Augmenting Traditional Books with Context-Aware Learning Supports from Online Learning Communities

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ABSTRACT
Recent advances in ubiquitous computing technologies have brought reality augmentation of traditional objects to context-aware and social supports. Although a significant proportion of students prefer poring over traditional paper textbooks over electronic books, few studies have enhanced reading practice of traditional books with ubiquitous context-aware and collaborative learning supports that provide timely, contextual assistance. This study proposed an innovative approach to develop a paper-based learning support environment in which mobile phones, traditional books and a Web-based discussion forum are integrated together to promote students' acquisition of knowledge. Students receive contextual messages from an online learning community based on their learning status. The timely recommendatory messages aim to facilitate collaboration among community members and offer guidance in students' study. The findings and results of an evaluation show that students' learning tasks and motivation were supported in the paper-based learning environment by community members. Students also generally had positive attitude to the context-aware recommendatory information delivered via mobile text messages. The ubiquity and immediacy of the recommendations may help students reach the right resources at the right time to improve their learning experience.

Keywords
Ubiquitous learning, Context awareness, Online learning community, Traditional books

Introduction
Advances in ubiquitous and context-aware computing technologies have enabled environments in which applications and tangible objects can proactively support users' activities based on their context. These context-aware applications are generally implemented to facilitate capturing relevant information, proposing appropriate resources, or executing services automatically (Dey, Abowd, & Salber, 2001). Supports from capable learners, such as academic advice, material recommendation, or study guidance, would assist learning performance (Tharp & Gallimore, 1988), and would benefit students the most if these learning supports are provided at the right time. Web-based learning environments that enables online learning communities or other online systems with resourceful databases demonstrate the useful platforms to deliver these learning supports or other contextual information (Billus, Hilbert, & Maynes-Aminzade, 2005; Derntl & Hummel, 2005; Jones & Brown, 2003; Kapsalis, Fidas, Tranoris, & Stoica, 2005; Lieberman, 1997; Ogata & Yano, 2004; Rhodes, 2000; Yang, 2006). The communicative and computational capabilities of these online systems allow them to acquire user context and deliver context-aware supports accordingly at the right time.

However, a significant proportion of students still perform reading activities more on traditional books than on electronic documents due to the better support of physical books in reading (Longhurst, 2003; O'Hara & Sellen, 1997; Robertson, 2006). Since integration of documents in electronic and physical worlds is limited, and the functions provided by the two worlds are different (Koike & Kobayashi, 2001; Wellner, 1993), these students would have to make extra efforts to acquire contextual resources from online systems due to the difficulty in collecting user context or the inaccessibility of computer resources in constrained environments. For example, when a student encounters a difficult passage interrupting her reading, she probably has emergent needs to seek for additional information through online support systems or search engines. She may have trouble in searching or determining the appropriate information among the recommendations from the search tools, or may even fail to find the appropriate information. Without the timely suggestion of appropriate information, these extra efforts and the difficulty in acquiring the right resources would disrupt students’ learning flow and may eventually impair students’ learning motivation and the quality of their learning activities.

Several studies have demonstrated augmentations on paper documents with audio, video or digital information...
Although these studies integrated information between physical and electronic documents to support user tasks, few studies have incorporated contextual supports from capable learners and peers into traditional book reading practice to enhance students’ text comprehension and knowledge acquisition. This study proposes an innovative approach to develop a paper-based learning support environment in which mobile phones, traditional books, and a Web-based discussion forum are integrated together. The integration allows capture of learning context during students’ study via mobile phones. It also augments reading practice of traditional books with timely, contextual recommendatory messages from capable learners in an online learning community through Short Message Service (SMS). To explore the implications of these context-aware learning supports to students, an evaluation was conducted to understand students’ use and perception of the proposed environment.

The remainder of this paper is organized as follows. Section 2 discusses the representation of learning context for context-aware learning supports and the matching strategies to deliver relevant resources based on students’ learning context. Section 3 demonstrates the system design as well as use scenarios that describe the ways in which learners interact with the environment. Section 4 describes the evaluation for the learning supports and its corresponding results. Finally, in Section 5, the discussion and conclusion are summarized.

