

The Use of Quick Response Codes in the Classroom

Jenni Rikala
University of Jyväskylä
Agora Center
P.O.Box 35, FIN-40014 FINLAND
jenni.p.rikala@jyu.fi

Marja Kankaanranta
University of Jyväskylä
Agora Center
P.O.Box 35, FIN-40014 FINLAND
marja.kankaanranta@jyu.fi

ABSTRACT

The purpose of this article is to explore and analyse teaching methods and processes that incorporate Quick Response (QR) codes and mobile devices into the classroom. Quick Response codes are two dimensional barcodes that are used to encode and decode information. QR codes can contain information such as text, URL links, automatic SMS messages, or just about any other information that can be embedded in a two-dimensional barcode. This encoded data can be decoded by scanning the barcode with a mobile device that is equipped with a camera and QR reader software. Although QR codes are very versatile and have been around for over fifteen years, their use in education is still in its infancy. This paper introduces the available implementations of QR codes in education. These implementations were developed with teachers to correspond to their needs and wishes. The students were very enthusiastic and motivated but the teachers' attitude was more sceptical. The main feedback from the teachers was that the planning of QR activities is an arduous task when one is not familiar with QR codes or the ways to utilize them. In our study we found that QR codes can support learning in different contexts. We also found that QR codes can support both independent and collaborative learning and that QR codes can motivate and engage learners.

Author Keywords

Quick Response (QR) Codes, Mobile Learning, Independent Learning, Collaborative Learning

INTRODUCTION

Mobile technologies have changed our societies in many respects. They have affected the way people interact with each other and how they communicate, work and spend their leisure time. Mobile devices, systems and technologies are now universally owned, accepted and used. As a consequence, also the meaning and significance of learning are changing. (Traxler, 2009)

Mobile technologies can respond to these changes in learning. Researchers and educators have recognized the potential of mobile technologies as learning tools, and mobile technology has promoted a new learning style, mobile learning. By mobile learning we mean learning that happens when the learner is not in a fixed, predetermined location and/or learning that happens when the learner takes advantage of the learning opportunities offered by mobile technologies (O'Malley et al., 2004). At best, mobile technologies facilitate learning outside of the classroom, and learning materials are no longer limited to textbooks (Shih, Chu, Hwang & Kinshuk, 2011).

The study of QR codes in education can be placed in the context of mobile learning. Research has been conducted on mobile learning all over the world but only a few studies have addressed the use of QR codes in education (Law & So, 2010). The aim of this study is to explore and analyse teaching methods and processes that incorporate QR codes and mobile devices into the classroom. This article is organized as follows: first the theoretical background is discussed, after which we will move on to provide examples of applying QR codes in an educational setting. There is a variety of ways to use QR codes in an educational context, which, based on our literature review, can be divided into five main categories. We introduce these five categories as well as our QR experiments and the responses received from the students and the teachers. We carried out five different QR experiments in schools in Central Finland in May 2012. We will conclude the paper with reflective remarks.

THEORETICAL BACKGROUND

Learning is changing and the educators, employers, parents and the public have begun to emphasize the need for lifelong learning and 21st century skills. Technologies can respond effectively to these changes in learning and technologies have made many new educational forms possible. It has been shown that innovative teaching practices can support students in developing the skills they will need in future life and work (Norrena, Kankaanranta & Nieminen, 2011). Based on the literature review (Rikala, 2012), innovative teaching practices (e.g. student-centred pedagogy, extending learning beyond the classroom) can be realized through different mobile learning solutions. We found that learning with mobile technologies can be very personalized, situated and authentic and that at best mobile technology can bridge formal and informal learning, make learning more student-centered and encourage creativity and innovation.

Based on the literature review (Rikala, 2012), we can suggest that the core characteristics of mobile learning are personalisation, authenticity, and collaboration. The authenticity feature can promote learning scenarios such as contextualized, participatory and situated learning (Kearney, Schuck, Burden & Aubusson, 2012). Situated learning

activities promote learning within an authentic context and culture. Mobile devices are very well suited for context-aware applications because mobile devices are available in different contexts and are able to extend the learning environment into authentic contexts. Mobile devices can provide additional information based, for example, on the location and make available activities that are relevant to the environment. (Naismith, Lonsdale, Vavoula & Sharples, 2004)

The study of Quick Response (QR) codes in education can be placed in the context of mobile learning. QR codes are two-dimensional barcodes consisting of black modules on a white background. These square pattern codes can contain information such as text, URL links, or other data that can direct users to sources for more information about a particular place or subject. (Lee, Lee & Kwon, 2011) Users with a camera phone equipped with a QR code reader application and a data connection can scan QR codes to display text, open a web page, send automatic SMS messages, or similar. There are several different mobile apps that can be used to read and decode QR codes.

