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# Effectiveness of QR Code Technology for the Child User's Informal Learning

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## ABSTRACT

Quick Response (QR) code technology plays an important role in scaffolding the child user's active learning in informal environments. This study examines the impact of mobile phones and QR codes on two informal learning outcomes: increased interest and greater knowledge understanding. Ninety-one children and their families participated in the study as part of the iQ Zoo Project. Qualitative findings suggest that most children's interest in learning about animals was either maintained or increased as a result of the experience. Quantitative results reveal that QR Code Technology was effective in promoting knowledge gains, especially on subjects that are challenging for the informal learner.

### Keywords

Personal mobile technologies, QR codes, children, informal learning, knowledge gain.

## INTRODUCTION

QR code technology plays an important role in stimulating and scaffolding active learning amongst child users in informal learning environments (Bell, Lewenstein, Shouse, & Feder, 2009; Naismith, Lonsdale, Vavoula, & Sharples, 2004). However, empirical research on the effectiveness of such tools in supporting the achievement of desired learning outcomes in informal environments is rather limited. For example, personal mobile technologies, ranging from smartphones to PDAs, have been used to support both formal and informal learning in new and engaging ways (Naismith et al., 2004; Scanlon, Jones, & Waycott, 2005) and for diverse learning goals (Clough, Jones, McAndrew, & Scanlon, 2008). However, their effectiveness has been studied largely in contexts of formal education, especially with the adult population (e.g., Chen, Teng, Lee, & Kinshuk, 2011; Ozcelik & Acarturk, 2011). In contrast, the extent to which such devices support informal learning effectively, particularly with the youth population, has received relatively little exploration.

The purpose of the present study is to empirically examine the impact of QR code technology use on young consumers' informal learning. By applying Bell et al.'s (2009) ecological framework of informal learning, we demonstrate that QR code technology has the promise to transform education in significant ways (Martin et al., 2011). QR codes, a form of two-dimensional barcodes, are a versatile tool for supporting and communicating with personal mobile devices. QR codes are easily scannable by most commercially available mobile devices with cameras and QR code scanner software.

### QR Code Technology for Formal and Informal Learning

Research on the application of mobile phone and QR code technologies to formal learning demonstrates significant promise of these tools for enhancing particular learning goals, such as reading comprehension (Ozcelik and Acarturk, 2011) In addition to facilitating the achievement of learning outcomes, integration of QR code technology into the formal learning environment also enhances the user's attitudes towards the learning materials and experience (Huang, Lin, & Cheng, 2010).

Besides formal schooling, much learning takes place in informal environments in public spaces, such as museums, zoos or shopping malls (Bell et al., 2009; Sefton-Green, 2004) especially when interactive technologies designed specifically for encouraging social learning are available (Crowley, Callanan, Tenenbaum, & Allen, 2001). Marketers commonly use such tools for the purpose of consumer engagement or product education Traditionally, these interactive technologies tend to be permanent installations at the institution, such as dinosaur exhibits at a museum (Crowley, Callanan, Tenenbaum et al., 2001). However, as mobile technologies become pervasive in everyday life, integrating mobile technologies into informal learning environments creates new methods for engaging the user (Clough et al., 2008; Downes, 2010; Naismith et al., 2004).

### Stimulating Child User Interest

QR code technology supports information and learning needs in the moment. QR code users tend to be more innovative than non-users (Wan, Wang, & Haggerty, 2008), and the technology allows the user to actively retrieve relevant facts just in time when discovery or learning takes place (Bell et al. 2009). Having prompt access to information is crucial for the development of complex cognitive skills (Kester, Kirschner, van Merriënboer, & Baumer, 2001). Like other computer-supported education tools, QR code technology may enable just-in-time presentation of both supportive and prerequisite knowledge prior to or during a performance task. Technology-supported presentation of supportive knowledge prior to the performance task, and prerequisite knowledge during the performance task, in particular, is effective in supporting the user in acquiring complex cognitive skills (Kester et al., 2001).

