Singapore primary school. SamEx system architecture consists of the following components (Fig. 1): server-side components, web application for system administrators and mobile clients (Android, Windows 8.1, Windows Phone applications for smartphone and tablet devices). The system is based on a centralized data model where clients are not responsible for data processing, and thus focus on the interactions with users. SamEx server-side components are: relational database, web application and web services for communication with mobile clients. All three components allow for seamless data storage and administration for both users and administrators. The key issue in SamEx system design is maintaining a consistent state of the data between the server and client applications.

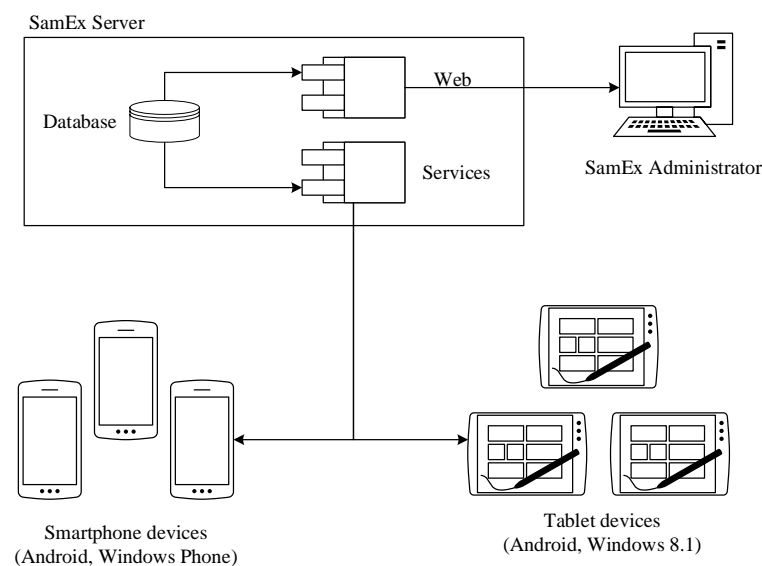


Fig. 1. SamEx system architecture

The generic SamEx mobile client application is built of several layers: a server communication service, a data access layer, and modules for user interaction (GUI). Data is periodically fetched from the server side and stored locally via a background service. A data access layer is implemented over the storage data structures, allowing developers to make easy structural changes without affecting the application logic for the communication with users.

SamEx can be installed on Android or Windows Phone smartphone or tablet devices. Students are given a mobile device with SamEx application preinstalled and preconfigured to immediately act as an active system component. SamEx web application provides an administrative user interface. Teachers and administrators are able to search, filter and sort data, and administer student groups or set up location-based prompts (so called “triggered questions”).

Activities in SamEx were designed for primary school students who used SamEx in their school activities. In addition to collecting, storing and accessing multimedia artifacts, SamEx can store contextual users’ information for potential educational use. Depending on the current time and users’

location, the system allows question prompts to be displayed on students' smartphones potentially facilitating or scaffolding learning tasks. Students can therefore be guided in outdoor mobile learning trails or just prompted periodically in connection with their homework observations or other work they are recommended or required to pursue outside of school. Students can also subscribe to their peers' contributions.

To reward students' activity, SamEx leverages on its own badge system, an extrinsic motivational tool. By collecting media, answering location-aware questions, providing comments to other students' questions and "liking" other students' work, students take part in a game to accumulate points leading to the earning of badges in five categories with four levels in each category. The badges were designed as recognition to motivate student to participate and share in the inquiry process. The content of uploads is not automatically checked for quality, so it is possible for students to upload content just in order to get high badge scores. This is solved by closely examining contributions of students with suspiciously high counts of content.

4. Technology Shift From Smartphones to Tablet Computers

Between the years of SamEx usage a technology shift was inevitable. The participating school decided to switch from smartphone devices to tablet computers, which pushed the evolution of SamEx system. The changes in the design of the mobile learning applications were carried out in collaboration with the teachers and researchers, as part of the design-based research methodology.