In our literature review we found that QR codes can support learning when students move in the field (e.g. in trail and field activities). With the QR codes embedded in the environment, students can obtain contextual or location-aware information (Osawa et al., 2007). QR codes also allow the implementation of innovative systems based on the paradigm of just-in-time learning and collaborative learning (De Pietro & Frontera, 2012). With QR codes it is also possible to connect digital resources to printed text. This implies the potential to enrich paper-based learning materials. These enriched learning materials can serve and motivate students with different learning needs. (Chen, Teng & Lee, 2010)

In our literature review we found that on the whole QR codes can expand the learning experience and provide authentic tasks that take place in real-world settings. Learning can happen outside of the classroom and learning materials are no longer limited to textbooks. Thus overall learning with QR codes can be very personalized, situated and authentic.

QR CODES IN AN EDUCATIONAL CONTEXT

When considering QR codes in an educational context, it is important to see QR technology as an enabler. The focus should be more on the learners and pedagogy than on QR technology, as mobile technologies do not guarantee enhanced learning by themselves. The potential for mobile learning is dependent on the provision and development of pedagogically meaningful opportunities and environments that enhance learning. The intention should be to promote more learner-centered learning, not to bind teaching and learning to mobile devices. (Zhang et al., 2010)

There is a variety of ways to use QR codes in an educational context. Our literature review indicated that they can be divided into five main categories as follows:

- Trail activities or treasure hunts (Law & So, 2010)
- Outdoor or field activities (Lee et al., 2011; Law & So, 2010)
- Paper-based tasks (Law & So, 2010)
- Learner generated content (Mikulski, 2011)
- Working instruction (Walker, 2010)

In trail activities or treasure hunts, pupils or students explore their communities and solve problems that relate to what they find. This kind of activity can be organized in the form of collaboration or competition between the students but may also be used to support individual study. Law and So (2010) carried out a math trail activity in which students explored their communities and created one or more math problems that related to what they found. At each location, the students answered a question by scanning a code and writing down their answer. Law and So (2010) discovered that the students found the activity interesting and they were very curious about the new approaches that deviated from their routine exercises.

In outdoor or field activities, pupils or students can explore life science subjects such as species of wild fauna or flora. A QR code can, for example, give hints when identifying the species or provide additional information about them. The code may, for example, include a link to resources that direct the learners to information about the living conditions of the species. Lee et al. (2011) incorporated QR codes and smart phones into field trips for biology classes. Students explored and identified species at the field study site using a QR code sheet and shared their results with their classmates via a social network system, presentations, and discussions. Lee et al. (2011) found that, with QR codes, teachers can create customized guidebooks for individual field studies and students learn more effectively because the code only contains information that is relevant to the matter at hand. They also noticed that QR code activities can integrate digital learning materials with field trips in a motivating way.

In paper-based tasks, QR codes can contain links to multimedia resources such as audio materials or video clips in the case of listening exercises. In paper-based tasks, QR codes can also guide learners through the self-assessment process. For example, a QR code on the worksheet can direct the learner to a web page showing the right answers and the learners can check up on how much they have learned. Law and So (2010) used QR codes to demonstrate how QR codes can be used as part of a listening exercise. They noticed that QR codes provided a very efficient and flexible way for the students to obtain the resources ubiquitously. Law and So (2010) also used QR codes to guide the learners through the

self-assessment process. The QR code printed on the worksheet directly linked to a web page with the right answers. Students' feedback indicated that it was more convenient and quick to use mobile devices and QR codes for individual exercises.

In learner-generated content, learners can produce reports or other materials online and share their work with QR codes. For example, students can record book reviews and attach the QR code to the inside cover of the book or they can write children's books and record their reading and then add QR codes linking to the audio to create an interactive reading experience. At best, this approach can support learner-centred learning.