Representation of Learning Context for Context-aware Learning Supports

Understanding the goals and difficulties of adopting learning strategies in paper-based learning practice helps identify useful learning context and the corresponding context-aware learning supports. The learning context, from both individual and group aspects, lays the foundation for matching contextual resources with appropriate learners according to different purposes of learning supports. These helpful resources, aiming to support students’ knowledge acquisition, are provided to students via SMS messages.

Context-aware Supports for Facilitating Acquisition of Knowledge

Some difficulties in paper-based learning practice seem to hinder students in acquiring comprehension from paper textbooks effectively. Students often rely heavily on these textbooks because the books play a major role in exams or homework assignments. These students generally pore over the textbooks and underline key sentences for later reviews. When they encounter difficult passages, the students may post their questions on a Web-based discussion forum or search for relevant information with a search engine. Although these learning strategies may facilitate comprehension acquisition, students may also find problems impairing the usefulness of these strategies. For example, students may have trouble identifying important sentences in a paragraph while underlining. They also have difficulty in deciding which piece of information among recommendations from a search engine is more appropriate for them currently. These problems would then increase the likelihood of interruptions of students’ learning flow. Sometimes, students are unaware of the fact that they are falling behind the exam-preparing schedule, or they are unable to follow the discussion topics among their classmates. This unawareness might decrease students’ motivation to engage in reading or to participate in discussion. When a student’s confusion regarding the textbook sections accumulated over time, the student probably gives up the course as a result of not knowing how to proceed with their study.

People may learn to solve problems by using their own knowledge and the knowledge inherent in an environment or organization (Rhodes, 2000). Similarly, students may benefit from a learning environment that includes an online learning community by acquiring relevant resources to improve the quality of their learning tasks. These resources intend to serve as context-aware learning supports when reaching appropriate students at the right time. Among the relevant resources are shared annotations regarding specific passages, reports of class learning status, and guidance from capable learners. The shared annotations mainly include identified key points, asked questions, and supplementary information suggested by other students. This peer support suggests useful information for students who are currently concerned with the same or relevant topics during study. Since the process of schema formation and refinement could be enhanced through comparing relevant examples (Gagné, Yekovich, & Yekovich, 1993), the
access to the shared annotations for immediate comparison or exploration may benefit the process, and would
decrease the possibility of interrupting students’ learning flow. The report of class learning status aims to invite
engagement in learning activities. Gaining the awareness of class learning status, such as hot topics, average reading
progress, or teaching progress, may help students structure their efforts for cooperation or competition among their
classmates.

The guidance in students’ study intends to recommend appropriate cognitive tasks and knowledge for students. These
cognitive tasks aim to encourage the application of useful cognitive processes on knowledge topics to achieve
learning objectives. These cognitive processes have been identified and categorized in the revised Bloom’s taxonomy
(Anderson & Krathwohl, 2001; Krathwohl, 2002). Some cognitive processes could be encouraged and sequenced
through the delivery of guidance messages. For example, to encourage the cognitive processes of Remembrance and
Understand, it is suggested to extracting key sentences from a specific paragraph that contains an important concept.
Comparing a concept with other relevant concepts may also support the processes of Remembrance, Understanding,
and Analyzing. Lastly, giving assignments such as editing reports may facilitate higher-level cognitive processes
such as Analyzing, Evaluating or Creating.

**Representation of Learning Context**

Albrecht Schmidt and Michael Beigl (1999) proposed a working model for context when a mobile device was
involved, which emphasizes the perspectives of human factor and physical environment. In this working model,
information on the user, user’s social environment and user’s tasks were included and classified into human factor
category. Dey, Abowd and Salber (2001) defined context as follows: “Context is typically the location, identity, and
state of people, groups, and computational and physical objects” (p. 106). Both Schmidt et al.’s working model and
Dey et al.’s definition of context includes human states as elements of user context in which these states intimately
couple with user’s tasks and social environments. Similarly, the learning context in paper-based learning practice
could be better shaped by adding individual and group learning status regarding users’ cognitive tasks and social
environments.