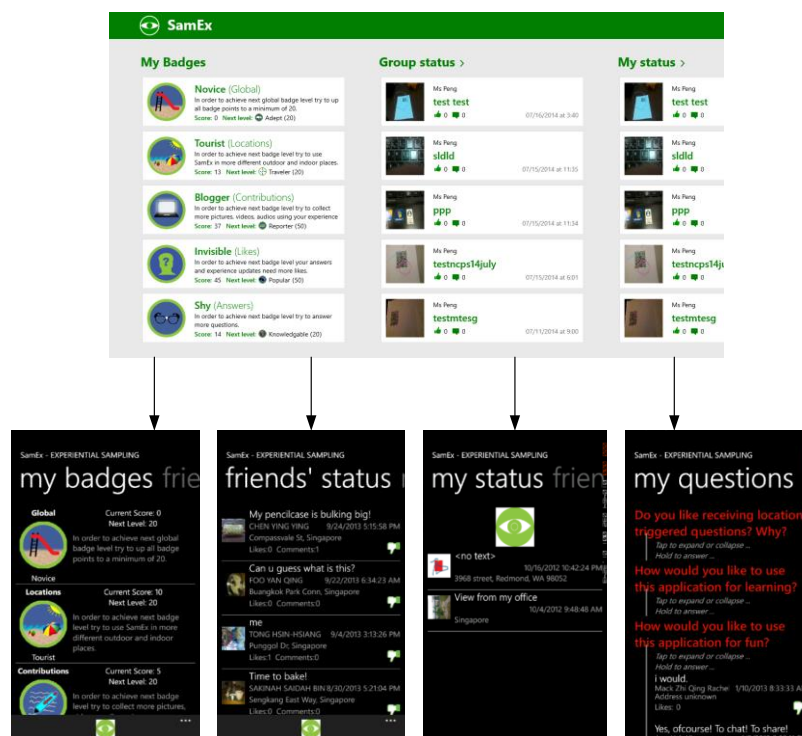


Fig. 2. Badges, my status, group status and questions in tablet (above) and smartphone (below) applications

The foundation of the new application design was the restructured home page for tablets (Fig. 2). In order to improve the application user experience, the new landing page exposes all important features on only one screen: recent statuses, questions and most importantly badge status for the current user. This design reduced the amount of time a user has to spend in the application by laying out the crucial information in a dashboard-like structure. With the new organization of the features, users rarely need to venture deeper into the application because the summary of the most important details is shown right after its launch.

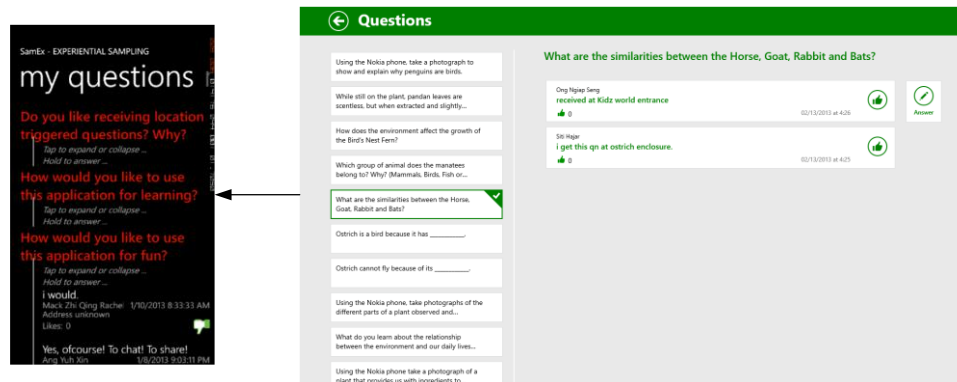


Fig. 3. Questions page in tablet (right) and smartphone applications (left)

Another improvement coming with the SamEx application on tablet devices is the enhanced interaction with media elements. Due to the larger screen, the preview of multimedia artifacts posted by the other students is now much more suitable from the visual perspective. Furthermore, the module for posting a new status now allows previewing, posting or discarding media on the same screen with a clean and user-friendly design (Fig. 4).