In working instruction, the teacher can give directions and information to students on how to complete their assignments. For example in art workshops, QR codes can be placed on pieces of equipment such as different kinds of brushes, or in an engineering workshop on different electronic equipment to guide students in their use. At best, this approach can support independent learning.

These above-mentioned activities and tasks can, of course, be mixed and combined. For example, there could be an outdoor treasure hunt and a paper-based task combined with a trail activity. In our experiments, we mixed and combined a variety of different types of activities. In the next chapter, we introduce our QR experiments and the responses we received from the students.

RESEARCH DESIGN

We carried out five different QR experiments in schools in Central Finland in May 2012 (Table 1.). The aim of the study was to explore and analyse teaching methods and processes that incorporate QR codes and mobile devices into the classroom. Our research methods included surveys and observations. We had a different survey for the primary school students and the secondary and upper secondary school students. The survey scales differed: the questions and the scales were easier for the primary school students.

School	Duration	Equipment	Grade level	Sample
Primary school 1	1 hour and 40 minutes 1 hour and 40 minutes	Loaned out by the researchers	3 rd -4 th grade students (aged 9-10 years) 5 th grade students (aged 10-11 years)	17 students 25 students
Primary school 2	2 hours and 30 minutes	Loaned out by the researchers, a few students used their personal devices	5 th -6 th grade students (aged 10-12 years)	15 students
Secondary school	2 x 45 minutes	Loaned out by the researchers	7 th grade students (aged 13-14 years)	15 students
Upper secondary school	30 minutes	Personal devices belonging to the school	Second year students (aged 17-18 years)	4 students
Total				76 students

Table 1. The experiment design.

In primary school 1, we arranged a treasure hunt for 3rd-4th grade students and for the 5th grade students. The overall objective of the lesson was to enhance the students' information retrieval skills and to bring some change to a traditional school day. The QR activity was planned out so that there was collaboration and also some competition among the students. Different coloured QR codes guided the students through the route. Each coloured QR code gave a hint of where to find the next code. Near each coloured QR code, there was a black QR code that contained the actual task. This task was an information retrieval task, which the students completed after the treasure hunt on a computer. The team that racked up most right answers was rewarded with applause. The students were very enthusiastic even though there were some technical problems: the mobile phone's camera and QR code reader did not always work as expected.

In primary school 2, we arranged a paper-based trail activity that guided learners through the self-assessment process. The activity also included collaboration between the students and learner-generated content. The overall objective of the lesson was to teach topics relating to physics. The primary school 2 teacher was eager to test new teaching methods and volunteered to design and test a QR activity. In the QR activity the students completed a group work and research task on topics relating to physics such as renewable and non-renewable energy sources. Each group prepared a web page about their main findings, a worksheet with questions, and an embedded QR code, which provided a link to the group's web page. The worksheets were distributed around the school and the students went through them trying to answer the questions. If the students did not know the right answer, they could scan the QR code and try to find the answer on the web page. The students were very enthusiastic even though there were some technical problems with signing on to the web page with mobile phones.

In the secondary school, we arranged a story trail activity for the 7th grade students. The main idea behind the QR activity was that the students would plan two stories: one in the classroom by using traditional methods and the other by going round the QR code trail in the woods. Actually the contents of the help questions were the same in the woods and in the classroom. The aim was to study if the students would get more inspiration in the woods than in the classroom. In the QR code trail, it seemed that planning the story remained in a secondary role. Some students played music on their phones; some discussed completely different matters, etc. It seemed that the code reading part was interesting but the activity itself was not. There were also some technical problems: the phone's camera and QR code reader did not always work as expected, which caused disorder.

In the upper secondary school, we arranged a QR activity that guided the students at the gym (Figure 1).



Figure 1. Preparing and implementing a QR code activity at the upper secondary school.