While QR code technology connects the user to content that is meaningful given the user's current location and time (Naismith et al., 2004), the time sensitive nature of informal learning suggests that it is also limited temporally. Content becomes available at the time that informal learning takes place, but access to content may also disappear as the learning episode ends. QR code technology specifically addresses the temporal limits of informal learning by enabling the user to scan and store educational content for consumption at a later time. The ability to preserve meaningful content over time and across locations is what makes QR code technology particularly suitable for informal learning (Law & So, 2010).

Most importantly, QR code technology may be particularly effective for engaging informal learners of a wide age range. The ability of QR code technology to support massive personalization creates opportunities for delivering learning materials in a developmentally appropriate fashion. For example, creative presentations and the use of interactive games and puzzles may engage the young user (Naismith et al., 2004), while older users may prefer methods that are more reading-intensive. Therefore we propose the following hypothesis:

Hypothesis 1 (H1): QR code technology enhances the child user's interest in the content subject of the informal learning activity.

### Enhancing Knowledge Understanding

QR code technology allows learning to take place in context. Due to their portability and connectivity, mobile devices afford contextual sensitivity, which allows situated learning to take place in authentic contexts (Naismith et al., 2004; (Klopfer, Squire, & Jenkins, 2002); Sefton-Green, 2004). This then enables mobile devices to address three challenges common in informal learning: location dependence, time dependence, and meaningful content (Law & So, 2010).

Connectivity is a property of mobile technologies that enables context-sensitive content provision and access. Connectivity allows the user to access information that is otherwise unavailable in the immediate learning environment (Klopfer et al., 2002). The connectivity of QR code technology effectively enables information to reach and impact a wider audience than the fixed information presented by the informal learning setting (Hong et al., 2000). Moreover, connectivity allows easy management of knowledge content. Compared to designing, producing and installing physical displays of knowledge content, the maintenance of mobile content can be more cost-effective and versatile by allowing for instant updating and expansive content storage (Bonis et al., 2009). Therefore we propose the following hypothesis:

Hypothesis 2 (H2): QR code technology enhances knowledge understanding in the content subject of the informal learning activity.

## METHOD

The study reported here was designed to evaluate the two hypotheses presented above using the iQZoo project. iQ Zoo is an educational project to connect PBS Kids content with zoo animal exhibitions through personal smart phones and QR codes, and a joint effort between WQED and the Pittsburgh Zoo and PPG Aquarium. QR codes were placed around the zoo at 14 different animal exhibits. When a user scans one of the codes on a smartphone, the barcode scanner application would translate the code into an URL address that takes the user to the iQ Zoo mobile site for information about the animal associated with the code.

### Recruitment and Participants

Ninety-one children and their families agreed to participate in the study. Forty-four children with access to a smartphone and 35 children without access to a smartphone (overall mean age = 8.54, SD = 1.82) completed the entire study, resulting in 79 participating children and an effective attrition rate of 12%. Full-board Institutional Review Board (IRB) review was utilized, given the inclusion of children as a vulnerable population in the study. To protect child participants, efforts were taken to maintain confidentiality and report results in aggregate form when possible. Consenting families without smartphone access served as the control group, while families with smartphone access served as the experimental treatment group (i.e., the "smartphone group"). Group assignment was naturally occurring; that is, families with smartphones were assigned to the smartphone group while families without smartphones were assigned to the control group.

A quasi-experimental design based on prior studies of informal learning (e.g., Crowley, Callanan, Tenenbaum, et al., 2001) was implemented. During the on-site study at

the zoo, researchers recruited, screened, and interviewed families at a colorful display table near the entrance; families also approached the iQ Zoo table inquiring about the project. Both the consenting parent/legal guardian and the participating child were interviewed at baseline (i.e., upon arrival at the zoo) regarding children's interest in and prior knowledge about animals and the family's smartphone usage. The child participant also completed an educational quiz at the same time (i.e. the "pre-test"). They were interviewed again just prior to exiting the zoo regarding their use of the iQ Zoo program. The child participant completed the same educational quiz again before leaving the zoo (i.e. the "post-test"). Incentives for participation in the study included animal hats for all child participants and the opportunity after completion of the study's post-test to select a small age-appropriate prize. Similar to Palmquist and Crowley's (2004) dinosaur study within the Carnegie Natural History Museum in Pittsburgh, PA, table placement and study design helped maximize participation and minimize the potential risk of data loss due to families leaving the study prematurely before study completion.