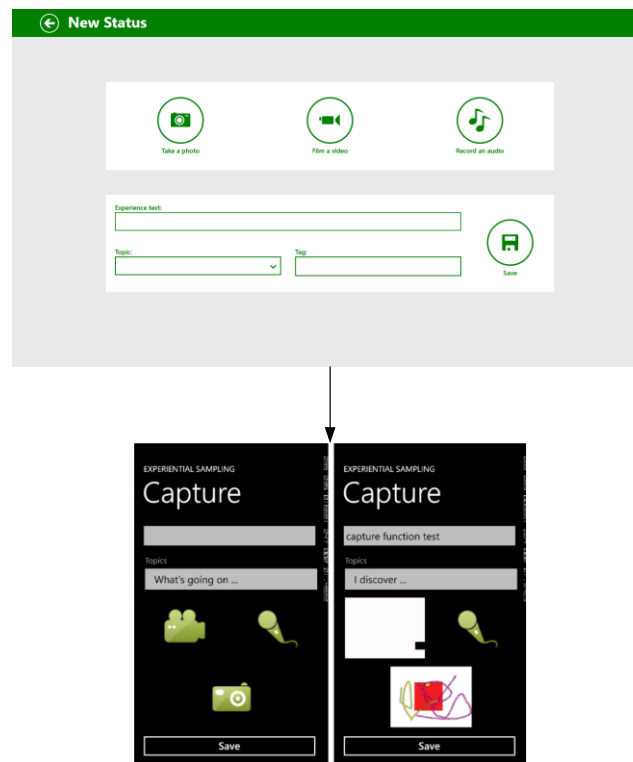


Fig. 4. New status page in tablet (above) and smartphone (below) applications

The SamEx module which gained the most from higher screen resolution on tablet devices is the Group Drawing module (Fig. 5). Students are presented with a canvas where they can draw, re-arrange the multimedia artifacts, add captions and collaborate in creating interactive dashboards. Interactive canvas functionality is much harder to utilize on smaller smartphone screens, which is why this module was not included in smartphone versions of SamEx mobile application.

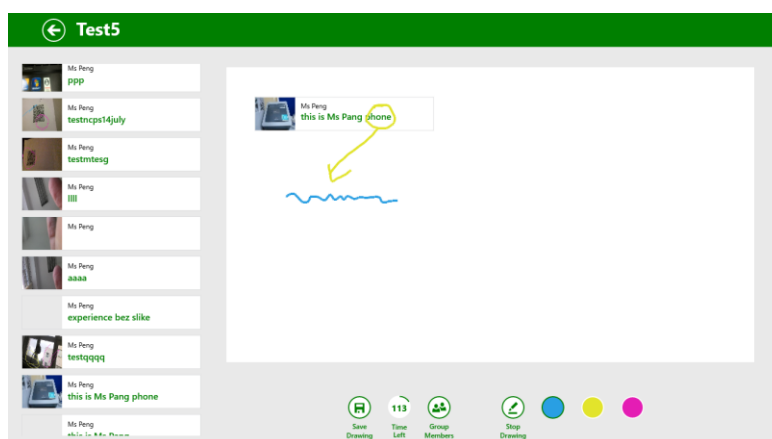


Fig. 5. Group drawing module in SamEx for tablet devices

On the other hand, tablet devices are larger and more robust which makes them difficult to use during highly mobile activities, whereas smartphone devices can easily be carried around in one hand or in students' pockets.

5. Methodology

The students taken into analysis are primary three class students, divided into eight level classes: A, B, C, D, E, F, G, H, both in 2013 and 2015. During both 2013 and 2015 each group had a one day visit to the Singapore zoo. During that visit, students are encouraged to answer predefined questions involving specific zoo exhibits and spots. Some of those questions are triggered via the application as a consequence of the user location change. Students can post their own text or media contributions, read their colleagues' observations and comment and like them. All the data provided by student contributions is collected and stored in the application database for further analysis. The result of SamEx application usage is a rich data set mostly composed of student contributions produced and stored in the period of two years.