This upper secondary school was looking for new ways for distance education and independent learning and was enthusiastic to test the potential of QR codes. The physical education teacher planned and prepared with the help of a media assistant videos that showed how to do gym movements correctly. These videos were transferred to YouTube and this YouTube link was embedded in a QR code. Four students were chosen to test these QR codes. The students scanned the QR codes with their mobile device's QR code reader and watched the videos. After watching the videos, the students performed the movements. The situation was not natural because there were four adults and four students at the small gym. Two adults were teachers documenting the activity for the school's purposes and the other two adults were researchers. One researcher took photos and another wrote down observations. As a result of the confusing situation, the students did not show much enthusiasm. QR codes will, however, remain at the gym, which will allow the students to take advantage of them later on. This time, no technical problems occurred during the test. In the upper secondary school, the students used tablet PCs to scan QR codes and watch the videos. A tablet PC's display is larger than that of a mobile phone, which made watching the videos easier.

RESULTS

Teachers' feedback

In primary school 1, the activity was mainly planned by the researcher with the help of the school's school assistant. Because of this, the two teachers made very few comments on the activity. Both of them noticed that the pupils really liked the activity. The 3rd-4th grade teacher said that he should do more information retrieval with his class because the students had problems with the search words. The 5th grade teacher commented that the students seemed enthusiastic and that it was exciting for the students to circulate within the school as a group.

The feedback from the teacher of primary school 2 was that the experiment involved a lot of work. The teacher said that the most time-consuming part was verifying that the material is accessible on different kinds of mobile devices. The teacher said that many multimedia resources such as animations do not, unfortunately, work on smart phones. The teacher suggested that textbook publishers could locate working multimedia resources and embed them in textbooks with QR codes. The teacher also considered that QR activities worked better with mobile devices that have a larger display. However, the teacher said that the pupils really liked working this way and that their motivation was high even though the only new things were loaned phones and QR codes. Nevertheless, the teacher was very glad that with QR codes the students can return to previously taught matters whenever they want, which can promote deeper learning. The teacher is going to continue the use of QR codes and is trying to find and develop new ways to use QR codes in an educational context.

The teacher from the secondary school said that it is important to plan the QR activity well in advance. The teacher had noticed that the activity failed to motivate the students because its contents were the same outside and inside the classroom. The teacher also considered the novelty effect. Nevertheless, the teacher said that schools really need more experiments of this kind.

The teacher from the upper secondary school said that YouTube videos and QR codes can support independent learning very well. The teacher also reflected on the use of QR codes in their school and said that QR codes could be utilized in different kinds of group work as well as in homework. The teacher also pointed out that the QR codes can, in certain situations, take the attention from the substance but that they are nonetheless well worth a try.

Student feedback

The student feedback from primary school 1 and primary school 2 was very positive. 49% of the students agreed that they learned new things with QR codes and 79% somewhat agreed that they learned new things about phone use. 42% of the students somewhat agreed that they needed help with QR codes. This is because there were some technical problems with the smart phones used. (Figure 2.)

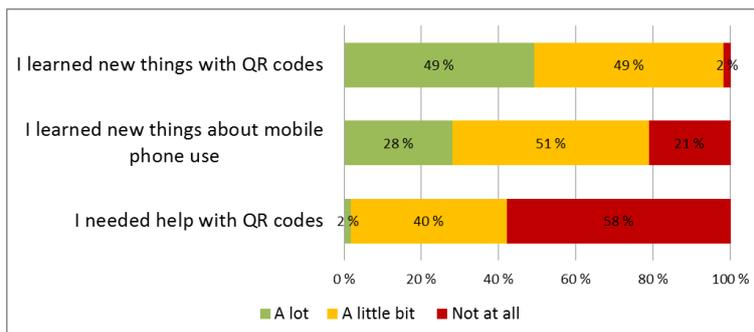


Figure 2. Primary school pupils’ feedback on learning with QR codes (n=57).

67% of the primary school 1 and primary school 2 students agreed that it was easy to use QR codes and 82% agreed that it was easy to read from the mobile device’s display. (Figure 3.)

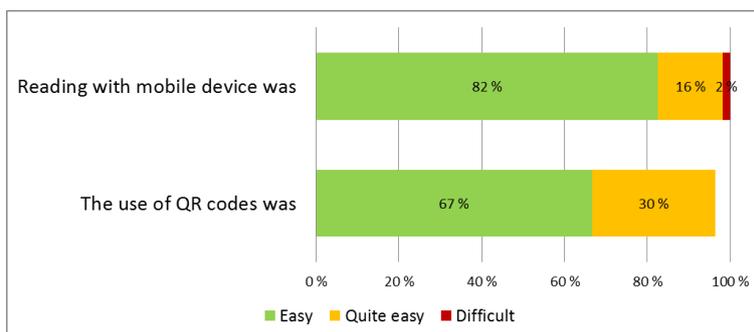


Figure 3. Primary school pupils’ feedback on the use of QR codes (n=57).

