



Augmenting paper-based reading activity with direct access to digital materials and scaffolded questioning

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ABSTRACT

Comprehension is the goal of reading. However, students often encounter reading difficulties due to the lack of background knowledge and proper reading strategy. Unfortunately, print text provides very limited assistance to one's reading comprehension through its static knowledge representations such as symbols, charts, and graphs. Integrating digital materials and reading strategy into paper-based reading activities may bring opportunities for learners to make meaning of the print material. In this study, QR codes were adopted in association with mobile technology to deliver supplementary materials and questions to support students' reading. QR codes were printed on paper prints to provide direct access to digital materials and scaffolded questions. Smartphones were used to scan the printed QR codes to fetch pre-designed digital resources and scaffolded questions over the Internet. A quasi-experiment was conducted to evaluate the effectiveness of direct access to the digital materials prepared by the instructor using QR codes and that of scaffolded questioning in improving students' reading comprehension. The results suggested that direct access to digital resources using QR codes does not significantly influence students' reading comprehension; however, the reading strategy of scaffolded questioning significantly improves students' understanding about the text. The survey showed that most students agreed that the integrated print-and-digital-material-based learning system benefits English reading comprehension but may not be as efficient as expected. The implications of the findings shed light on future improvement of the system.

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1. Introduction

In the past few decades, the development of information and computer technology (ICT) has offered various alternatives supporting reading activities. However, a considerable number of learners still prefer reading from paper prints (Chao & Chen, 2009; Coiro, 2003; Longhurst, 2003; O'Hara & Sellen, 1997). Early in the late 90's, O'Hara and Sellen (1997) investigated computer users' preference of reading from paper prints and from online. Their findings suggested several salient characteristics of paper prints which made them prevail over online text reading, including (1) the support of free-text annotation and note-taking, which helped learners extract, highlight, or/and summarize the text from the whole content for later references; (2) the support of navigation, which provided learners spatial orientation with respect to the physical layout of the print (or book) when one was planning the reading process, searching for a specific segment of texts, or cross-referencing to different parts of the article; and (3) the flexibility of spatial arrangement, which facilitates learners to perceive the overall structure of the print (or book) for quick-referencing, non-linear reading, and the interwoven reading-writing activities. A decade later, Morris, Brush, and Meyers (2007) replicated O'Hara and Sellen's (1997) study but provided subjects papers, the dual-screen desktop computer system, pen-based horizontal display surface, and multiple tablet computers. They reported similar results that, even equipped with the most updated computer technology, people still favor reading from paper prints.

Reading is the foundation of learning (Berninger & Richards, 2002; Cunningham & Stanovich, 2001; IRA & NCTE, 1996). It is an active, purposeful process of constructing meaning from texts to create new knowledge (Armbruster, Lehr, & Osborn, 2001; Oakhill, Cain, & Yuill,

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1998; Smagorinsky, 2001). Reading failure may give rise to long-term learning difficulties which further lead to low self-confidence and motivation to learn (Armbruster et al., 2001; Nation, Clarke, & Snowling, 2002).

Comprehension is the ultimate goal of reading. It is a process of “simultaneously extracting and constructing meaning through interaction and involvement with written language” (RAND Reading Study Group, 2002, p. 11). Reading comprehension is a process “when readers actively relate the ideas represented in print to their own knowledge and experiences and construct mental representations in memory” (National Institute of Child Health and Human Development, 2000, p. 14). Unfortunately, not all readers have the essential knowledge and experience to relate to the print text. Brown, Campione, and Day (1981) suggested that inadequate background knowledge and improper reading strategies are two general types of difficulties that hinder effective reading. To help readers comprehend the text efficiently, relevant background knowledge essential to understand the text and reading strategies for facilitating the reading process should be made available in real time for students.

Scaffolding is a conception of providing students necessary learning support to help them resolve what they cannot accomplish alone to achieve the goal (Wood, Bruner, & Ross, 1976). It has been a flexible yet effective strategy in assisting students doing higher-order cognitive activities, such as reading (Pearson & Fielding, 1991), inquiry (Li & Lim, 2008), and problem solving (Kim & Hannafin, 2011). Among others, questioning is a conventional scaffold for teachers to “facilitate explanation construction, planning, monitoring, and evaluating, and making justifications” (Ge & Land, 2003, p. 24). Proposing proper questions to students may benefit them in knowledge construction (King, 1994), reasoning (McDaniel & Donnelly, 1996), problem solving, and metacognition (Ge & Land, 2004). In this study, questions were used as scaffolds in students’ reading process to help them monitor and evaluate their own understanding of print texts.

The emergence of mobile technology provides people alternatives in not only interpersonal communication and Internet access, but also learning and instruction. A considerable number of studies have suggested the advantages of utilizing mobile devices in pedagogy (Chen, Kao, & Sheu, 2003; Denk, Weber, & Belfin, 2007; Hwang, Yang, Tsai, & Yang, 2009; Uzunboylu, Cavus, & Ercag, 2009; Zurita & Nussbaum, 2004). A newer design of mobile phone, the smartphone, is a sophisticated integration of a media player, a personal data assistant (PDA) and a netbook computer. It is nowadays empowered with strong computing and networking capability for making communication, entertainment, and Internet access feasible.