Observations in this paper are based on the comparison of the data collected as a result of these two zoo trips. This was decided due to the conclusions of the preceding study where the application usage was the highest during the trips and thus richest in terms of content provided (Boticki, Baksa, Seow, & Looi, 2015). Even though both trips are characterized by almost the same locations visited and almost the same visit duration, the following differences were observed:

- Number of question prompts decreased from 23 in 2013 to 12 in 2015 in order to focus on student involvement in trip activities
- Questions in 2013 require a multiple choice, textual or experience based answer, while questions in 2015 are only experience-based
- Tablets used in 2015 had constant WiFi connectivity and GPS signal, which was not the case with smartphones used in 2013
- Eight group visits were spread throughout two weeks in 2013, while in 2015 the zoo visits were conducted in one week time
- Number of enrolled P3 students in 2013 was 305, while in 2015 a total of 321 primary three students were involved in the study

Taking these differences into account, the methodology of this study is aligned in order to respect and properly analyze these two approaches to the zoo visit. Student contributions taken into the analysis are exclusively the ones corresponding to the dates of the visit of the student's group in order to avoid at home or classroom usage and to only focus on the trip data. Student experiences are filtered in order to avoid repetitive duplicate experiences, due to errors in the system operation mainly due to the lack of WiFi connectivity.

Experience updates submitted by the students are grouped by text, user, and the quantity of audio records, videos, pictures and time. In case more than one experience with the same text and media files have been uploaded in a short time span, they are declared as repetitions, and only one is taken into consideration for the data analysis. Experience updates which contain no text and no media files are disregarded. Audio experiences are disregarded in analysis due to the considerable lack of this type of experiences. Furthermore, data analysis is based on contribution efficiency and frequencies, and not solely on the number of contributions in order to respect differences caused by the different number of question prompts, which will be described in more detail in further text.

6. Data Analysis and Interpretation

The first step in data analysis is the comparison of means of student contribution quantities from the two given years. The results of this step are presented in Table 1. Group 1 represents the cohort of 2013 students, while Group 2 represents 2015 cohort of students.

The variable named *Experiences* presents the total number of any type of student contribution (textual, media or mixed). Experiences can be uploaded either as answers to question prompts or as standalone. *Pictures* and *Videos* represent the number of contributions which include media files. *BaseUsageTime* is a variable which gives the information on total usage time of the application in seconds in the given time frame (during the trip). *QuestionAnswers* represents the number of uploaded answers to teachers question prompts. Question answers can be either textual answers, multiple choice answers or answers in form of experiences. Comments can be added to experiences, while likes can be added to either question answers or experiences. All the variable values are grouped by users.

Table 1 shows raw means are greater in group 1 compared to group 2. As previously mentioned, the number of questions was greater in the year 2013 (23 questions) than in 2015 (12 questions). This difference explains the decrease trend of variable values. However, an unexpected increase in number of question answers is present. Since the number of question answers is lower in 2013 than in 2015, but the total number of experiences is greater, it can be concluded that 2013 students uploaded their own contents more often than directly answering the predefined questions. A substantial difference between groups is present in *BaseUsageTime*. This is partially due to less content upload in general in 2015, and partially due to overall simplicity of tablet usage.

Next step in the analysis is the computation of efficiencies and frequencies based on the previously defined variables. Equations used to calculate these values are following:

$$\text{Experience Efficiency} = \text{Experiences} / \text{BaseUsageTime} \quad (1)$$

$$\text{Picture Efficiency} = \text{Pictures} / \text{BaseUsageTime} \quad (2)$$

$$\text{Video Efficiency} = \text{Videos} / \text{BaseUsageTime} \quad (3)$$

$$\text{Answer Efficiency} = \text{QuestionAnswers} / (\text{TotalQuestions} / 10) \quad (4)$$

$$\text{Comment Frequency} = \text{Comments} / (\text{TotalExperiences} / 1000) \quad (5)$$

$$\text{ExperienceLike Frequency} = \text{ExperienceLikes} / (\text{TotalExperiences} / 1000) \quad (6)$$

$$\text{AnswerLike Frequency} = \text{QuestionAnswerLikes} / (\text{TotalQuestionAnswers} / 1000) \quad (7)$$

BaseUsageTime in (1), (2) and (3) is transformed into hours in order to make the results easier to interpret. The same principle is followed by introducing the factors 10 in (4) and 1000 in (5), (6) and (7).