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Person</td>
<td>Who performs the cognitive task?</td>
</tr>
<tr>
<td>Time</td>
<td>When does the student begin to perform the cognitive task?</td>
</tr>
<tr>
<td>Cognitive Task</td>
<td>Summary extraction, question asking, exploration on discussion forum, review of summaries, production of assignment reports, or other cognitive activities.</td>
</tr>
<tr>
<td>Passage</td>
<td>Passage that the learner is interested or concerned about. The range exhibited by combinations of chapter title and line numbers within a chapter.</td>
</tr>
<tr>
<td>Topic</td>
<td>The topic or keyword that learners are currently concerned about.</td>
</tr>
<tr>
<td>Question Type</td>
<td>Types of question associated with the passage: “Do not understand”; “Any relevant examples”; “Why can be that”; and “Any application”</td>
</tr>
<tr>
<td>Question</td>
<td>Questions entered from a keyboard of desktop computers or keypad of mobile phones.</td>
</tr>
<tr>
<td>Grade</td>
<td>Student’s test scores regarding specific topics.</td>
</tr>
<tr>
<td>Device</td>
<td>Mobile phones or desktop computers.</td>
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</table>

The representation of learning context in this study is categorized into two aspects: namely personal and class
learning context. The personal aspect mainly describes individual state or preference regarding learning tasks.
Although the representation of learning context is similar to Zheng and Yano’s (2007) five-dimensional activity
context in the e-learning context, the personal learning context emphasizes more description of learning tasks that
apply different cognitive process or learning strategies regarding a specific passage or topic in a paper textbook. For
example, Alice uses her mobile phone to review extracted summaries addressing the concept of “polymorphism” between line 20 to 40 in chapter 12 on Friday morning. John uses a desktop computer to post a question about “overloading” to ask for more examples by quoting passage between line 65 to 70 in chapter 14 on Monday evening. This aspect of learning context may facilitate the inference about students’ needs in reaching their learning goals. Table 1 summarizes the data structure used to represent the personal learning context. Person and Time attributes record the identity and temporal data about the performance of a cognitive task. Cognitive Task attribute captures the cognitive process or strategy that a student could apply in the system to achieve his goals. Passage attribute addresses the exact location indicated by a student. Topic attribute describes keywords representing a specific concept regarding a passage that learners are currently concerned about. Question or Question Type attribute collects students’ questions or question types regarding difficult passages. Student’s test scores regarding a specific topic are recorded in Grade attribute. Finally, Device attribute records the use of reading devices under current circumstances to imply a currently favored platform for a specific student to receive learning supports.

The class learning context depicts the status of a class, such as topic focus, teaching progress, mean reading progress, mean test scores, activity events, and other collective information in the class. In this study, the class learning context is treated more as a resource for recommendation than as a basis for inferring potential needs. These resources may enhance class status awareness, thus creating more opportunities for online learning community participation or allowing students to engage more in their study. For example, knowing the hot topics that attract most classmates’ attention may arouse one’s interest to join the discussion or to monitor the ongoing development about that topic. Comparing one’s reading progress among other classmates may stimulate desire to study harder. Since class learning context includes discussion context on a discussion forum, popular discussions, challenging questions, or hot news selected from the discussion forum could therefore serve as important resources in facilitating collaboration or inviting participation.

**Matching Contextual Resources with Learners**

Different purposes of context-aware learning supports lead to different matching strategies. To support processes of knowledge construction by delivering shared annotations to appropriate students, these annotations need to be categorized into topics so that students who read relevant topics can share their annotations. A concept map (Novak, 1990) representing the content of paper textbooks is employed to organize these annotations. The concept map features its networked connections to relevant concepts. When these concepts are mapped onto sections or paragraphs of the textbooks, the networked structure for the concepts helps measure the relevance among shared annotations. Chang et al. (2005) proposed a “weighted concept map” in which teachers determined the weights of propositions in a concept map to represent the importance among the propositions for assessing concept mapping (p. 140). Similarly, in this study, weight factors were assigned between connected concepts to represent the extent of relevance. A domain expert such as a textbook author or a course instructor may relate relevant concepts and determine the weight factors among concepts in a concept map on the basis of content organization of a textbook and of his own domain expertise. The match between textbook paragraphs and the concepts is facilitated by a data structure in which a range of line numbers and its corresponding concept are paired. Each concept is also associated with other relevant concepts and their weight factors in the data structure. As illustrated in Figure 1, a concept map representing a paragraph about object-oriented programming shows the concept of “Inheritance” and its relevant concepts. Each pair of connected concepts is assigned a weight factor to characterize corresponding relevance (value of 1 stands for the most relevant). Each annotation made by students is classified into one of these concepts based on their personal learning context. For instance, when a student reads a paragraph addressing the concept “Encapsulation” on a textbook, the sentences highlighted or the questions asked by the student are recorded as annotations and are categorized into “Encapsulation” concept.