With the aim to improve students’ reading comprehension, an innovative reading system has been developed to augment conventional paper-based reading activities using smartphone in association with QR codes. QR codes were printed in the paper print to provide direct access to additional digital materials and scaffolded questions. Students used the smartphones to scan QR codes to access and display the fetched digital materials on demand. The purpose of the present study is to evaluate the effectiveness of the design of using QR codes to provide students direct access to pre-designed digital materials and the use of scaffolded questioning in promoting students’ reading comprehension. In the following sections, the literature related to the theory of reading and comprehension as well as the reading strategy of scaffolded questioning is reviewed. The notion of integrating digital materials into paper prints is discussed next. The details of the experiment to evaluate the effectiveness of the system in a college-level English class are then presented along with the results of the experiment. The findings are then discussed and implications of this study in enhancing student reading comprehension are finally enumerated.

2. Theoretical background

2.1. Reading and comprehension

Contemporary learning theories posit learners at the center of learning activities (Bransford, Brown, & Cocking, 2000; Shuell, 1986). Studies based on this constructivist stance emphasize the interactive nature of reading and the constructive, generative nature of comprehension (Paris, Wixson, & Palincsar, 1986; Tracey & Morrow, 2006; Wittrock, 1990). RAND Reading Study Group (2002), for example, defined reading as “the process of simultaneously extracting and constructing meaning through interaction and involvement with written language” (p. 11). National Institute of Child Health and Human Development (2000) defined comprehension as the process which happens “when readers actively relate the ideas represented in print to their own knowledge and experiences and construct mental representations in memory” (p. 14). In line with these definitions, reading comprehension is itself a process of learning, in terms of the underlying cognitive processes – relating the new to what is already known (Smith, 2004). Therefore, the reader is assumed to be active, constructive, and self-regulated in reading activities (Dole, Duffy, Roehler, & Pearson, 1991; Palincsar & Brown, 1984; Paris et al., 1986; Shuell, 1986).

Educators and researchers have been attempting to develop effective instructional strategies to enhance students’ reading comprehension (e.g., Calfree & Patrick, 1995; Coleman, Brown, & Rivkin, 1997; Dole et al., 1991; Palincsar & Brown, 1984; Paris & Oka, 1989; Pearson, Roehler, Dole, & Duffy, 1992; Souvignier & Moxhlesgerami, 2006). Coiro and Dobler (2007) and Chi (2000) suggested that the readers’ (1) prior knowledge, (2) inferential reasoning and self-explanation, (3) self-regulation, and (4) affection relating to efficacy and motivation are critical components to reading comprehension. Brown et al. (1981) suggested that impoverished prior knowledge and inefficient application of reading strategies are two general categories of difficulties that impede effective reading.

In an active reading process, however, the learner may not always have adequate prior knowledge and proper strategy to efficiently construct meaning from text, not to mention making inferences about the content. Unfortunately, print text provides very limited resources to help students resolve this situation with its static representations including symbols, texts, charts, and graphs. If content-related knowledge can be afforded with multiple representations (Ainsworth, 1999; Höffler & Leutner, 2007; Mayer, 2001; Mayer & Gallini, 1990) and the reading process can be scaffolded by an appropriate strategy (Paris & Oka, 1989; Paris et al., 1986; Pearson & Fielding, 1991), students’ reading comprehension can be enhanced.

2.2. Scaffolded questioning in reading

Scaffolding refers to the process that enables a child or novice to solve a problem, carry out a task or achieve a goal which would not be possible to achieve without some external help (Wood et al., 1976). It is a conception closely related to the notion of zone of proximal development (Vygotsky, 1978), which states that the assistance (i.e., the scaffold) provided by an adult or more capable peers in one’s individual learning process enables the learner to move from the current developmental level to the level of potential development.

Depending on the purpose it serves, [Hannafin, Land, and Oliver \(1999\)](#) suggested that a scaffold can be conceptual (guidance about what to consider), metacognitive (guidance about how to think during learning), procedural (guidance about how to utilize available resources), or strategic (guidance about analyzing and approach the learning goal).

Scaffolds are not restricted to any specific mechanism. [Saye and Brush \(2002\)](#) conceptualized two types of scaffolds in developing curriculum: hard and soft. Hard scaffolds are static supports developed in advance based on students' typical learning difficulties in a task. Contrary to hard scaffolds, soft scaffolds are dynamic and situational. Soft scaffolding requires the teacher to have continual interactions with students to diagnose their understanding and to provide timely support in response to students' learning ([Wood & Wood, 1996](#)).

[Pearson and Fielding \(1991\)](#) suggested that scaffolding is an effective strategy for promoting student reading comprehension. [Wharton-McDonald, Pressley, and Jampston \(1998\)](#) reported their findings in classroom observations and in-depth interviews in language art classes in nine first-grade classrooms. They found three teachers (two nominated as outstanding and one as typical) whose students demonstrated higher-level achievement in reading and writing extensively used scaffolding in instruction among other successful practices.

[Graves and Graves \(2003\)](#) proposed an instructional framework for reading, namely the "Scaffolded Reading Experience" (SRE). It is a flexible lesson plan tailored to a specific learning situation. An SRE consists of a set of activities before, during, and after reading, specifically designed to help students to be successful readers. A set of possible pre-, during-, and post-reading activities are listed in [Table 1](#). According to the learning situation, teachers in each reading stage can choose a proper activity to promote students reading comprehension.

Pre-reading activities prepare students to read the selected material. They were developed to motivate students to read, relate the content to students' preexisting knowledge, and activate or build up students' background knowledge. Possible pre-reading activities may also include, as listed in [Table 1](#), pre-teaching difficult concepts, vocabulary, questions, or predictions in the reading piece. During-reading activities are what students do or what the teacher does to assist students as they are reading. These activities are to consolidate students' understanding of the section they just read. Possible activities may include silent reading, reading to students, supported reading, oral reading by students, or modifying the text. Post-reading activities provide students opportunities to synthesize and reflect on the text they read, and to evaluate their own understanding of the content. Post-reading activities were designed for students to externalize their understanding of the text, including questioning, discussion, writing, drama, or other outreach activities.

