Does informal learning benefit from interactivity? The effect of trial and error on knowledge acquisition during a museum visit

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Abstract: Informal learning settings, such as museums and cultural heritage locations, have employed interactive mobile applications. Educators and museum curators recognise the value of interactivity, but the optimum level of interactivity in informal learning remains unclear. We developed an informal learning activity with quiz questions about art theory, which we integrated in a between-groups experimental design with three groups of high-school students at an art gallery. Each of the three groups received a different treatment: (a) an interactive mobile-based learning activity, (b) a paper-based version of the same learning activity, and (c) a self-guided museum tour. Students who enrolled with the interactive version showed higher performance in the post-assessment test when compared to the paper-based version. Notably, the benefits of the interactive version are attributed to the immediate feedback of the quiz application during the visit. Further research should perform similar controlled experiments in order to assess the learning benefit of more immersive interactive systems, such as three-dimensional graphics and augmented reality.

Keywords: mobile learning; interactivity; trial and error; informal learning; knowledge acquisition; perceptions; museum.

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1 Introduction

Young generations are exposed to technology to a great extent. As a result, they are familiar with various forms of technology, particularly mobile devices. Students spend their leisure time playing games, taking pictures, surfing the web, and listening to music.

Scholars and educators have already suggested leveraging the use of mobile technologies towards learning objectives and they have already developed several educational systems, but there is limited evaluation of their actual effect on learning. Therefore, one worthwhile research topic is the effect of interactive applications on learning in informal contexts, such as museums. In this study, we have designed an interactive mobile-based learning activity that leverages student familiarity with interactive applications, and we have devised a controlled experiment in order to explore the educational impact and overall experience during a museum visit.

Interactive mobile technologies can be used outdoors, in exhibitions, and in other non-classroom settings, extending the depth and breadth of informal learning. Mobile technologies open up a vast range of possibilities as they enable information sharing from any location and notably provide feedback and reinforcement (Naismith et al., 2004; Looi et al., 2009). Although there has been research on how interactive devices can support and enhance learning (i.e. Roussou, 2004; Siau et al., 2006; Chu et al., 2010; Hwang et al., 2011a; Hwang et al., 2011a), there is relatively little literature on how interactivity affects knowledge acquisition. In addition, one of the critical developmental tasks that students face in their activities is to identify and solidify their interests (Harackiewicz et al., 2008). Why do some students become interested in museums with interactive applications (Horn et al., 2012)? Does students' interest increase with real-time feedback applications? These questions highlight how the interactivity might be a motivational factor for students' interest in outdoor activities. Thus, the research issue regarding the impact of interactivity on informal learning has emerged.

This study aims to clarify issues regarding the following research questions:

- Q1: What is the effect of interactivity on student knowledge acquisition during a museum visit?
- Q2: Does interactivity affect interest to museum visit?

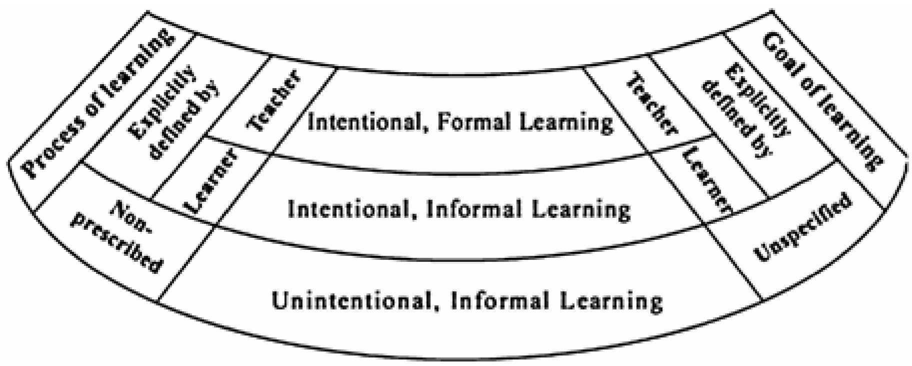
The rest of this paper is structured as follows. Section 2 provides a grounding of our motivations and measures through the literature review of related work. Section 3 describes the design of the interactive quiz game. Section 4 presents the research method that was employed to measure the performance of and the attitudes towards the three levels of interactivity. Section 5 presents results of the empirical findings, while Section 6 of this paper deliberates and gives insights of the results. Finally, the paper concludes with theoretical and practical implications and recommendations for future research.