After recruitment, on-site researchers screened all participants according to the following criteria: age of the child, presence of parent/legal guardian, and possession of a smartphone during the zoo visit. The target age range for children was between the approximate ages of five and 12 years. If a family had more than one child within the target range, all children were permitted to participate in the study. If a child was not within the age range or the adult with them was not the child's parent or legal guardian, the child was given a sticker and the adult was given information on accessing iQ Zoo's non-mobile website. Participating children and their parents or legal guardians received consent forms explaining the study procedure and the interview and testing process.

Participants most commonly used Android smartphones, with iPhone smartphones the second most common. The most common application for scanning QR codes was the Barcode Scanner, partly due to study personnel helping participants download an easily available scanner when the families did not previously have a scanner. Other scanners used by participants were the AT&T scanner, Red Optical Laser, and QR Code scanner.

The two groups were comparable in terms of the participant child's age, gender, median family income (based on the family's ZIP code[1]), parent education level[2], and geographical location. Most importantly, the two groups were comparable in internet access at home and frequency of zoo visits, because prior experience was found to be a potentially significant confounding variable in previous studies. None of the group comparisons were statistically significant. The two groups differed only in terms of smartphone ownership ($\chi^2(1) = 44.22$, $p < .0001$).

### Procedure

After obtaining informed consent, researchers orally interviewed parents and children separately. Study staff also orally read children the educational pretest. For non-smartphone using adults, completion of the baseline interview marked the conclusion of their baseline assessment. However, adults in the smartphone group additionally received a brief explanation of QR codes, aid in downloading a barcode scanner if needed, and instruction on how to scan QR codes to ensure that all smartphone families were knowledgeable on how to access the iQ Zoo information. After receiving these instructions, families received scavenger hunt passport book(s) and pens. Children also received animal hats so that iQ Zoo staff could readily identify study participants.

Participating families were asked to travel normally through the zoo and read the zoo's posted signs and information at each of the five exhibits being targeted. Families with a smartphone were additionally asked to scan each of the five target exhibits' QR codes connected with iQ Zoo project. After the families concluded their zoo experience, parents and children were again interviewed separately on their experiences and the children answered the educational post-test. After the post-test, researchers thanked the families for participating and directed the children to select one prize.

## RESULTS

### Hypothesis 1: QR Code Technology and Interest

Hypothesis 1 was tested qualitatively using the interview data. When children were asked whether their interest in animals increased after participating in the iQ Zoo experience, children either answered that they are now more interested or that they were already very interested before using iQ Zoo. One child stated, "I only knew about certain animals before," indicating that iQ Zoo expanded familiarity with different types of animals. Another stated an interest in learning about the differences between animals, such as the crocodile and alligator. Nearly all children in the smartphone group responded that scanning the QR codes as part of iQ Zoo made learning about animals fun when asked if the iQ Zoo program was fun to use. For example, children said the following: "Fun to use while learning;" "Learned a lot;" "Helps you learn more about animals;" "Learned a lot of facts." Two children did not give this response; one child said that QR code-scanning was fun but did not mention the educational benefits, and a second child said that the experience was boring. Finally, most children stated that they would like to use iQ Zoo in the future because it was fun and informative.

[1] The median family income was determined by ZIP code based on data available from www.city-data.com. Using zip code to proxy income level is a standard practice in population-based research studies (e.g., Thomas, 2006).

[2] Parent education reflects the highest level of education of the consenting parent.

**Hypothesis 2: QR Code Technology and Knowledge understanding**

To examine educational gains in animal knowledge understanding as a result of smartphone usage, we compared children's pre- and post-test scores between the smartphone and the control groups. The total score possible on the pre- and post-tests was 25 points each (five questions on each of the five target animals.) Paired-samples *t*-tests were run to compare children's pre- and post-test scores on the educational tests. The smartphone group had an average total pretest score of 14.13 (*SD* = 2.15) whereas the control group had an average total pretest score of 15.26 (*SD* = 2.39). The two groups did not differ significantly on the pre-test ($t(66)=1.50$, p = .139). Regarding the post-test, the smartphone group scored on average 18.42 (*SD* = 2.72), whereas the control group scored 17.29 (*SD* = 3.09) on average. Again the two groups did not differ significantly on the post-test ($t(62) = 1.56$, $p = .123$). However, a repeated-measures ANOVA test revealed that the gains from the pre-test to the post-test were statistically significant ($F(1,56) = 62.12$, $p < .001$). Most importantly, the group contrast was also significant statistically ($F(1,56) = 4.43$, $p = .04$). In other words, the test-retest gains were greater in the smartphone group than in the control group.