95% of the primary school 1 and primary school 2 students agreed that QR activities were an interesting new way to learn and 98% of the students would like to do QR activities again. Some students had difficulties with their smart phone and this is why 30% of the students disagreed with the statement that the phone always worked as they wanted. (Figure4.)

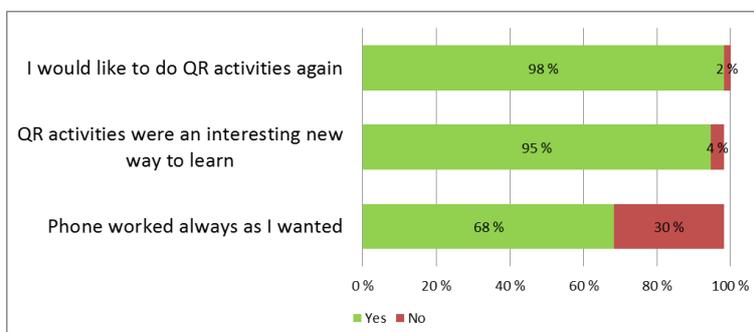


Figure 4. Primary school pupils’ feedback on QR codes motivational aspect (n=57).

In primary school 1, a girl wrote that “it was really fun even though the phone did not work very well.” Another girl wrote that “the QR activity was a really nice variation to the normal school day!” A boy wrote that the experiment was “fun but I didn’t grasp the idea.”

In primary school 2, a girl wrote that “it was really fun and nice. It was nice to learn in a different way rather than by reading a book. There were some problems with the phone but it was fun!” A boy wrote that the class was “more fun than usually.” Another girl wrote that “it was fun and I learned to use QR codes.”

53% of the students from the secondary school and the upper secondary school strongly agreed that it was easy to use QR codes and only 5% of the students thought that they had to learn many new things before they could use QR codes. 26% of the students strongly agreed that QR codes should be utilized more in education. 16% of the students strongly agreed that they learned new things with QR codes and the same number of students strongly agreed that QR codes are motivating. Only 11% of the students thought that QR codes are useless. 53% of the students somewhat agreed that QR codes can provide more information. What is surprising is that 37% of the students somewhat agreed that when using QR codes, the attention is drawn too much on technology. This is probably because the activity itself was not well-planned and did not motivate the students. When the activity is not well-planned, the attention of the students may be diverted to something else. Also the technical problems may have had a negative impact on motivation. (Figure 5.)