An annotation is also automatically copied to those concepts that have connections with the concept it belongs. As a result, each concept can have its own queue of shared annotations prioritizing in term of weight factors. As shown in Figure 1, the annotation Ai, originally classified into the concept “Inheritance”, is copied to its connected concepts with a weight factor (denoted as \( w \) in parentheses). Similarly, annotations originated from the concept “Operator overloading” (Ao) and “Encapsulation” (Ae) are also respectively copied to the concept “Inheritance.” Consequently, whenever a student reads the paragraph addressing concept “Inheritance,” these prioritized annotations in the queue can be treated as contextual resources that will proactively suggest to the reader in sequence.
Reporting individual and class learning status could be useful in arousing learning motivation. When comparing or exploring average performance with other students, students may restructure their time and efforts to respond accordingly. Deciding which student should receive a notification depends mostly on the gap between the individual’s current and expected learning performance. For example, a student whose reading progress is below the class average might receive a message implying that the student should study harder. Delivering such a message also needs to promise good timing due to the requirement of effectiveness. Activity events of a specific course should provide a useful timeline in deciding when to send messages and determining the expected learning performance. For instance, a week before an exam might be the suitable timing to alert those students with reading progress below 50%. The discussion context in a discussion forum could also provide interesting messages that most students are concerned about. By introducing messages such as hot topic discussions or challenging questions to students who have not read yet, students are likely to start participating in discussion.

The guidance in student study aims to gradually lead the students to higher levels of comprehension. Therefore, students are not only recommended with knowledge units but also cognitive tasks that may facilitate comprehension acquisition. Similar to Schmidt and Winterhalter’s (2004) matching strategy, the gap between a student’s current and required level is first determined. Then appropriate cognitive tasks are recommended to close the gap. These cognitive tasks help encourage appropriate cognitive processes based on revised Bloom’s taxonomy (Anderson & Krathwohl, 2001; Krathwohl, 2002). However, learning guidance needs to consider interdependence among knowledge units (Hwang, 2003) and assessment of student performance. The learning support for guidance in study by delivering recommendatory messages is not fully automatic at the current stage. Parts of decisions in matching guidance messages with specific students still rely on instructors’ experience and observation.

**System Description**

The representation of learning context and the matching strategies assist to develop the paper-based learning support environment where students are encouraged to extract summaries, post questions, and explore recommendatory messages through mobile phones. The use of mobile phone allows students to acquire learning context during study and to receive contextual resources via SMS messages.

**System Architecture**

Figure 2 illustrates an overview of the paper-based learning support environment. Students could use Smartphone and Traditional Books together to extract sentences or ask questions. During the extraction or question asking via Smartphones, inputs entered on Smartphone keypads are submitted to Summary Extraction and Question Resolving Modules. These inputs are then transformed into concrete sentences based on mapping tables that store the index to specific sentences. The Question Resolving Module then forms a message by aggregating passed data and posts that
message on the Web-based Discussion Forum. The extracted sentences or asked questions are then sent to Context
Recognizer Module so that they can be represented as personal learning context and stored into Learning Status
Database.

The Learning Status Monitoring Module displays reports based on students’ learning status. Instructors can send
SMS or email messages to inform, guide, encourage or care for specific groups of students to increase their
motivation to study. In the Web-based Discussion Forum, once the questions are replied, the experienced managers
of the discussion forum should arrange and organize the replied messages into two versions of digital documents,
one for detailed reports and the other for SMS messages. Those documents are tailored to adapt to different devices
and delivered in different manners. Hot topics or other interesting events on the Web-based Discussion Forum are
selected as class learning context and are stored into Learning Status Database. The Recommendation Module
acquires relevant information from Learning Status Database according to the recognized context; and then produces
the SMS-based recommendation messages. Finally, the messages are delivered to students.