2 Related work

2.1 Informal learning

Informal learning has primarily been defined in contradiction to the traditional school learning (Dewey, 1966). However, as research progressed and informal learning could not be formalised (Wenger and Snyder, 2000), an increasing number of criteria now define informal learning throughout different contexts. Dimensions such as the environment, media, motivation and pedagogical influence are some of the most frequent criteria for the distinction between formal and informal learning. Nevertheless, most forms of learning are combinations that fit in a wide spectrum of possible designs between formal and informal learning. There is, however, little or no interaction between learner and instructor in informal learning activities with real world conditions, which lack guidance. A typology of learning according to the goals and process of learning has been suggested by Vavoula et al. (2005). This framework (Figure 1) also defines formal and informal learning, and it includes a category for unintentional informal learning. It does not distinguish between different levels of learner interactivity in the process of learning.

Figure 1 Typology of informal learning (Vavoula et al., 2005)



2.2 Interactivity on mobile-assisted learning

Interactivity as informal learning (Rogers, 2006) is also a natural activity as it happens over time and space in different settings of our daily lives. The level of interactivity during an informal learning procedure varies from activity to activity. Prior research on interactivity in learning has shown that the interactivity of the devices enables students to become more active learners (Looi et al., 2010). The success of handhelds as museum guidebooks (Hsi 2003; Sung et al., 2010) and learning systems (Hwang et al., 2008; Huang et al., 2010) portray the growing interest in the use of interactive devises as learning tools in informal learning contexts. Previous research (Klopfer et al., 2005; Ogata et al., 2011) have revealed the benefits of certain properties of PDAs (i.e. portability, context sensitivity) in informal learning; however, there has been limited research on the optimum level of interactivity in informal settings.

Many studies have shown the potential of portable devices to increase learning opportunities. Informal learning with real world experiences has some remarkable advantages. Mobile devices' portability and functionality make them suitable for out-of-classroom learning, such as bird-watching (Chen et al., 2003), plant-hunting (Huang et al., 2010) and museum-guiding (Hsi, 2003) are some of the most successful case studies. Students' interest in mobile devices could potentially motivate them and make knowledge acquisition more enjoyable (Sung et al., 2010). In the context of museums, many researchers have employed new technologies and customised mobile devices (Cabrera et al., 2005) for improving the interest and the experience of the visitor. Although the role of mobile devices and interactivity is beneficial for students' interest in the activity, limited research currently exists on how interactivity affects students' interest in the museum visit.

2.3 The importance of interactivity

Learning improvements are difficult for those students who are not able to receive the appropriate feedback at the right time (Kao et al., 2008), implying that the provision of immediate information is needed for assisting the students in reflecting on and revising their knowledge. On the contrary, students are likely to lose interest in the guidance or hints and in continuing to learn if the guidance cannot be provided in time (Gibbs and Habeshaw, 1993, p.95). Hwang and Chang's (2011) study confirms that such a problem could be very serious for mobile learning activities since learning tasks are likely to be interrupted if necessary information cannot be provided instantly. Therefore, providing on time and meaningful information for learning tasks, such as developing concept maps in the field, is an important and challenging issue (Denton et al., 2008).