Questioning was applied as the SRE activity in this study. Questioning is one of the most conventional classroom activities used to scaffold students' learning processes to "facilitate explanation construction, planning, monitoring, and evaluating, and making justifications" ([Ge & Land, 2003](#), p. 24). Teachers used questions to promote students' knowledge construction and reflection ([King, 1994](#)), reasoning ([McDaniel & Donnelly, 1996](#)), problem solving ([King, 1991](#)) and metacognition ([Chen, Wei, Wu, & Uden, 2009](#); [Ge & Land, 2004](#)). In this present study, questions were given to students before, during, and after reading as a scaffold in students' reading processes. Based on [King's \(1994\)](#) classification of questions, comprehension questions were applied in the pre- and post-reading questions to prompt students important concepts in the reading piece, and factual questions mostly during reading to help them monitor and evaluate their own understanding in a section of the whole article.

2.3. Integrating digital materials into paper-based reading via mobile technology

Since the late 90's researchers have been attempting to enrich reading activities using information and computer technologies (ICTs) such as innovating digital reading devices (e.g., [Golovchinsky, Price, & Schilit, 1998](#); [Price, Schilit, & Golovchinsky, 1998](#); [Schilit, Golovchinsky, & Price, 1998](#)) or augmenting print text (e.g., [Back, Cohen, Gold, Harrison, & Minneman, 2001](#); [Grasset, Dunser, & Billighurst, 2008](#); [Koike, Sato, & Kobayashi, 2001](#); [Mackay, Pothier, Letondal, Bøegh, & Sørensen, 2002](#); [Chen, Kinshuk, Wei, & Yang, 2008](#)) with multimodal, interactive information. These studies demonstrated successful applications of ICTs in reading; however, they required readers either to read on or with a specific computing device apart from the printed materials. Given that the reader is the actor of reading activities and reading comprehension is a result of the interaction between the reader and print texts, an ideal reading assistance should ideally be brought *into* the undergoing reading process on reader's demand ([Chen, Teng, & Lee, 2010](#)).

[Weiser \(1991\)](#) in the early 90's proposed the vision of "embedded virtuality", which refers to bringing computations into the physical world and become an integral part of it. Applying this very idea in reading, varieties of Internet resources should be able to be accessed and integrated into the existent (physical) learning materials without interrupting the learner's concurrent reading process. [MacColl, Chalmers, Rogers, and Smith \(2002\)](#) suggested that the connection of virtual and physical resources should be overt, simple, robust, flexible, and manipulable, so that learners can be aware of the peripheral functionality of the connection and the availability of the associated digital resources.

Among other emerging ICTs, mobile technology has a great potential to support the augmentation of conventional paper-based reading. A mobile device, such as a PDA or mobile phone, can be integrated into reading activities due to its (1) mobility and portability, (2) capability of wireless networking, and (3) pervasive, frequent, and personal use. [Tatar, Roschelle, Vahey, and Penuel \(2003\)](#) suggested that integrating

Table 1
Possible activities in a Scaffolded Reading Experience ([Graves & Graves, 2003](#)).

Pre-reading	During-reading	Post-reading
<ul style="list-style-type: none"> • Relating the reading to student's lives • Motivating • Activating and building background knowledge • Providing text-specific knowledge • Pre-teaching vocabulary • Pre-teaching concepts • Pre-questioning, predicting and direction setting • Suggesting strategies 	<ul style="list-style-type: none"> • Silent reading • Reading to students • Supported reading • Oral reading by students • Modifying the text 	<ul style="list-style-type: none"> • Questioning • Discussion • Writing • Drama • Artistic and outreach activities • Application and outreach activities • Building connections • Re-teaching

mobile devices into learning contributes to the expectation that students have from computers to assist them master difficult concepts by letting them explore and interact with information on their own pace, regardless of the scheduled class hour or availability of school computer facilities (Roschelle, Patton, & Tatar, 2007). Recent studies (e.g., Chu, Hwang, Tsai, & Tseng, 2010; Hwang & Chang, 2011) showed convincing evidence that integrating mobile technology in learning activities can be effective not only in improving students' learning attitudes, but also in their learning achievements. The idea of employing mobile devices in conventional paper-based reading was therefore proposed to (1) deliver digital materials to supplement students with relevant background knowledge; and, (2) provide the strategy of scaffolded questioning to facilitate individuals' reading processes and improve their reading comprehension.

3. Methodology

This section describes the conceptual framework and implementation of the system and the experiment conducted to evaluate of the effectiveness of the system.

3.1. The conceptual framework

As illustrated in Fig. 1, the augmented paper-based reading system consists of three interconnected parts, namely (1) the print material, (2) the mobile device, and (3) the digital resource repository. The learner is at the center of reading activities, who purposefully and actively reads from the print material. The selected text in the print material is supplemented with additional digital resources stored in the digital resource repository. The digital resource repository can be any Internet resources in this framework. However, in this present study, a web server was employed to store digital resources. The mobile device connects digital resources and print materials, as it reads the learner's query from the paper print, fetches the corresponding digital resource from the repository, and displays it to the learner.

The system was implemented using printed learning material, which included printed QR codes, smartphone, and pre-designed digital resources that included additional learning materials and scaffolded questions. QR codes were used to mediate the linkage between a selected section in the print material and relevant digital resources.