Use Scenarios of Context-aware Learning Supports

Providing students with context-aware learning supports via Smartphones may facilitate acquiring text
comprehension, sustaining connections to the online learning community, or obtaining learning skills to cope with
academic problems. Some use scenarios are given as follows:

Use scenario 1: Mary, a student, often pores over a paper textbook in a library. She rereads a section addressing
classic polymorphism concept in object-oriented programming and extracts key sentences via a Smartphone. However, she
still doubts about whether she has correctly identified key sentences in a paragraph. She remembered receiving a
SMS message in which a capable classmate shared his extract of key points about the paragraph. She reads these key
points via a Smartphone and compares the key points with hers. On her way to lunch, she also receives two
suggested SMS messages in which questions about the relationships among polymorphism, overriding, and
overloading are presented. She discusses these questions with her friends by showing the messages to them at lunch.
Later in a computer classroom, she logs on a Web-based discussion forum to explore the details of these questions.
She also refers to specific passages on the paper textbook for the questions through the line numbers suggested in the
SMS messages. Mary synthesizes diverse responses on the forum and decides to contribute her opinions to the
Use scenario 2: Another student, Jack, does not connect to the learning support system for a few days. When receiving a new SMS message reporting classmates’ learning progress, he learns that he did not study hard enough compared with his classmates. Jack starts studying by reviewing extracted summaries via his Smartphone. He later receives a SMS notification introducing a few hot topics discussed on the discussion forum. He explores them by logging onto the discussion forum with a desktop computer in the dormitory. Exploring the discussion also arouses his interest to relevant paragraph in the paper textbook and allows him to keep up with the mainstream opinions in the class.

Use scenario 3: A teacher finds that Alan has trouble with the object-oriented programming course. After analyzing Alan’s learning portfolio, the teacher decides to offer guidance by sending recommendatory messages. Alan first receives a message that encourages him to extract key sentences in a specific paragraph describing the concept of recursion. He gains understanding about the concept during the process of identifying key sentences. Alan then also receives a message in which a collection of relevant information from the discussion forum and paper textbook is summarized for comparison of recursion and loop techniques. He explores the discussion forum while poring over the paper textbook to differentiate between these two techniques. At the weekend, Alan gets a homework assignment which requires him to discuss the advantages and disadvantages of programming using recursion and loop. He rewrites two examples obtained from the discussion forum and produces his own opinions based on his implementation experience and the summaries extracted from the paper textbook.

These scenarios demonstrate how recommended messages could help students acquire knowledge. The first scenario exhibits the timely reference to shared key points and questions from community members in a constrained environment. With these supports, Mary may gain her awareness of useful resources and develop her understanding through exploring the resources. Use scenario 2 demonstrates that students could monitor their own learning progress and class status to respond appropriately. This awareness may enable a sustained connection not only to the system but also to the learning community. Finally, use scenario 3 shows how the employment of guidance messages could gradually lead a student to achieve higher levels of learning objectives.

Figure 3. A Smartphone and book pages with line numbers
Capture of Personal Learning Context during Summary Extraction and Question Resolving

One of the valuable uses of underlining for students is to identify key sentences that can later serve as effective tools, such as summaries, to achieve good grades in exams. Students usually read these summaries repeatedly before taking exams regardless of whether they are in class, dormitories, on their ways to school, or even in breaks between two classes. These summaries help the students recall key concepts and monitor their comprehension. Due to the advances of mobile and telecommunication technologies, mobile phones have become small enough to be carried with people intimately for a long time, and be employed in a wide range of education as well as facilitate learning activities regardless of constrained situations (Chen & Kinshuk, 2005). A Smartphone with Web-enabled browser (Mio 8390 support overview, 2006) was used to facilitate acquisition of students’ learning context by allowing the students to ubiquitously extract summaries and post questions related to passages in a traditional book. Figure 3 shows a traditional book with line numbers beside each line and the Smartphone. Passages on the book can be located with pairs of line numbers. Students can extract sentences as summaries or quote them in questions by entering pairs of line numbers via a Smartphone keypad.