2.4 The problem and our approach

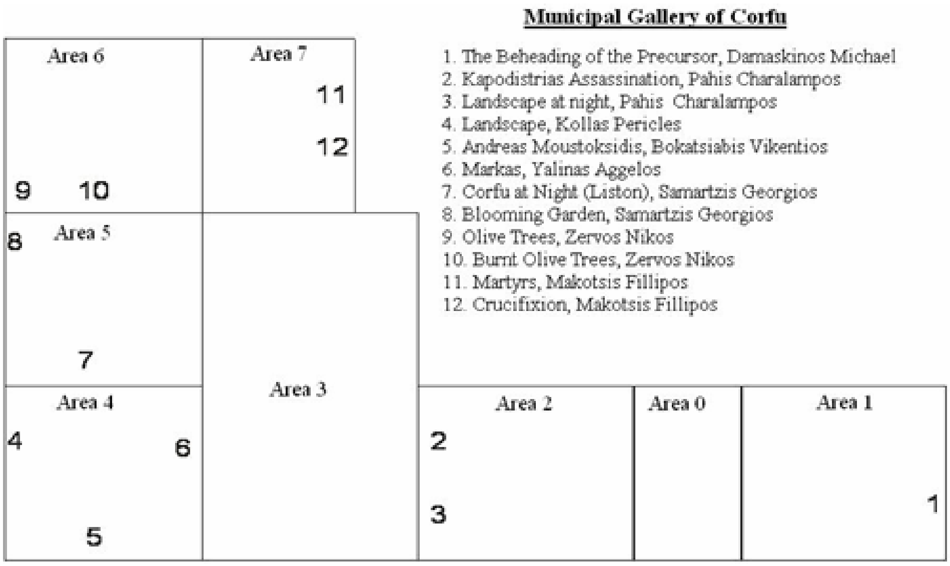
Informal learning is becoming increasingly popular, and mobile technology has opened up a vast range of possibilities as it provides feedback and reinforcement (Naismith et al., 2004). Although there has been some research on how mobile devices can support and enhance learning (i.e. Roussou, 2004; Siau et al., 2006), there is limited work on how interactivity affects learning performance, if at all. As such, the research question regarding the impact of interactivity in informal learning has emerged. In our approach, we employed an interactive mobile application with gaming elements (e.g. time limits, score, team competition) and a paper-based game with exactly the same features except for interactivity. Afterwards, a controlled experiment among the interactive mobile application, the paper-based game, and a traditional guide in a museum was conducted to identify differences in terms of learning performance and museum visit experience.

3 The museum learning activity & application

3.1 Museum learning activity

We designed a gamified learning activity based on multiple-choice questions, total score, and a time limit to complete. In this way, the learning activity includes several main gaming elements, such as purpose, rules, score and limitations (space-time). The main purpose of the learning activity was to identify a series of paintings, at an Art Museum, based on visual elements description. Our motivation for developing a learning activity on the basic principles of visual elements in works of art was to avoid the (negative or positive) attitude of some students towards a classic curriculum (i.e. mathematics, history). Twenty-four out of approximately 80 paintings from the Gallery's permanent collection, from all areas of the Gallery (see Figure 2), served as potential answers to the quiz questions. The total number of paintings was double the total number of questions in order to make the activity moderately difficult and to avoid possible ambiguities. The gallery's curator and the school's teacher collaborated to determine the selection of the paintings, the set of questions, and the order of appearance. The theory and the respective questions concerned the basic principles of visual elements in works of art and did not consider more advanced concepts, such as art history or painter styles.

Figure 2 The layout of the public art gallery



During the activity, students have the option of selecting a painting as an answer to the specific visual elements of the question. For each question, students have to browse through the rooms of the museum, in order to locate the requested visual elements on the paintings. For example, in Figure 3 students could select urban landscape, and warm colours with respect to the left painting and action scene, religious theme, and perspective with respect to the right painting.

Figure 3 Kapodistrias Assassination (left), and the Beheading of the Precursor (right) (see online version for colours)

Table 1 presents the visual elements of the paintings and the respective paintings (answers).

Table 1 The visual elements and the respective paintings

Visual elements	*Correct Painting (Name, Artist)*
Religious Theme. Action Scene. Perspective in two spots.	The Beheading of the Precursor, Damaskinos Michael
Action Scene. Urban Landscape. Warm Colours.	Kapodistrias Assassination, Pahis Charalampos
Night scene with cool colours.	Landscape at night, Pahis Charalampos
Landscape. Sun rising with cool colours.	Landscape, Kollas Pericles
Portrait with basic colour background.	Andreas Moustoksidis, Bokatsiabis Vikentios
Daily life scene with warm colours.	Markas, Yalinas Aggelos
Night scene with warm colours.	Corfu at Night (Liston), Samartzis Georgios
Landscape. Complementary colours.	Blooming Garden, Samartzis Georgios
Natural landscape. Organic shapes with warm colours.	Olive Trees, Zervos Nikos
Natural landscape. Organic shapes with cool colours.	Burnt Olive Trees, Zervos Nikos
Geometric shapes with warm colours. Cool colours' background.	Martyrs, Makotsis Fillipos
Religious Theme. Cool colours and three spots perspective	Crucifixion, Makotsis Fillipos

Note: * All paintings in http://www.artcorfu.com/en/mnucollection/digitals collections.html

We implemented two versions of the learning activity: a mobile-based (MB) and a paper-based (PB) version. In the MB version, QR codes are placed next to the paintings. Each team is provided with two mobile phones: one for displaying questions and submitting answers, and a second one for scanning QR codes. When the players identify a painting as an answer to a question, they scan the QR code next to it and type a four-digit number as the answer (Figure 4). If the answer is correct they receive a message indicating so. If the answer is incorrect, they receive a message indicating that they have one more chance to answer correctly. Each team, then, has up to two chances to identify a correct answer.