A QR code is a specific two-dimensional bar code which consists of a matrix of black modules arranged in a square on a white background. It has been widely used to encode data such as text and URL in commercial advertisements. Hwang, Wu, Tseng, and Huang (2010) suggested that QR-code technology can be an ideal way of providing students instant learning helps at a low cost. QR codes were used in this study because (1) they can be printed on varieties of textures, (2) their coding software is freely available over the Internet, and (3) they are capable of encoding URLs of digital resources located on the Web servers.

Smartphones are emerging products of mobile technology. They typically have built-in cameras with adequate resolution for scanning the QR codes. Most smartphones also support Wi-Fi and 3G wireless networks to connect to the Internet, so that the learners can access essential learning materials in real time from the digital resource repositories. Most smartphones are also able to process multimedia data and keep fetched data in the local storage if necessary. Moreover, smartphones allow learners to interact with the system directly through several input mechanisms, such as touch screen and keypad.

3.2. The context and participants

The experiment was conducted in a class entitled "Advanced Business English and Communications" in a public university in southern Taiwan. A total of 77 students (including 8 sophomores, 14 juniors, 9 seniors, and 46 graduate students) participated in the experiment.

3.3. The experimental design

A quasi-experiment was conducted to evaluate the design of direct access to the pre-designed digital materials using QR codes and the reading strategy of scaffolded questioning (SQ) in improving students' reading comprehension. Seventy-seven participants of this experiment were randomly assigned into one of the following four groups: (1) Group 1, reading the print material printed with the QR codes and with scaffolded questions, (2) Group 2, reading the print material printed with the QR codes but without scaffolded questions, (3) Group 3, reading the print material without the printed QR codes but with scaffolded questions, and (4) Group 4, reading the print material without the printed QR codes and without the scaffolded questions. The distribution of participants in the four experimental groups is presented in Table 2.

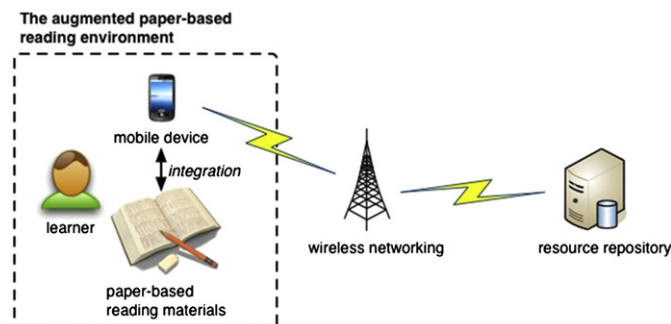


Fig. 1. The conceptual framework of the augmented paper-based reading system.

Table 2
The distribution of participants in four experimental groups.

Direct access	Reading strategy	
	SQ	no SQ
using QR codes	(Group 1) 19	(Group 2) 19
not using QR codes	(Group 3) 20	(Group 4) 19

SQ = scaffolded questioning.

3.4. Instruments

3.4.1. Print reading materials

Several articles were deliberately selected from the textbook as the reading material, which were further re-designed to meet the specific needs of each experimental group. For the groups reading with QR codes (i.e., Groups 1 and 2), QR codes were printed at the right margin of the page next to the text they were associated with, to visually indicate the availability of digital materials to students. The arrangement of QR codes is shown in Fig. 2. Different types of digital materials were distinguished by colors and icons. In Fig. 2, for example, the QR code associated with an audio clip (for read along) was printed in green with an icon of an amplifier. The video clip showing the teacher's explanation of vocabulary was printed in blue with an icon of play.

QR codes, linked to scaffolded questions, were placed at the center of the page before the first paragraph, in-between paragraphs, and after the last paragraph to provide pre-reading, during-reading, and after-reading questions, respectively. They were so designed to scaffold students' reading process toward a better understanding of the text. An example of the QR code indicating pre-reading questions is shown in Fig. 3 (a), and a screenshot of the smartphone presenting the pre-reading questions after scanning the QR code is shown in Fig. 3 (b).

Before reading, a few questions were given to students to highlight the main points of the reading content. After scanning the QR code, pre-reading questions were displayed in the smartphone as presented in Fig. 3 (b). Students could read the questions and proceed to read the print material.

During-reading questions were given to students after reading a paragraph (or a section of texts). These questions were designed to help students reflect on what has been read and evaluate their own understanding about the content. After scanning the QR code, a few multiple-choice questions popped up in the smartphone, one at a time. If students chose a correct answer, the system guided them to read the next paragraph. If they gave a wrong answer, the system prompted them to a specific paragraph or the associated digital material to review the content. Fig. 4 (a) is an example of a QR code linked to a during-reading question; Fig. 4 (b) is a snapshot of the question on the smartphone; and, Fig. 4 (c) is an example of the system feedback after the student answered the question.

A post-reading question was given to students after the end of the text. The post-reading question was the same as the pre-reading one, but was given in the form of multiple-choice question so that the students had the opportunity to reflect on the text and evaluate their own understanding about it. If students got the question wrong, the system referred them to specific paragraph(s) to review the content.

For the group reading without QR codes but with scaffolded questions (i.e., Group 3), the digital materials, as well as scaffolded questions, were given by referring students to a web page where a list of hyperlinks, linked to digital resources, were provided. Students needed to follow the instruction in the printed material to find the associated digital materials by the file name. The group reading without QR codes and without scaffolded questions (i.e., Group 4) used the printed material without any indication about digital materials and scaffolded questions.