As shown in Figure 4, a student extracted sentences from line 121 sentence 3 to line 123 sentence 1 in a paragraph on chapter 12 (Figure 4d). The student simply enters 1213#1231 on a Smartphone keypad to locate the passage, and then submits it to the system by pushing the Extract Summaries button (Figure 4a). The inputs of line numbers are separated by a '#' character to denote a range of a passage. In spite of submitting to extract the passage as summaries, the student could choose to send the extracted passage as a part of a question published on a discussion forum. When the student wants to quote the passage for a post on a discussion, she can reuse the inputs and click the list for selecting a question type (Figure 4b). After posting the question comprising a question and relevant passages, the student would later receive a notification message encouraging her to explore the answers responded by other members in an online learning community (Figure 4c). This notification consists of a keyword, a hyperlink, and a pair of line numbers. These components remind the student of the question while allowing him to quickly review the answer and to find the original passages in a traditional book.

Figure 4. Extracting summaries or publishing questions for answers via a Smartphone
Augmenting with Online Learning Community through Recommendatory Messages

Participants who interact with the learning system through line-numbered books, Smartphones, and the Web-based discussion forum together with related artifacts help to shape an online learning community. The participants were involved in different levels and of various interaction styles. For example, students extract summaries, ask questions or receive recommendation messages through the system while reading. Teachers or teaching assistants give reading assignments, provide answers to questions on the discussion forum, or guide students in their studies. The learning status of community members such as “What is the key concept in the paragraph that most of my classmates have identified?”, “Have I made significant progress in my study when compared to other classmates?”, and “How do my good friends deal with this difficult passage?” may influence students’ decisions of what, when and how to study.

One of the most essential aims of context-aware application is to deliver contextual resources efficiently and effectively (Brown & Jones, 2001). The trace of learning context regarding individual students and the whole class as well as SMS techniques helps achieve this aim by sending recommendatory messages to interested students. To access easily and receive relevant resources in time, hyperlinks to more detailed information can be embedded in SMS messages. A student who receives a notification (cf., Figure 4c) may use navigation keys on a Smartphone keypad to position a cursor on an intended hyperlink for exploration. After a student clicks a hyperlink, the web-enabled browser of the Smartphone connects to the learning system through the General Packet Radio Service (GPRS) and then presents the corresponding web page on the Smartphone screen (cf., Figure 5a). This easy access may facilitate acquisition of learning supports or arouse users’ awareness of his learning progress in constrained situations. In a case of sharing comprehension questions, Figure 5(a) shows a question asked by one student when he reads a difficult section being recommended to another student, who currently reads the same section in a textbook in a library. The recommended message includes a confusing passage, a question, a pair of line numbers, and a summarized version of answer. A student can test her understanding of the section by trying to answer the question. The pair of line numbers helps locate relevant passages in the textbook to support the formulation of an answer. During the process of comparing her answer with the proposed one, the student may gain understanding of the passage or discover key points she has overlooked. Figure 5(b) shows a report of students’ reading progress that allows a student to gain awareness of class learning status. A ranking list of students’ progress may assist a student to arrange his efforts for reaching his learning goals. The act of comparing with classmates may drive students to make progress in study. Finally, Figure 5(c) shows a guiding message that suggests a student compares two relevant but confusing concepts in C# programming language. The message first tests the student if he could tell the difference between two keywords in order to arouse his interest or curiosity; then follows by presenting a reference to relevant passages in paper textbooks via chapter numbers and a pairs of line numbers to encourage further study on the textbooks; finally, a hyperlink to detailed discussion on a discussion forum is provided for further exploration.