Each team (consisted of two players) has 25 minutes to answer 12 questions that lead them to certain paintings. The team with the highest number of correct answers wins. In case of a draw, the team that completed the activity first wins. In this way, while playing, students may practice both factual knowledge of the arts and reasoning ability, and thus they are motivated by playful knowledge acquisition.

In order to investigate the gameplay aspects of the learning activity, we used two pilot teams. The teams were briefed and then given a demo quiz to familiarise themselves with the software before playing. No time constrains were established at this time for the game, but teams were encouraged to complete the game without hassle. Upon completion, the 25 minutes of playing time was considered adequate. Additionally, pilot teams suggested readjusting some QR codes to a height of approximately 130 cm (Figure 4), to allow easier focusing the camera for scanning the code, which we did.

Figure 4 The QR codes and the post-it notes were placed next to the paintings (left). The students scan the QR code in order to obtain a four-digit number, which they input to the quiz application (right) (see online version for colours)

The PB version of the activity was identical in terms of questions, score and time constraints, except students obtained the four-digit number from post-its rather than QR codes, and the questions were printed on paper. The major difference in the gameplay between the two versions was that players do not receive any feedback regarding their answers during the PB activity, so there is also no score counting until the end of the activity. Hence, the MB version was based on the concept of trial and error with up to two chances to answer correctly, while the PB version offers only one chance to correctly answer each question during the learning activity at the museum.

3.2 Museum mobile quiz implementation

The name of the MB application is Museum Mobile Quiz (MuMoQuiz). MuMoQuiz provides simple question and answer functionality for Java-enabled mobile phones. In agreement to most learning applications, MuMoQuiz consists of three main components, namely the domain model, the teaching model and the user interface (Antal and Koncz, 2011). The domain model handles all the contents to be used by the application. The teaching model incorporates the knowledge of the system, consisting of a set of rules that provide the learner with feedback. Finally, the user interface represents the medium that interacts directly with the student. In the case of MuMoQuiz, the domain model stores all the contents to be used by the application. The teaching model generates simple feedback (correct or incorrect) according to the student's answer. The user interface provides simple navigation through the given questions. The main advantage of MuMoQuiz is the immediate feedback to student's answers, and a possible disadvantage is the distraction from the museum activity.

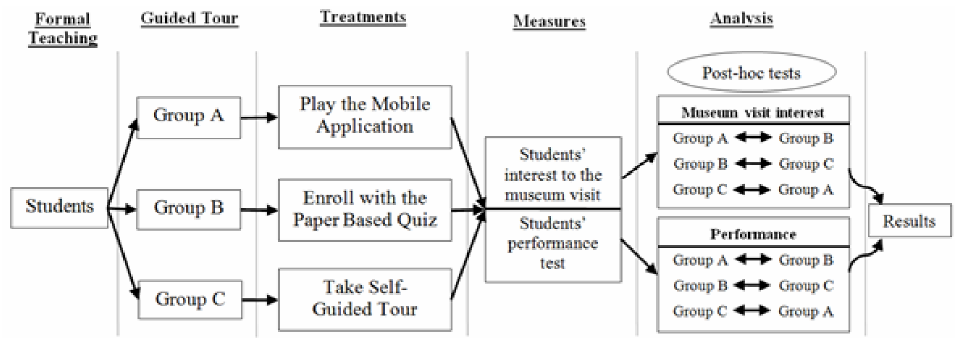
We used two software tools for implementing the MuMoQuiz, a QR application and a quiz application. The only hardware requirement for running the software is a Java-enabled mobile phone. A camera feature was a requirement for the QR application.[1] The design of the questions was implemented with MyMLE[2] application, which allows the creation of mobile learning content. A future version of MuMoQuiz could be a smartphone application, which integrates the QR and the quiz functionality into one user terminal device.