3.4.2. Digital resources

To understand what digital resources should be prepared for students, the instructor of the class "Advanced Business English and Communications" was interviewed. The instructor suggested that digital materials may include lexical information for vocabularies, text reading audio, and class video clips which would be helpful to students to understand the selected articles. The pre-, during-, and post-reading questions were developed based on the instructor's earlier lectures and the comprehension questions that go with the selected article in the textbook, to scaffold students' comprehension process. These questions not only highlighted important points of the texts, but also provided opportunities for students to evaluate their own understanding about the content.

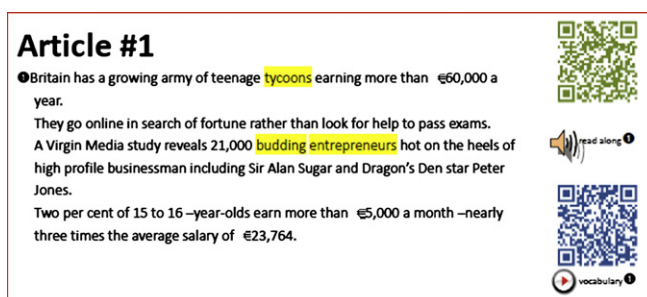


Fig. 2. The design and arrangement of QR codes in the paper print.

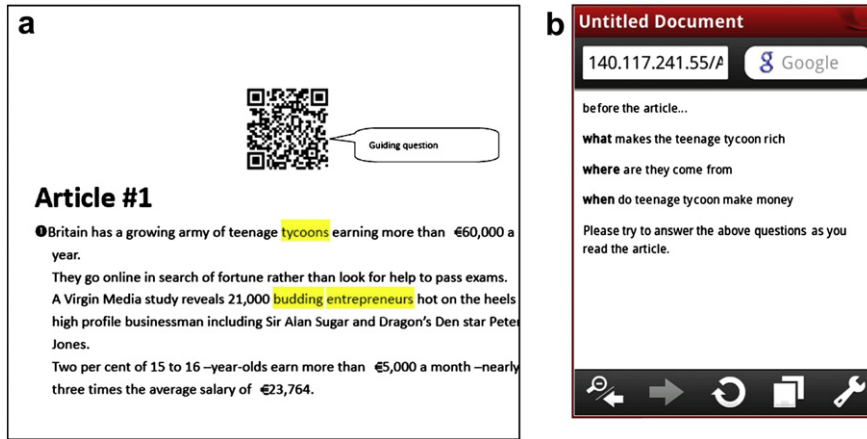


Fig. 3. (a) The QR code indicating pre-reading questions; (b) a screenshot of the smart phone showing the pre-reading questions.

3.4.3. The smartphone

Two models of smartphones were adopted in this study, namely Asus Garmin M10 and HTC HD 2. These two models were both equipped with 5 million pixels cameras, which were adequate to scan QR codes. Their 3.4" touch screen allowed students to interact with the system by fingers or stylus. Both models of smartphone were loaded with the Windows Mobile OS 6.5 operating system. The overall system performance of both models was capable of sustaining the present study.

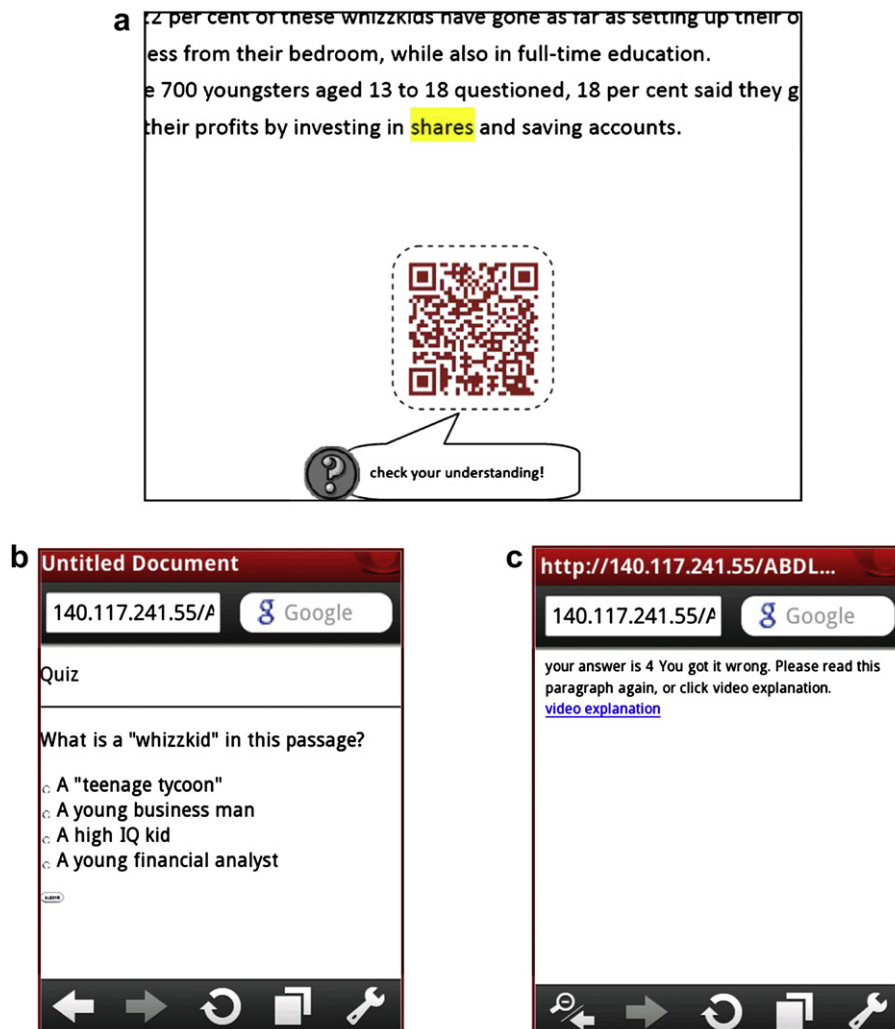


Fig. 4. (a) A QR code for during-reading question; (b) a during-reading question shown in the smart phone; and (c) the system feedback after students gave their answer.