Figure 5. Recommended messages on a Smartphone
Evaluation and Results

An eight-week evaluation was conducted to explore the implication of augmented context-aware learning supports. Since qualitative methodologies are suitable for inquiries that explore and seek to understand a central phenomenon (Creswell, 2002), this study employed a qualitative approach to understand students’ use and perception of the learning supports in students’ everyday learning environments. Participants were 20 (16 men and 4 women) undergraduate students enrolled in a course of “The Introduction of Computer Science” in the same class. All of the participants were freshmen and had at least half a year of experience of computer C# programming. At the beginning of the evaluation, each participant was supplied with a Smartphone and two traditional books with line numbers added. The books addressed C# programming and consisted of text, figures and C# program examples. Most of the text in the two books was written in Chinese. The corresponding concept maps and the weight factors among the concepts for the text in the two books were constructed beforehand by the course instructor and were imported into the learning system by database tools. Participants were allowed to bring their Smartphones and books anywhere they felt comfortable studying during the eight weeks. The Smartphones offered all the features common to general mobile phones and also supported access to the Internet through GPRS. During the evaluation, each participant was asked to study the two line-numbered traditional books as parts of the course materials.

Quantitative and qualitative data were collected mainly from system logs, interviews and a questionnaire. The system logs were designed to record all students’ clicks on hyperlinks that link to contextual recommendations and the students’ ratings about the recommendations and to log other details that would help understand the Smartphone use. During the period from the 5th to 8th week, eight students were selected on the basis of system logs for semi-structured interviews. These participants were asked to describe and explain how they acquired the context-aware learning supports with their Smartphones and line-numbered textbooks. A self-administrative questionnaire was performed to all students in the 8th week to explore students’ perception of the learning supports.

Use of Context-aware Learning Supports

Eight students were given interviews to elicit how they used the context-aware learning supports. When they were asked about how and why they use the text annotations shared from their classmates, they generally agreed that the support of shared annotations was useful in bringing different aspects of knowledge and in organizing their own annotations. For example, one student replied:
I often use them (shared key points and questions from classmates) to help arrange my annotations. Those recommended questions and key sentences help me understand the text better due to other students’ viewpoints. They are useful especially when a paragraph or section is lengthy…I underline sentences with different colors (on paper textbooks) to differentiate my annotations from others.

Another student described how the shared messages influenced his learning practice:
If the recommended key sentences are very different from mine, I will ponder through the recommended sentences and the corresponding reason why they were selected. If two or more classmates have underlined the sentences that I did not underlined, I will think I might be wrong…When I get more SMS messages, it is not convenient to arrange them on a Smartphone. Therefore, I always write down important messages in the margins of [traditional] textbooks.

When the students were asked about how they responded to reading progress reports and the hot topics under discussion via Smartphones, they all appreciated the given hot topics but gave different value on the progress reports. One student replied:
There must be some reasons behind the hot topics; maybe the teacher said this topic will be tested in an exam. I usually skim the heading of the topic and directly search for the critique or opinions of the topic on a Smartphone screen. If it is worthwhile, I will read the details on the discussion forum…When my progress falls behind others, I usually ask those classmates who make relatively good progress for help; it is more efficient.

One student stated his doubts about progress reports:
I have my own schedule. Therefore, reporting classmates’ reading progress does not affect me. Moreover, the progress does not necessarily mean true understanding. Some people, like me, do not
read sequentially. It is not accurate; and not important to me.

When these students were asked about how they followed the guidance messages that recommended appropriate learning tasks and knowledge topics, they all agreed that they generally did exactly what they were recommended. Although the messages were designed for personal learning supports, the students still shared the messages with their friends. One student replied:

It is very useful; I will do what I am told because I believe in the teacher…When I receive a message, I will ask my friends whether they received the same messages. If they did not, I will share the message with them.

One student also expresses how he felt when he first received a guidance message:

It (the message) gives me the direction so that I will not study blindly. It is good to know what to read next. It is not like a feeling of joy; just a feeling of knowing what to do next.

The Attitude toward Contextual Messages

Based on system logs, 176 (85.4%) out of 206 hyperlinks in recommendatory messages were clicked for retrieval of detailed information. The high access rate to these messages reveals that students may feel interested or curious about the messages. To understand how suggested messages can fit students’ concern, the last 60 messages were embedded with a Likert scale ranging from 5 (strongly agree) to 1 (strongly disagree) to measure the students’ satisfaction in terms of relevance to their concern. The mean satisfaction value was 3.85. Thirty (65%) out of 46 collected data indicated the agreement of satisfaction; the other 16 (35%) indicated neutral attitude and none of the messages was evaluated as disagreement of satisfaction. These results demonstrate that delivering context-aware resources as learning supports via SMS messages seems feasible and could be effective for reaching students.