4 Methodology

4.1 Experimental design

The study consisted of the following stages (Figure 5): (a) formal teaching in the classroom, (b) guided tour in the museum, (c) treatments, (d) measures (performance test and museum visit interest survey), and (e) analysis of performance and interest. This type of design is generally not considered as strong as a randomised experiment (Cook et al., 2002); however, according to Marczyk et al. (2005) a non-equivalent groups post-test design has potential application in representing a different type of teaching method, which applies to our case since the game was integrated with the educational process. In order to strengthen the design, we also introduced a control group. According to the analysis that took place at the beginning of our study, there was no significant difference among the three groups in terms of age, gender and school grades.

Figure 5 Graphical representation of the methodology of the experiment



4.2 Participants

The initial sample of the study was 61-grade lyceum (upper general secondary school) students, aged between 15 and 16 years. All the students were attending an elective course in ICT and a multimedia course at a general lyceum at Corfu, Greece. For the study, we employed three groups of 20 students each, which corresponded to the three different classes of the aforementioned course (mobile-based game, paper-based game, and the passive guided tour). Group A consisted of 16 males and four females, Group B consisted of 17 males and three females, and Group C consisted of 16 males and four females. It should be noted that according to the school's policy, students were assigned to the classes of the elective course in a rather 'random' manner. At the initial sample of 60 students, we had five drop-outs, one female student from Group A, two female students from Group B and two male students from Group C, leaving a total of 55 (19 for the first group and 18 for the remaining two). The drop out was 5% ($N = 1$) for the first group (MB) and 10% ($N = 2$) for each of the remaining two groups. Although some students did not attend some part of the study, the drop-out rates are quite low and the groups can be considered approximately equal.

4.3 Data collection instruments

The main measures employed in our study were the data from the performance test and the data from the survey (interest to the museum visit). In addition, we used the data from the learning activity (i.e. time limit, number of correct answers) in order to get a more complete view of the study. In particular, the playing time, the number of correct answers, and the number of second answers were collected from the game. The performance test consisted of 12 multiple-choice questions. Students were presented with a series of pictures and had to choose one out of the four qualities that was more accurate. The quality was referring to the same visual elements that were also employed during the game, which were combinations of all of the following: primary and secondary colours, warm and cold colours, geometric and organic shapes, depth and perspective. The final performance test was identical for the three groups.

A 13-item questionnaire was developed to assess students' attitude towards ICT and their interest in the museum (and game) experience. In order to explore the interest in the visit, we relied on a self-report with a 5-point Likert-scale. Owing to the lack of relative research in the field of arts, the questions used followed the 'pattern' of other educational fields, like mathematics and physics (Harackiewicz et al., 2008; Hulleman et al., 2008). For all responses, we employed a balanced interval scale with values from 1 to 5 (1 for strongly agree and 5 for strongly disagree).

4.4 Procedure

The study was conducted over a three-week period. During the first week, students participated in formal classroom teaching. During the second week, students visited the Art Gallery (Figure 5) of the Municipality of Corfu. The final performance test (attitudes questionnaire and final test) took place during the third week.

During the first week of the study, students were instructed on the basic principles of visual elements in works of art in the classroom. The teaching lasted two school hours, and the lessons followed guidelines set forth by the Greek Ministry of Education. The traditional teaching method was based on the teachers' lecture in conjunction with discussion with the students' (mostly answering students' questions). Teachers also presented students with paintings exemplifying the educational concepts through use of the Artist's Toolkit (Artconnected[3]), which has been designed for teaching visual elements. The main objectives of these lessons were the presentation of the visual elements (line, shape, colour, space, texture) and their characteristics. For instance, the main attributes of 'colour' are Primary & Secondary, Warm & Cool, Complementary, Natural & Arbitrary and Tints & Shades, and the main attributes of 'space' are Depth, Positive & Negative and Linear & Aerial perspective.

In the following week, each of the groups visited the gallery at a different time, and attended a guided tour. The duration of the tour was approximately 45 minutes. Upon completion of the tour, students from Groups A and B were briefed on the rules and participated in the learning activity (mobile-based and paper-based, respectively) (Figure 6). The students of Group A were also provided with mobile phones with a sample quiz, as well as sample QR codes in order to familiarise themselves with the software. The same devices were used during the learning activity. Students of Group C given instead 30 minutes extra time to spend at the gallery (extended tour), in order to identify visual elements on their own as they wished. For the final week of the study, the students from all three groups took the final performance test (assessment) and answered the ICT attitudes questionnaire.