3.4.4. The pre- and post-tests

The pretest was developed to evaluate students' English reading ability before the treatment. The pretest consisted of four articles excerpted from the past midterms. Two to four comprehension questions were given for each article. There were a total of 12 comprehension questions in the pretest, with a moderate reliability (Cronbach alpha) of .57.

The posttest was developed to evaluate students' reading comprehension after the treatment. Two articles along with the corresponding comprehension questions were selected from the textbook. There were 18 questions, with 7 questions related to the first article and 11 questions related to the second article. The reliability (Cronbach alpha) of the posttest was .50.

3.4.5. The questionnaire

A questionnaire was developed based on Davis' (1989) Technology Acceptance Model to evaluate students' reading experience with the system developed in this study. A five-point Likert scale was used ranging from 1 (strongly disagree) to 5 (strongly agree). The questionnaire was composed of three constructs, including the perceived usefulness, the perceived ease of use, and the attitude and attempt of future use. The questionnaire contained a total of 17 items, including six items related to the perceived usefulness, six related to the perceived ease of use, and the remaining five related to the attitude and attempt of future use.

In addition, seven open questions were given in the questionnaire to investigate students' learning experience in terms of system functionality, accessing digital resources using QR codes, scaffolded questions, and the design of smartphone interface and that of the print materials.

3.4.6. The procedure

The procedure of the experiment is presented in Fig. 5. The total length of the experiment was 90 min. Participants first took a 15-min pretest, and then received a 10-min instruction on the upcoming procedure and the operation of the smartphone. All participants were then randomly assigned into one of the four experimental groups, and were given a smartphone, and a copy of the print reading material relevant to their group assignment. During the next 50 min, participants read the two articles in the print material. When they finished reading an article, a comprehension test (i.e., the posttest) was given. After finished reading both articles and completing the associated comprehension tests, the participants took a 15-min survey on their learning experience with the new system.

4. Results

4.1. Correlation analysis

Initially, analysis was done to identify whether a linear relationship existed among variables. The Pearson correlation coefficients suggested a significant positive relationship between students' pretest score and their posttest scores ($r = .45, p < .01, N = 77$). Students' posttest scores were significantly related to their pretest scores, so the confounding effect of students' pretest scores should be eliminated in subsequent analyses.

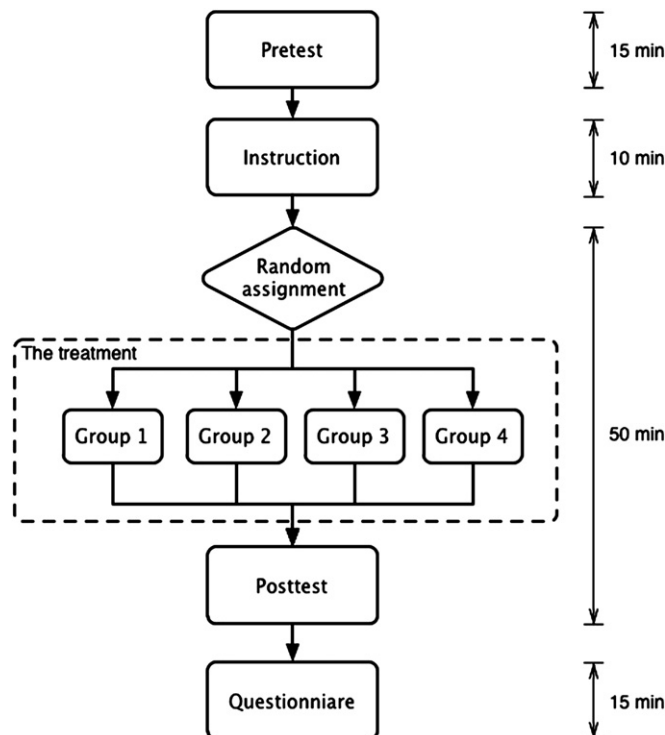


Fig. 5. The procedure and the length of the experiment.

4.2. Two-way ANCOVA

The descriptive statistics are presented in Table 3. To eliminate the confounding effect of students' pretest scores to the posttest outcome, two-way ANCOVA was used to examine the main effect of the design of direct access to digital materials (DA) using QR codes and the reading strategy (RS) of scaffolded questioning for improving reading comprehension. The independent variables in this analysis were DA and RS, and the dependent variable was students' posttest scores (Posttest). The covariate was students' pretest scores (Pretest).

The analysis of ANCOVA, as presented in Table 4, suggested that the main effect of DA was not significant ($F[1, 72] = 1.05, p = .308$), but that of RS was significant ($F[1, 72] = 4.15, p = .045$). The interaction between DA and RS was not significant either ($F[1, 72] = 1.15, p = .287$). The design of direct access using QR codes, therefore, did not significantly contribute to students' reading comprehension, but that of the reading strategy of scaffolded questioning did. Students who read with the aid of scaffolded questioning performed significantly better in the posttest than their counterparts.

4.3. Further analysis on the effect of scaffolded questioning

Earlier analysis revealed that the scaffolded questions were beneficial for students' reading comprehension. However, because the posttest consisted of two different articles, the effect of scaffolding on these two different articles was needed to be investigated.