Participants were asked to fill in a questionnaire to reflect their attitude toward recommended question answers and contextual messages via Smartphones. Seventeen out of 20 have completed the questions (another student partially completed them) on a Likert scale ranging from 5 (strongly agree) to 1 (strongly disagree). As shown in Table 2, the students scored highly on the immediacy of SMS messages and would save those messages for future reviews (Question 1, 3). The relevance and satisfactory evaluation of recommendatory messages sent to students were also positive (Question 2, 7). Ten (56%) out of 18 students showed the agreement to the relevance of recommendatory messages; the other 8 (44%) students displayed neutral attitude and no student showed disagreement. Students also showed their positive attitude to the learning opportunity that brought them to the discussion forum or traditional textbooks (Question 4, 5, 6).

<table>
<thead>
<tr>
<th>No</th>
<th>Question</th>
<th>Mean</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>The system sends you an SMS message as a reply to your post question. I believe this method is timelier than checking a traditional Web-based discussion forum.</td>
<td>4.28</td>
</tr>
<tr>
<td>2</td>
<td>I believe that the recommendation sent to me is relevant to what I am currently reading.</td>
<td>3.67</td>
</tr>
<tr>
<td>3</td>
<td>I will not delete the messages from the Smartphone and would like to read the interesting parts of them when I have time.</td>
<td>3.94</td>
</tr>
<tr>
<td>4</td>
<td>I believe that receiving recommended messages based on the paragraph where I am currently reading increases my motivation to log on the discussion forum.</td>
<td>3.75</td>
</tr>
<tr>
<td>5</td>
<td>I believe that receiving recommended messages based on where I am currently reading increases my motivation to pore over textbooks.</td>
<td>3.81</td>
</tr>
<tr>
<td>6</td>
<td>I believe that recommended messages raise the opportunity to study.</td>
<td>3.72</td>
</tr>
<tr>
<td>7</td>
<td>I believe, overall, I am satisfied with the answers or recommendation sent to me.</td>
<td>3.56</td>
</tr>
</tbody>
</table>

Discussion and Conclusion

This study developed a paper-based learning environment incorporating with line-numbered traditional books,
mobile phones, and a Web-based discussion forum. By detecting the knowledge units and the cognitive tasks which students are currently concerned about through mobile phones, students’ learning context could be represented and corresponding context-aware learning supports could proactively reach appropriate students. The context-aware supports recommend useful learning tasks and resources, collaboratively constructed or guided by community members in an online learning community, to facilitate text comprehension or knowledge construction.

An evaluation was conducted to assess the proposed context-aware learning supports and understand how students use them. The findings of the interviews show that the recommended annotations may assist students to better construct their knowledge by synthesizing different aspects of viewpoints from other classmates or by following a sequence of guidance from capable learners. Students’ learning motivation and behavior might be influenced by community members probably due to the conformity with class status. The results of exploring hyperlinks and attitude toward contextual messages suggest that these messages could be relevant to the students’ learning tasks and could be effective for reaching students. The ubiquity and immediacy of the recommendatory messages may help students reach the right resources at the right time, improving the opportunity to acquire learning supports.

Although the evaluation was generally positive, the system had limitations. The capture of learning context requires precise and effortless techniques. Sensory devices such as RFID, electronic pens could be introduced to improve the detection of students’ learning status. In addition, the balance between context sensitivity and non-obstruction of message remains an important issue in this study. Providing finer context sensitivity in the system means that recommended messages are more likely to obstruct students. Some students suggested that the system provide functions to formulate personal policies, including the time and number of recommendatory messages to receive based on message types. Future works will conduct more sophisticated experiments to collect data for the fitness of contextual messages and will focus on the augmentation of new sensors to broaden the representation of learning context. Additional work will be conducted to include new functions such as keywords searching or formulating policies to augment paper-based learning practice.

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