Figure 6 Students completing the interactive quiz were immersed in questions displayed on their mobile phones (see online version for colours)

4.5 Data analysis

Firstly, in order to examine the difference in correct answers in MB and PB treatments, we conducted a Mann–Whitney U test among Group A first answers and Group B answers. In order to examine the improvement of interactivity when the second (i.e. final) answers for Group A were taken into account, a Mann–Whitney U test was also conducted among Group A second answers and Group B answers.

Aside from the data provided by the correct answers of the learning activity, this study also gathered information from the final performance test (post assessments). A Games–Howell criterion was utilised in order to separately examine for each group the influence of (a) mobile-based game, (b) paper-based game and (c) extended tour guide on the students' performance and interest. The Games–Howell criterion is a modification of Tukey's HSD test, which is appropriate for situations of unequal sample sizes and unequal variances when examining all pairwise comparisons (Toothacker, 1993).

5 Results

5.1 Trial and error during informal learning

Students from both Groups A and B spent approximately 19 minutes on average at the gallery during the game session. Students from Group C, given an additional 30 minutes, used approximately 20 minutes in the gallery. We can therefore safely assume that all three groups spent roughly the same total time at the gallery.

To address the difference in correct answers between MB ($M_1 = 8.84$, $SD_1 = 1.80$) and BP ($M_2 = 9.22$, $SD_2 = 2.07$) games, a Mann–Whitney U test was conducted. Using a Mann–Whitney U test of two groups, Groups A and B ($U = 145.00$, $z = -0.805$), the results showed a statistically insignificant difference ($p = .421 > 0.05$). Students from Group A had an average rank of 17.63, while students from Group B had an average rank of 20.44. Consequently, there is no significant difference between MB and PB game correct answers.

Owing to the interactivity (feedback) of the MB version of the game, students from Group A had the chance to correct an incorrect answer; however, when the final answers of Group A are taken into account ($M = 10.95$, $SD = 1.22$) the results are completely opposite. Therefore, a Mann–Whitney U test was conducted, only this time the second (i.e. final) answers for Group A were taken into account ($U = 84.0$, $z = -2.71$). The test indicated that there is a highly statistical difference between the answers of the two Groups A and B ($p = .007 < 0.05$). Students from Group A had an average rank of 23.58, while students from Group B had an average rank of 14.17.

5.2 *Post-visit performance assessment*

To examine the research questions regarding post-visit learning performance, an assessment was conducted using the Games–Howell criterion, which is most appropriate for situations of unequal variances when examining all pairwise comparisons (Toothacker, 1993). Post-hoc analyses were conducted to verify whether the different learning procedures (Group) are related to the different performance of the students. The results (summarised in Table 2) highlighted a significant difference between the performance of Groups A and B. Additionally, post-hoc tests also revealed an insignificant relationship between Groups B and C, as well as Groups A and C.

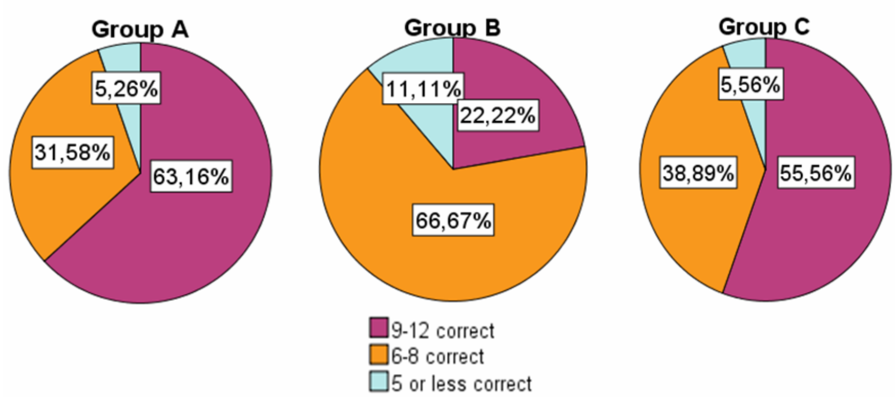
Table 2 Testing the differences in performance among the three groups

	Mean (SD)		*Mean Difference (I–J)*	*Std. Error*	*Sign.*
	(I)	*(J)*			
Performance	Group A 9.00 (2.08)	Group B 7.28 (1.67)	1.72	0.62	0.02*
	Group B 7.28 (1.67)	Group C 8.50 (1.79)	–1.22	0.58	0.10
	Group C 8.50 (1.79)	Group A 9.00 (2.08)	–0.50	0.64	0.72

Note: *$p < 0.01$; SD, Standard Deviation.