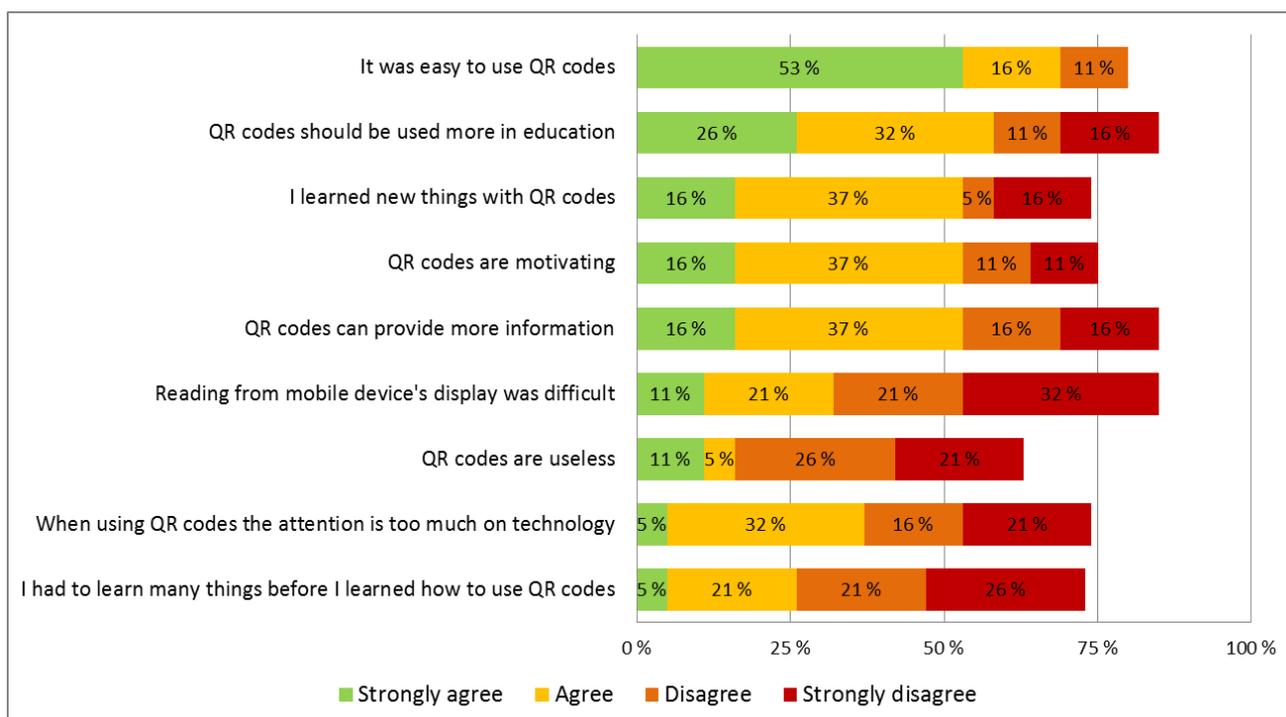


Figure 5. Secondary school and upper secondary school students feedback (n=19).

The secondary school students criticized that the contents were the same in the woods and in the classroom. A girl said that “there is no inspiration anymore because we already planned one story in the classroom.” There were also some technical problems and afterwards the students commented that “my phone’s camera did not read the codes correctly.” In the secondary school, the students’ feedback was inconsistent but slightly positive. A boy wrote that “everyone concentrates better when the teaching is varied.” But another boy wrote that “I think that it was a totally useless activity. It was good that we were able to go outdoors during the lesson, though.” A girl wrote that “QR codes were a bit difficult to use but they motivate to learn and it was fun.” Another girl wrote that “it was nicer than traditional learning.”

In the upper secondary school, the students did not show much enthusiasm. This is perhaps because the conditions were not natural. There were four adults and four students in a small gym. Nevertheless, the students did go through all the codes and made all the movements. One student said that he learned a new movement with a QR code, and also the survey showed that the students thought that they had learned new things with QR codes. The students disagreed that the attention would have been too much on technology. One student wrote that “QR codes can tell you more than you could learn by reading a book.” One student, however, considered that the students might concentrate on irrelevant things but that at best learning with QR codes can be quick.

Technical and pedagogical challenges

Technology can bring challenges to education. The students' motivation can suffer and they become frustrated if they encounter problems with technology. The software that we used for decoding the QR codes was slightly unsteady and some students grew impatient with it. In the future it would be reasonable to test various QR code readers.

Also the scanning of the QR codes could become more difficult depending on the circumstances. In our experiments we noticed that a rounded surface can twist the code and interfere with the scanning. Also reflections, lighting and shadows can interfere with the scanning. Targeting the QR code scanner also calls for accuracy. The first QR code was always the trickiest for the students but when they learned how to use the scanner properly the following codes were much easier for them and their frustration declined.

In primary school 2 the contents did not scale to the display properly and because of this signing on to the web page and searching for the right information was a bit awkward for the students. The most notable problem was the small screen and tiny keys of the loaned equipment. The contents should be designed so that they are proper for mobile learning. Gu, Gu, and Laffey (2011) emphasized that the usable mobile learning products should be practical, micro and simple both for content and activity. Based on our experiments we can agree with this point of view.

DISCUSSION

This study explored and analysed teaching methods and processes that incorporate QR codes and mobile devices into the classroom. Our primary data indicated that with QR codes it is possible to enhance personalized, situated and authentic learning as well as collaboration, which are also core characteristics of mobile learning.