Table 2. shows the means of these transformed variables. It can be seen that after these transformations the means are in fact greater in Group 2 in contrast to the initial results. Exceptions are variables *Video Efficiency* and *Picture Efficiency*. This can be explained by the fact that none of the questions in 2015 strictly required students to upload their collected pictures or videos. To query the significance of this difference among groups, an independent samples t-test has been conducted. Equal variances were not assumed for any of the variables except for *Comment Frequency*.

TABLE I. MEANS OF CONTRIBUTIONS FOR GROUPS OF 2013 AND 2015

Measured variable / Group Id		N	Mean
Experiences	1	277	9.47
	2	192	7.95
Videos	1	277	0.36
	2	192	0.19
Pictures	1	277	7.79
	2	192	1.29
BaseUsageTime	1	294	3120.40
	2	247	929.07
Comments	1	68	5.22
	2	51	4.49
QuestionAnswers	1	287	5.90
	2	182	7.62
ExperienceLikes	1	83	14.12
	2	92	12.52
QuestionAnswerLikes	1	32	1.91
	2	137	11.99

The results show that students demonstrated greater efficiency in the second group, by uploading more content in less time and providing a greater frequency of comments, likes and question answers.

TABLE II. T TEST RESULTS FOR CONTRIBUTION MEAN DIFFERENCES BETWEEN COHORTS OF 2013 AND 2015 STUDENTS

	Group	Mean	MeanDiff	Sig(2-tailed)
Experience Efficiency	1	10.5459	-17.74	0.000***
	2	28.2831		
Video Efficiency	1	0.5011	0.28	0.041**
	2	0.2241		
Picture Efficiency	1	8.4991	4.43	0.000***
	2	4.0708		
Comment Frequency	1	2.0417	-0.90	0.305
	2	2.9425		
Answer Efficiency	1	2.5632	-3.78	0.000***
	2	6.3462		
ExperienceLike Frequency	1	5.5223	-2.68	0.165
	2	8.2056		
Answer Like Frequency	1	1.1266	-7.53	0.000***
	2	8.6527		

***p<0.001, ** p<0.05

7. Interaction Specifics

An important feature of SamEx is question prompts, designed by the teachers in order to motivate and encourage students to participate in SamEx activities. The system allows for three types of question prompts to be created: open-ended (type 1), multiple-choice (type 2) and media (type 3) questions. Media questions encourage students to document their learning process with a photo, video or audio.

The reaction of students to various questions with different content, level of detail and type was analyzed. The questions set for the zoo trip in 2013 were of all three types of questions. The results are unexpected - there was a large number of incomplete or very brief textual answers, while the attached media was of high quality and to the point. Students seemed to gain a lot by making observations based

on media questions and produced high quality media content, but failed to give the proper textual explanations along with the photographed artefacts. For example, the question “Using your phone, take a photograph to show and explain why penguins are birds” produced a lot of quality photos and videos, but the majority of students failed to answer the second part of the question. Giving the students too extensive tasks resulted in a lower contribution quality than expected.

Using the observations from 2013, the questions for the zoo trip in 2015 were designed differently. Teachers stopped actively encouraging students to provide media content and focused on shorter, simpler questions. Despite not being explicitly prompted to take pictures, the students continued to provide media contributions along with the textual answers, but with one big difference: the textual answers were now of much higher quality and more focused on the actual question when compared to the previous zoo activities. By giving the students more freedom and more open-ended questions, along with some hints about what to focus on, their answers became more creative while still in line with the learning objectives.

TABLE III. COMPARISON OF QUESTIONS FORMATS IN 2013 AND 2015

2013.	2015.
Using your phone, take a photograph to show and explain why penguins are birds.	How do you think the Stingray breathes in water? Hint: Is it similar to other fish?
Observe the fish and describe at least 5 characteristics that you can see.	Why is the bat a mammal? Hint: Which characteristic(s) of a mammal does the bat have?
Take a video of an insect to show that it is a living thing.	Which group of animals would you classify the hissing cockroach as? Give 2 reasons why.

8. Conclusions

Results of the two groups of students laid out in this paper are challenging when it comes to comparison since the differences between them and the concept of their zoo visits are characterized by a number of differentiating factors. Through the analysis the authors came to a conclusion that the factors which carry the most differences are the number of questions, the type of questions and the use of tablets opposed to the use smartphones.