In addition to the test for the statistical difference of students' performance among the groups, we conducted a frequency analysis among all the groups. Based on the frequency analysis between Groups B and C, it can be inferred that even though both methods produced almost the same performance in the experiment, Group C produced a greater academic performance than Group B (Figure 7).

Figure 7 Frequency diagrams of correct answers for the three treatment groups (see online version for colours)



5.3 Interest in the museum visit

To examine the research question regarding students' interest in the museum visit, post-hoc analyses were conducted using the Games–Howell criterion to verify whether the different learning procedures (Group) are related to students' interest for museum experience. The results (summarised in Table 3) highlighted an insignificant difference among all the Groups. This indicates that playing games (using mobile or not) does not influence students interest for the museum experience.

Table 3 Testing the differences in interest among the three groups

	Mean (SD)		*Mean Difference (I–J)*	*Std. Error*	*Sign.*
	(I)	*(J)*			
Interest	Group A 3.16 (0.83)	Group B 3.33 (0.91)	–0.18	0.28	0.80
	Group B 3.33 (0.91)	Group C 3.61 (0.78)	–0.28	0.28	0.59
	Group C 3.61 (0.78)	Group A 3.16 (0.83)	0.45	0.28	0.24

Note: $*p < 0.01$; SD, Standard Deviation.

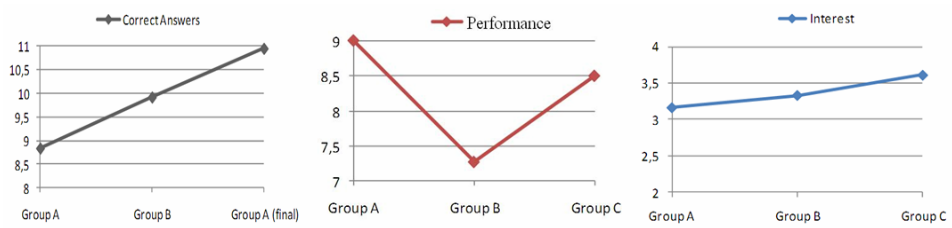
6 Discussion

According to the results of students' final performance, no student in Group A scored less than five correct answers on the final test, while one student from each of the remaining two groups did. Additionally, 21.0% ($N = 4$) of the students in Group A answered all 12 questions correctly on the final test, while none of the students from the other groups did. The statistical analysis indicates a significant benefit to students' performance in usage of the MB version of the game over the PB version; however, in comparison to the extended tour, no significant difference resulted. The above findings may be explained by the fact that informal learning activities are beneficial for the learners, but a game (either electronic or non-electronic) used in that environment must feature incentive (i.e. interactivity) to attract and engage students.

According to Oblinger (2004), game activities have many attributes associated with learning. The attributes we included in our activity are: activation of prior learning, feedback and assessment, social, experiential. The last three of them apply to a higher degree in the MB version of the game due to feedback that was provided during the game. Therefore, not only students were able to assess their progress during the activity, but they also had to discuss actively in order to find the right answers. The opportunity to experiment was also an asset provided to them through the option of having a second chance in answering, since 'Learning is often by trial and error: hypotheses are tested and users learn from the results'.

Regarding the results of the correct answers in the learning activity (Figure 8, left), Group A's first correct answers are less than Group B's correct answers. This result can be explained by the fact that Group A students know that they always had a second chance, so they answer without through the question thoroughly. On the other hand, Group B students know that they had only one answer, so they are more careful with their response. Group A's second (i.e. final) correct answers are reasonably higher than in the other groups, as the second chance eliminates their first incorrect answer and gives them more possibility to find the correct answer.

Figure 8 Diagram regarding correct answers during the visit (left), post-assessment of learning performance (middle) and interest in the museum visit (right) among the groups (see online version for colours)



Regarding the results in the assessment (Figure 8, middle), Group A has the most correct answers, followed by Group C, and then Group B. Although we expected the success of Group A, we did not expect that Group C would have more correct answers than Group B. Between Groups A and B (the groups trained by MB and PB version, respectively), the results exhibit a significant difference. As such, the enrolment (training) with an interactive activity (as opposed to a non-interactive activity) provides benefits to the learner to acquire knowledge. In the case of Group C, there is no significant difference in the performance with either Group A or with Group B.