We found that with QR codes it is possible to arrange activities where students move in the field or in the community. This is consistent with Law and So (2010), Lee et al. (2010) and Osawa et al. (2007) who reported that with QR codes embedded in the environment students can obtain relevant information. Our experiments showed that with QR codes learning can happen in different contexts such as the woods, the gym, and the school surroundings. We also found that learning materials and activities embedded in QR codes can be designed so that they are contextual or location-aware, in other words relevant to the environment like the gym. Just like Law and So (2010) and Chen et al. (2010), also we found in our experiments that with QR codes it is possible to enrich paper-based learning materials. We also found that QR codes can support collaborative learning. This is consistent with the findings of De Pietro and Frontera (2012) who reported that QR codes allow the implementation of innovative systems based on the paradigm of collaborative learning.

To clarify our findings that QR codes can enhance personalized, situated and authentic learning as well as collaboration, more thorough and longer-term evaluations should be conducted. Our study has limitations. One major shortcoming of our study is that we did not measure learning effects sufficiently. We are going to examine the learning effects, especially the added value, in more detail in our future experiments. Another notable shortcoming of our study is that we did not control the novelty effect. Our future experiments would be more thorough and longer-term. For a longer-term period the bias of the novelty effect can be controlled better.

Our aim in future experiments is to find more proper educational uses of QR codes and to categorize them. We also expect that our future work will offer examples and tips for teachers on how to utilize QR codes in an educational context and that way we can promote mobile learning.

CONCLUSION

The use of QR codes in education is still in its infancy and published studies on the subject are few. We carried out five different QR experiments and explored and analysed how QR codes work in an educational context. A longer test period is required to gain more profound knowledge about their impact on learning. In our future experiments we will examine the learning effects in more detail.

In our experiments we found that teachers are somewhat sceptic about the use of QR codes in education. However, teachers who have tested QR codes in education say that they are worth a try. We found that the teachers' main feedback was that planning a QR activity is an arduous task especially when one is not familiar with QR codes and the ways to utilize them in an educational context. This might be why QR codes are not commonly used in education: it simply takes too much of the teachers' time and energy to interweave all crucial aspects together. There should be more examples and tips available to teachers on how to utilize QR codes in an educational context. In this paper, we introduced some examples and implementations of QR activities in an educational context.

Our experiments showed that it is important to take the pedagogical aspect into account when planning QR activities. The focus should be more on the learners than on the technologies used. When the focus is too much on technology and the activity is not well-planned, it fails to motivate the students and their attention may be diverted to something else. We also noticed that technical problems may have a negative impact. The students' motivation can suffer and they become frustrated if they encounter problems with technology.

Just like Law and So (2010), we also found that the students considered the QR activities to be interesting, and the students were very curious about these new approaches that deviated from their routine exercises. We found that the general perception of the students and pupils of QR codes in education was positive. They found QR codes motivating especially when the QR activity was well-planned and organised and the technology was functioning well. The students also liked getting out of the classroom. In some cases technical problems affected their motivation negatively, but, overall, the students and pupils were very enthusiastic and motivated and said that they learned new things with QR codes. In our experiments, the students also stated that QR codes brought much-wanted variation to the school day. Our

experiments indicated that QR codes could be an effective way to motivate and engage students in learning but the novelty effect should be inspected in more detail.

In our study we found that QR codes can support learning in different contexts (e.g. in the woods, in the gym, within the school surroundings). Our experiments showed that with QR codes, learning can be extended beyond the classroom, and learning materials will no longer be limited to textbooks. Learning materials could be videos, texts, pictures, etc. Our experiments also showed that QR codes can support independent learning as well as collaboration.

ACKNOWLEDGEMENTS

This study and the pilot tests were part of the Personal Mobile Space project. The Personal Mobile Space project is coordinated by The University of Jyväskylä, Agora Center. The study would not have been possible without the support and help of many people. We would like to extend our sincere gratitude to all the teachers and students for their co-operation which helped us in the completion of this study.