Mean item difficulty was used to estimate how difficult the first and second articles were in relation to all participants. The item difficulty of a comprehension question was measured by the percentage of the total participants that got the item correct. Averaging the item difficulty of the questions related to the first and second articles, the mean item difficulty of the first article was found to be .47 and that of the second .63. In other words, the first posttest article was more difficult for the participants than the second article.

The same procedure of analyzing the effect of DA and RS in reading comprehension, as described earlier in section 4.1 and 4.2, was replicated. The correlation coefficients showed that students' posttest scores on the second article were significantly related to their pretest scores ($r = .53, p < .01, N = 77$), but their posttest scores on the first article were not found to be significantly related to their pretest scores ($r = .02, p = .89, N = 77$). This result showed that students who performed better in the pretest tend to obtain higher score in the posttest of second article. Therefore, students' pretest score was then a confounding factor in explaining their reading comprehension in the second article.

Two-way ANCOVA was used to examine the main effects of direct access (DA) to pre-designed digital materials using QR codes and the reading strategy (RS) of scaffolded questioning on students' reading comprehension of the first and second posttest articles. The results showed that RS significantly contributed to students' reading comprehension in the first posttest article ($F[1, 75] = 6.65, p < .05$), but not the second ($F[1, 72] = .31, p = .58$). DA did not influence students reading performance in the first ($F[1, 72] = 1.75, p = .19$) nor the second article ($F[1, 72] = .07, p = .79$). This result showed that the strategy of scaffolded questioning benefitted students' reading comprehension, especially when the content is difficult to understand.

4.4. The survey of students' learning experience

Students' learning experience was further investigated in terms of the perceived usefulness (PU), the perceived ease of use (PE), and the attitude and attempt of future use (PA). The reliability of the construct of PU was .76, PE .82, and PA .86. Students rated each item in the range of 1 (strongly disagree) to 5 (strongly agree). The average scores on the 5-point Likert scale of these three constructs are presented in Table 5.

Comparing students' ratings on PU, it was found that students in group 1 had a significantly higher rating than those in group 4 ($t[36] = 2.90, p < .05$). Similarly, students in group 2 had a significantly higher rating on PU than those in group 4 ($t[36] = 2.66, p < .05$), so did students in group 3 ($t[37] = 3.08, p < .01$). This result showed that students regarded the new system useful in improving reading comprehension if they received assistance in understanding the print reading material, whether it was pre-designed supplemental digital material or the reading strategy of scaffolded questionings. There was no significant difference among four groups on the ratings of PE and PA.

Students' responses to the open questions concerning the system functionality, automatic linking using QR codes, scaffolded questioning, design of the user interface and design of the print materials were collected and analyzed. In terms of the system functionality, students commented that real-time lexical information, class audio and video clips really helped comprehend the text. But the design of QR codes was troublesome in accessing relevant digital materials. They complained that they had to keep finding an "optimal" angle to obtain a recognizable QR codes. Also, they mentioned that the dim environmental lighting also influenced the precision of the process of scanning QR codes. One student commented, "Frequent access to QR codes interrupted my reading process". He suggested that the number of QR codes should be less or QR codes should be placed at the end of the article to prevent interruption.

With respect to the reading strategy of scaffolded questioning, some students mentioned that they felt the two articles in the print materials were with different difficulties. They commented that scaffolded questions were helpful in highlighting important points in the

Table 3
Descriptive statistics.

DA	RS	N	Pretest Mean (S.D.)	Posttest Mean (S.D.)
using QR code	SQ (Group 1)	19	6.00 (2.43)	10.68 (1.92)
	no SQ (Group 2)	19	6.84 (2.91)	10.58 (2.34)
	Total	38	6.42 (2.68)	10.63 (2.11)
not using QR code	SQ (Group 3)	20	5.65 (1.84)	10.55 (1.85)
	no SQ (Group 4)	19	5.11 (2.21)	8.79 (3.14)
	Total	39	5.38 (2.02)	9.69 (2.68)
Total	SQ	39	5.82 (2.13)	10.62 (1.86)
	no SQ	38	5.97 (2.70)	9.68 (2.88)
	Total	77	5.90 (2.41)	10.16 (2.44)

SQ = scaffolded questioning.

Table 4
The ANCOVA table.

Source	SS	df	MS	F	Sig.
Corrected Model	122.68	4	30.67	6.66	0.000
Intercept	594.87	1	594.87	129.22	0.000
Pretest	75.40	1	75.40	16.38	0.000
DA	4.85	1	4.85	1.05	0.308
RS	19.09	1	19.09	4.15	0.045*
DA × RS	5.30	1	5.30	1.15	0.287
Error	331.45	72	4.60		
Total	8396.00	77			
Corrected Total	454.13	76			

* $p < .05$.

harder article. As far as the design of user interface, one student mentioned that the button shown in the smartphone's touch screen was too small to operate, which restricted the fluency of the operation.

5. Discussions and suggestions

A number of issues have been identified from the result of data analysis, with respect to the design of direct access to digital materials the instructor prepared for students to comprehend the print material using QR codes, the reading strategy of scaffolded questioning, and the integration of digital and print materials.