Additional analysis revealed that contrasts between the groups in knowledge gains were due primarily to certain animal exhibits. We compared the two groups with respect to their total scores on each of the five animal exhibits. The crocodile questions were the most challenging set for both groups. On the pre-test, the smartphone group scored a meager 1.05 (*SD* = .87) on average whereas the control group performed significantly better with an average score of 1.91 (*SD* = .90) ($t(75) = 4.26$, $p < .001$). On the post-test, the smartphone group, with a mean score of 2.6 (*SD* = 1.28), was comparable to the control group which demonstrated a mean score of 2.34 (*SD* = 1.00). However, a repeated-measures ANOVA revealed that gains from the pre-test to the post-test were statistically significant ($F(1,68) = 38.83$, $p < .001$). Most importantly, the group contrast was also significant statistically ($F(1,68) = 8.15$, $p = .006$). In other words, the smartphone group demonstrated significantly more test-retest gains than the control group did for the crocodile questions.

The gazelle questions were also very challenging for both groups. On the pre-test, the smartphone group scored 2.05 (*SD* = 1.00) on average, which was comparable to the control group's average score of 2.22 (*SD* = .97). Similarly, the two groups were comparable on the post-test. The smartphone group averaged 3.09 (*SD* = 1.08), whereas the control group averaged 2.87 (*SD* = 1.45). A repeated-measures ANOVA revealed that gains from the pre-test to the post-test were statistically significant ($F(1,58) = 23.07$, $p < .001$). The group contrast, however, was not significant statistically. In other words, although participants improved from the pre-test to the post-test in general, the extent of the gains was comparable across the two groups for the gazelle questions.

The smartphone group averaged 3.02 (*SD* = .95) on the gorilla questions in the pre-test, whereas the control group scored 3.25 (*SD* = .91). On the post-test, the smartphone group averaged 3.9 (*SD* = .89) whereas the control group scored 3.85 (*SD* = .86). A repeated-measures ANOVA revealed that gains from the pre-test to the post-test were statistically significant ($F(1,73) = 30.97$, $p < .001$), although the two groups did not differ significantly in terms of test-retest improvement.

Finally, the giraffe and lion questions were fairly easy for both groups. On the giraffe questions, the smartphone group averaged 3.84 (*SD* = .83) on the pre-test, whereas the control group averaged 3.78 (*SD* = .76). On the post-test, the smartphone group averaged 4.15 (*SD* = .79) whereas the control group averaged 4.00 (*SD* = .65). A repeated-measures ANOVA revealed that gains from the pre-test to the post-test were statistically significant ($F(1,73) = 7.19$, $p = .009$). The group contrast, however, was not significant statistically. On the lion questions, the smartphone group averaged 4.35 (*SD* = .95) on the pre-test, whereas the control group demonstrated an average score of 3.97 (*SD* = .94). On the post-test the smartphone group averaged 4.32 (*SD* = .93) whereas the control group averaged 4.26 (*SD* = .71). The repeated-measures test was not statistically significant. In other words, neither group demonstrated significant test-retest gains for the lion questions.

## CONCLUSION

This paper reports one of the first research studies that examine children as the user population in the Information Systems literature. Results from this study indicate that QR code technology can serve as an effective, informative, and engaging tool for supporting informal learning. Children of ages five to 12 demonstrated significant knowledge gains by using QR code technology to access informational content in informal learning settings. The use of QR code technology enhanced retention and retrieval of declarative animal knowledge in some cases, and maintained children's interest in informal learning about animals. This research has significant implications for HCI research on child users, as well as ecommerce research on children and families as mobile consumers.

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