Regarding the results in the level of interest of the students for the museum visit (Figure 8, right), there is no significant difference among the groups. We hypothesised the learning activity could have decreased the interest in the museum visit and that the effect could be higher in the MB version of the learning activity. Although the control group that did not participate in the learning activity reported higher interest in the museum visit, there was no significant difference among the three groups. The results appear to following our reasoning, though, as Group A exhibited interest in the museum on a lower level, Group B on a moderate level, and Group C on a higher level.

The most significant finding is that the use of the interactive mobile application increased the performance in the final performance test. The study shows that interactivity of the MB treatment has a significantly positive impact on knowledge acquisition during the game, when compared to the PB version. Therefore, the introduction of immediate feedback in informal learning activity contexts can benefit students' performance.

In summary, the MB activity design was successful, mainly for the following reasons:

- The activity relied on gameplay, featuring a set of rules that increased competition.
- Mobile devices did not speed down or pose any limitation to the learning activity.

Moreover, it provided instant feedback (interactivity) that reinforced learning.

- The introduction of MB activity did not take the interest out of the physical setting; students still focused on the painting to identify the visual elements.
- The activity was designed to be an integral part of the educational process – not a standalone event.

7 Conclusion

Previous research has already proposed advanced educational technology for enhanced learning, both formal and informal. In the case of informal learning, interactive mobile applications provide an opportunity, but previous works have only considered technological features and usability performance. Indeed, there has been limited work on actual benefits of interactivity to informal learning. In our work, we emphasised the integration of formal and informal learning, and most importantly the integration of an interactive mobile application into informal learning. Moreover, we have evaluated the proposed interactive application in a controlled setting and compared the performance and attitudes of students with alternative levels of interactivity. Therefore, this work contributes to the following research and practice issues: (a) design of informal learning activities and integration with formal ones, (b) practical suggestions for teachers and curators, and (c) methodology for elaborate experimental measurement of informal learning activities.

The trials have shown that the MB activity can successfully bridge the museum-classroom gap by facilitating the teachers' design of formal teaching with the informal activity. Prior formal teaching enables students to explore the artefacts in the museum. New tools (i.e. mobiles phones) that enable learners to perform new activities may change the way they perceive and carry out old activities (with more interaction). In addition, this study provides evidence that the integration of informal learning activities (i.e. interactive mobile application in a museum) with formal learning (classroom teaching) motivates students to engage in the informal activity, thereby resulting in better performance.

For the case of teachers and curators, this study provides insights and suggestions regarding the visitors' interest and knowledge acquisition during a museum visit. The role of museums in education varies across groups, which may complicate their relationship to museum experiences. For example, some curators may simultaneously express a very strong commitment to education, fail to see museums as a place where education happens, and defer to teachers and schools on matters related to educational practice. In view of the results of our study, museum curators may carefully use interactive applications in order to maintain visitors' interest in the museum. Additionally, when teachers are using activities in out-of-classroom contexts (i.e. museums), they should enrol as much interactivity as they can in order to increase knowledge acquisition.

In conclusion, the current study is one of the few so far testing the influence of interactivity of a mobile application in students' performance. Conducting a field study of this kind with a sample of 60 students was not an easy task because several parameters must be considered, such as domain theory, mobile application development, learning activity, and coordination with stake-holders in an informal learning context. Nevertheless, the results indicate that this effort is worthwhile, because the mobile-based activity ultimately had a positive effect on students' performance without significantly affecting their interest in visiting the gallery. Moreover, the evaluation framework that was presented in the methodology section (Figure 5) provided an efficient way to structure both the data collection and analysis for the evaluation in an integrated format of formal and informal learning.

The findings of this study must be interpreted in light of some potential limitations; these limitations should be considered for future research to increase the generalisability of the results. First, this study was conducted in a single context with specific content and instructions. Second, the design was limited to students at one grade level and was not longitudinal; therefore; the data could not reveal the continuation of the students' behaviour. Despite these limitations, the findings generate valuable insights, which can be used as part of hypotheses for representative follow-up studies in technological tools' educational performance and experience.

Further studies should consider the effect of the learning activity in different topics (e.g. math, science, history). It is also worth investigating the effect of interactivity on students' performance over a long-term period, as well as between groups of students that only receive formal training. In further research, we plan to examine students' performance and attitude towards high definition graphics and augmented reality applications.

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Notes

1 http://qrcode.sourceforge.jp

2 http://mle.sourceforge.net

3 http://www.artsconnected.org/toolkit/index.html