The number of questions is greater in the year 2013 in comparison to 2015, but students gave better answers in 2015, both in terms of quality and quantity. Teachers decided to decrease the number of questions in 2015 in order to allow students to focus more on the zoo artefacts and exhibits and verbal communication. This proved to be a successful approach, since students react well to a small number of well-defined questions, giving answers which are in most cases correct, concise and often accompanied by media even though not instructed. The better quality answers given by the students prompted their peers to view and respond to the contributions causing the comment and like frequency to rise.

The second factor is the type of questions used. In 2013 students provided adequate answers to multiple type questions and textual questions but the quality was lower in the case of experience-based questions. In contrast, in 2015 students gave high quality experience-based answers. The question type disparity, can be explained by the fact that the questions in 2013 contained more sub-questions and strict rules, while questions in 2015 were more concise and provided optional possibilities of uploading media content which caused a favorable reaction from students.

Informal observations also offer an explanation of a more efficient user interface provided by tablets. As previously described, tablet devices offer the possibility of simpler and more accessible application usage. The smaller number of answers in 2013 can thus be explained with an issue of connectivity and location acquisition which was present in the smartphone version of the SamEx application and caused

inconsistent prompts, so the students had to use experiences instead. What is more, graphic interface in the tablet application version offered easier and faster question answering and media attachment which explains the decrease of application usage time. The improved graphic interface on the larger tablet screen also promoted better social interaction between the students as they are able to easily view the answers and experiences contributed by their peers.

An obvious progress can be noticed in the gathered data, mainly in terms of efficiency and quality of the contributions provided by students. Technology shift, application improvement and graphical user interface redesign as well as the change in terms of class organization have proven beneficial for students. Cooperation between the technology and educational expertise through constant iterative redesign gives the expected affirmative results which are expected to further excel in the following years.

Acknowledgment

The paper is a part of work from project “Bridging Formal and Informal Learning Spaces for Self-directed & Collaborative Inquiry Learning in Science” funded by Singapore National Research Foundation (NRF2011 - EDU002-EL005). This work has been in part supported by Croatian Science Foundation under the project UIP-2013-11-7908.

References

- Boticki, I., Baksa, J., Seow, P., & Looi, C.-K. (2015). Usage of a mobile social learning platform with virtual badges in a primary school. *Computers & Education*, 86, 120–136. <http://doi.org/10.1016/j.compedu.2015.02.015>
- Chen, X.-B. (2013). Tablets for Informal Language Learning: Student Usage and Attitudes. *Language Learning & Technology*, 17, 20–36.
- Chuang, Y. (2014). SSCLS : A Smartphone-Supported Collaborative Learning System. *TELEMATICS AND INFORMATICS*, (November). <http://doi.org/10.1016/j.tele.2014.10.004>
- Hokyoung, R., & Parsons, D. (2007). Software architectures for mobile learning. *Mobile Software Architecture Technologies and Applications Conference (MoLTA 2007)*.
- Jacob, S., & Issac, B. (2008). The mobile devices and its mobile learning usage analysis. *Proceedings of the International MultiConference of Engineers and Computer Scientists*, 1, 19–21.
- Martin, S., Diaz, G., Plaza, I., Ruiz, E., Castro, M., & Peire, J. (2011). State of the art of frameworks and middleware for facilitating mobile and ubiquitous learning development. *Journal of Systems and Software*, 84(11), 1883–1891. <http://doi.org/10.1016/j.jss.2011.06.042>
- Sharples, M. (2013). Mobile learning: research, practice and challenges. *Distance Education in China*, 3(5), 5–11.
- Wald, M., Li, Y., & Draffan, E. a. (2014). Synote: Collaborative Mobile Learning for All. *Procedia Computer Science*, 27(Dsai 2013), 240–250. <http://doi.org/10.1016/j.procs.2014.02.027>
- Wu, W.-H., Jim Wu, Y.-C., Chen, C.-Y., Kao, H.-Y., Lin, C.-H., & Huang, S.-H. (2012). Review of trends from mobile learning studies: A meta-analysis. *Computers & Education*, 59(2), 817–827. <http://doi.org/http://dx.doi.org/10.1016/j.compedu.2012.03.016>