5.1. Direct access to pre-designed digital materials using QR codes

QR codes were used in this study as a way to connect pre-designed digital materials as supplementary learning resources with the printed materials. The result showed that students who had direct access to digital materials using QR codes in printed materials did not significantly outperform their counterparts. In other words, the access to digital reading resources, whether given in the form of QR codes or hyperlinks, may equally benefit reading comprehension. A possible reason for this result was that students need relevant prior knowledge to make sense of the text and construct new knowledge (van den Broek, Rapp, & Kendeou, 2005). Given that students attended to the supplementary digital materials to grasp relevant information to foster their own understanding of the content, the provision of background knowledge, either using QR codes or hyperlinks, may both benefit reading comprehension (Kendeou & van den Broek, 2007).

Students' feedback on direct access to digital resources using QR codes revealed two issues which need to be taken care of. These include (1) too many QR codes on the printed materials; and, (2) the precision of scanning QR codes. QR codes in this study provide direct access to digital materials and visual indication of availability of supplemental digital materials. Different QR codes were created alongside paragraphs for providing different types of digital materials, if available. More than one QR code was thus printed next to a paragraph. Such design consumed much of students' efforts in scanning the QR codes, which inevitably lowered the reading efficiency. This could be the reason why students who read without QR codes (Group 2 in Table 5) had a slightly higher rating on the perceived ease of use than those in other groups. To resolve this issue, QR codes could simply be used as a portal to the resource repository, where there a list of available digital resources, instead of placing multiple QR codes with each corresponding to a piece of digital resource. Students can thus scan the QR code to enter in the repository and access various types of materials all at the same time, without having to scan QR codes one by one for viewing different types of digital learning resources.

The results of using QR codes as a way to access digital materials, though not as effective as expected, suggested that QR-code technology itself is still fine. But the inefficiency was mainly caused by the slow response (about 2 s on average) of the available QR-code reader on smartphone. Further study on how to improve the efficiency of QR-code reader would be helpful. Also, using the normal built-in camera in smartphone for image input was also found to be clumsy. If a special digital pen-like QR-code reader could be used, the effectiveness should be improved dramatically in the precision of recognizing text information. If QR code becomes pervasively used in our daily life, the aforementioned features will be implemented by smartphone manufacturers.

5.2. The reading strategy of scaffolded questioning

Scaffolded questioning was found to be a useful reading strategy in this study. Students who read with the aid of scaffolded questions performed significantly better than their counterparts. The statistical analysis as well as students' feedbacks showed that scaffolded questions were helpful, especially for reading difficult articles.

Table 5
Average ratings of students' learning experience.

Constructs	Average ratings (S.D.)			
	Group 1 (QR code, SQ)	Group 2 (QR code, no SQ)	Group 3 (no QR code, SQ)	Group 4 (no QR code, no SQ)
PU	3.64 (.56)	3.64 (.71)	3.64 (.49)	2.99 (.80)
PE	3.60 (.70)	3.87 (.68)	3.66 (.62)	3.58 (.58)
PA	3.93 (.51)	4.11 (.36)	3.76 (.58)	4.00 (.65)

However, students received exactly the same questions from the system, regardless of the individual students' learning needs at a particular moment in time. In conventional class settings, the instructor scaffolds the learning activity and evaluates students' moment-by-moment learning performance in order to provide proper assistance (Graves & Graves, 2003; Wharton-McDonald et al., 1998). Similarly, scaffolded questions given by the learning system should be derived from students' learning trajectory to meet individual students' need and to stimulate higher-order thinking (Li & Lim, 2008; Yelland & Masters, 2007).

5.3. The integration of digital and print materials

In the survey, students who were given either the direct access to digital materials or the scaffolded questioning (Groups 1, 2, and 3 in Table 5) had a significantly higher rating on the perceived usefulness of the system (PU) than their counterparts in Group 4. This result showed that students benefit from the supplementary materials and the reading strategy. Students who lacked relevant background knowledge, such as vocabularies, may obtain necessary lexical information from the provided digital resources. Also, those who did not have a proper reading strategy may benefit from scaffolded questions in monitoring and evaluating their understanding of the printed content.

Though most students agreed that the system was useful, no significant difference was found among four groups of students in terms of the ease of use (PU) and the attitude and attempt for future use of the system (PA). This revealed the need to improve the aforementioned issues of design and arrangement of QR codes and the user interface on the smartphone.

6. Conclusions

Reading is a critical learning activity, and reading comprehension is the purpose of reading. In conventional paper-based reading activities, students may have a hard time when they have inadequate background knowledge to comprehend the text or have improper reading strategy to evaluate their own understanding about the content. The emergence of smartphones brings feasibility and flexibility in interpersonal communication and Internet access. It may also be used to supplement students with relevant background knowledge and reading strategy in conventional paper-based reading activities to help students become successful readers.

The present study demonstrated a possible approach to integrate digital resources into paper-based reading on learner's demand through mobile technology. QR codes were used in association with smartphones to implement the linking between printed materials and digital resources, including supplementary materials and the reading strategy of scaffolded questioning. QR codes were used to encode the URLs of digital resources, and the smartphones were used to scan QR codes and display the fetched digital resources. When reading, students used smartphones to scan QR codes to obtain the corresponding digital materials and/or the questions to scaffold the reading process.

The results of the study showed that scaffolded questioning significantly benefits students' reading comprehension, especially when the article is difficult. However, the scaffolded questions given in this study was not adaptive to individual student's need. A better design of scaffold questions could be that questions are personalized for individual learners and are adaptive to their learning situation.

Overall, students' responses to the learning experience survey showed that most students felt positive toward the system developed in this study in terms of enhancing their reading comprehension. They were impressed by the feasibility of accessing digital resources directly from the printed content. However, several issues needed to be resolved in the future, such as the design and arrangement of QR codes on the printed materials, the precision of the process of scanning QR codes using smartphone's camera, and interface design of the system.

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