REFERENCES

- Chen, N.-S., Teng, D. C.-E., & Lee, C.-H. (2010). Augmenting Paper-Based Reading Activities with Mobile Technology to Enhance Reading Comprehension. *Proceedings of the 6th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education* (pp. 201-203). doi: 10.1109/WMUTE.2010.39
- Chen, W., Tan, N. Y. L., Looi, C., Zhang, B., & Seow, P. S. K. (2008). Handheld computers as cognitive tools: Technology-enhanced environmental learning. *Research and Practice in Technology Enhanced Learning*, Vol. 3, No.3, 231-252. doi: 10.1142/S1793206808000513
- De Pietro, O., & Fronter, G. (2012). Mobile Tutoring for Situated Learning and Collaborative Learning in AIML Application Using QR-Code. *2012 Sixth International Conference on Complex, Intelligent, and Software Intensive Systems* (pp. 799-805). doi: 10.1109/CISIS.2012.154
- Gu, X., Gu, F., & Laffey, J.M. (2011). Designing a mobile system for lifelong learning on the move. *Journal of Computer Assisted Learning*, 27, 204–215. doi: 10.1111/j.1365-2729.2010.00391.x
- Kearney, M., Schuck, S., Burden, K., & Aubusson, P. (2012). Viewing mobile learning from a pedagogical perspective. *Research in Learning Technology 2012*, 20. doi:10.3402/rlt.v20i0/14406
- Law, C., & So, S. (2010). QR codes in education. *Journal of Educational Technology Development and Exchange*, 3(1), 85-100. Retrieved from <http://www.sicet.org/journals/jetde/jetde10/7-So.pdf>
- Lee, J.-K., Lee, I.-S., & Kwon, Y.-J. (2011). Scan & Learn! Use of Quick Response Codes & Smartphones in a Biology Field Study. *The American Biology Teacher*, Vol. 73, No. 8, 485-492. doi: 10.1525/abt.2011.73.8.11
- Mikulski, J. (2011). 10 Ways to Use QR codes in the Classroom. *Classroom in the Cloud*. Retrieved from <http://www.classroominthecloud.net/2011/06/10-ways-to-use-qr-codes-in-classroom.html>
- Naismith, L., Lonsdale, P., Vavoula, G., & Sharples, M. (2004). *Literature Review in Mobile Technologies and Learning*. Bristol, UK: NESTA Futurelab.
- Norrena, J.-M., Kankaanranta, M. & Nieminen, M. (2011). Kohti innovatiivisia opetuskäytänteitä. In M. Kankaanranta (Ed.), *Opetusteknologia koulum arjessa* (pp. 77-100). Jyväskylä, Finland: University of Jyväskylä.
- O'Malley, C., Vavoula, G., Glew, J.P., Taylor, J., Sharples, M., Lefrere, P., Lonsdale, P., Naismith, L., & Waycott, J. (2005). Guidelines for learning/teaching/tutoring in a mobile environment. MOBIlearn WP 4 - Pedagogical Methodologies and Paradigms. MOBIlearn/UoN,UoB,OU/WP4/D4.1/1.2.
- Osawa, N., Noda, K., Tsukagoshi, S., Noma, Y., Ando, A., Shinuya, T., & Kondo, K. (2007). Outdoor Education Support System with Location Awareness Using RFID and Symbology Tags. *Journal of Educational Multimedia and Hypermedia*, 16(4), 411-428.
- Rikala, J. (2012). *Mobile learning. A Review of Current Research*. Unpublished manuscript, University of Jyväskylä, Jyväskylä, Finland.
- Shih, J.-L., Chu, H.-C., Hwang, G.-J., & Kinshuk. (2011). An investigation of attitudes of students and teachers about participating in a context-aware ubiquitous learning activity. *British Journal of Educational Technology*, 42, 373–394. doi: 10.1111/j.1467-8535.2009.01020.x
- Traxler, J. (2009). Learning in a Mobile Age. *International Journal of Mobile and Blended Learning*, 1(1), 1-12. doi: 10.4018/jmbl.2009010101
- Walker, C. (2010). QR Codes: Applications in education. Learn Tech Bits. Retrieved from <http://cawa.co.uk/workshops/qr-codes-applications-in-education/>
- Zhang, B.H., Looi, C.-K., Seow, P., Chia, G., Wong, L.-H., Chen, W., So, H.-J., Soloway, E., & Norris, C. (2010). Deconstructing and reconstructing: Transforming primary science learning via a mobilized curriculum. *Computers & Education*, 55 (4), 1504-1523. doi: 10.1016/j.compedu.2010.06.016