Using annotation services in a ubiquitous Jigsaw cooperative learning environment

Yueh-Min Huang and Tien-Chi Huang
Department of Engineering Science, National Cheng Kung University, Taiwan // Tel: +886-6-2757575 ext. 63336 // Fax: +886-6-2766549 // huang@mail.ncku.edu.tw // kylin@easylearn.org

Meng-Yeh Hsieh
Department of Information Science, Hsing-Kuo University of Management, Taiwan // Tel: +886-6-2872035 // tab.hsieh@mail.hku.edu.tw

ABSTRACT

This study describes the development of a ubiquitous cooperative learning environment using proposed annotation services, wireless communication devices, and the Jigsaw method of cooperative learning. The purpose of the study is to investigate the potential benefits of studying digital course materials with embedded annotations. The SQ3R study method is introduced during the individual study phase of a series of Jigsaw learning activities, enabling students to access and familiarize themselves with course content. In this phase, learners use the SQ3R method to enhance the quality of their annotations. It is noted that during this phase, individual students worked in separate locations. After the individual study phase, an expert group meeting process refines the annotations made by student experts and then the annotations discussed are provided to all members of the Jigsaw group during the group meeting phase. Importantly, annotations from different levels of literal meaning and connotation are assigned to different learners to help the group members develop a greater sense of context awareness of the different aspects of the topics under study. Analysis of data collected from questionnaires given to participants at the end of the study indicates that the proposed annotation services using handheld devices can enhance students' learning potential. The results also indicate the suitability and practicality of annotation services in an ubiquitous Jigsaw cooperative learning environment.

Keywords

Ubiquitous learning, Mobile learning, Annotation services, Jigsaw method, SQ3R study method, Context-awareness

Introduction

In recent years, the use of wireless technology has become increasingly popular and its use in education is expanding rapidly. Handheld devices are essential components of this type of learning. The handheld devices utilized in mobile learning (m-Learning) usually include mobile phones (also called cellphones or handphones), smartphones, palmtops, and PDAs (Personal Digital Assistants) which are portable, lightweight devices, often small enough to fit in the palm of one's hand. "*Wireless [access] is an important key to e-learning [since] it takes e-learning to the field, where the best hands-on learning takes place,*" said Robert Meinhardt, AvantGo's vice-president of Enterprise Marketing (Setaro, 2001). At this time, mobile learning (which can be regarded as an integrated achievement of combining advanced handheld devices and wireless technologies) has attracted a great deal of attention and expectations regarding its promise are high (Roschelle & Pea, 2002; Norris & Soloway, 2004). The environments in which the study of mobile learning has been conducted have some features found in previous studies, including: (1) the enhancement of availability and accessibility of information networks; (2) engaging students in learning-related activities in diverse physical locations; (3) support of project-based group work; (4) the improvements of communication and collaborative learning in the classroom, and (5) supporting quick content delivery (Gay *et al*., 2001; Roschelle & Pea, 2002; Hoppe *et al*., 2003; Liu *et al*., 2003; Wang *et al*., 2004; Liang *et al*., 2005). Considering the features listed above, it can be argued that mobile learning environments may be more suitable than conventional classrooms or computer classrooms for encouraging teaching and learning (Roschelle, 2003; Zurita *et al*., 2005).

A ubiquitous learning (u-Learning) environment which is a further step of mobile learning environment focuses on providing learning at the right time and the right place with right learning resources. The amount of studies which investigated the extension of mobile learning in ubiquitous learning environment has obviously increased in recent years (Wang *et al*., 2007; Chen *et al*., 2007; Hsieh *et al*., 2007). Due to the high mobility, handheld devices are often regarded as one kind of essential learning devices in a ubiquitous learning environment. A growing number of

research studies have also suggested the benefit of the use of handheld devices in ubiquitous learning environments. However, most of studies focus on providing the learning opportunities at the right place rather than providing right resources. From education perspective, it is more difficult to provide appropriate learning materials for learners than providing a right learning environment. Since the assistance of software and hardware technologies, rendering an appropriate learning environment has been easily achieved nowadays. The appropriate learning materials should render to different learners according to their different learning abilities. Therefore, the process of material design needs experts to highly involve in. In this paper, we present how to carry out the discussion process among topic experts in a ubiquitous learning environment.

Another issue related to wireless learning is the use of annotation systems in educational settings, and this too has been widely discussed during the last decade. An annotation system is a system that can be used by students to make marks on electronic reading materials. There are two types of annotation proposed by Marshall (1997), namely inexplicit and explicit annotations. Explicit annotations (such as text) generally convey more information than inexplicit ones (such as highlighting, underlining, asterisks, arrows, and graphics). Annotation benefits learning in several areas, according to Yang *et al*. (2004), including attention, discussion, organization, and indexing. These benefits help students identify the areas of emphasis in a lesson or unit and construct important concepts rather than merely acquire discrete pieces of information. A web-based shared annotation system, called Annotea, has been proposed by W3C which enhances collaboration by allowing for the sharing of annotations, bookmarks, and their combinations (Kahan *et al*., 2001). In 1995, the CoNote system was proposed to enable a group of people to communicate through shared annotations on a set of electronic documents (Davis & Huttenlocher, 1995). The findings revealed that the use of shared annotations resulted in a richer communication environment than one built around electronic media which include newsgroups, bulletin boards, and email distribution lists. Additionally, a shared document-based annotation tool, EDUCOSM, has been presented to investigate how learner's use of learning strategies, self-rated motivation, and social abilities are associated with cognitive outcomes and completion of various tasks in the system (Nokelainen *et al*., 2005). Hwang *et al.* (2007) have proposed an advanced annotation system to be used in web-based learning. The study described a web-based tool for creating and sharing annotations and investigated the effects of its use on the learning of college students. The experimental results also showed the research potential of an annotation mechanism for online materials. The abovementioned studies have indicated the benefits of using annotation systems on both personal learning and group learning. It should be noted, however, that there have been few attempts to establish a direct relationship between cooperative learning and mobile annotation services.

In this study, we investigate how to embed mobile annotation services in learners' cooperative learning. The chosen cooperative learning method is the Jigsaw, which is a widely used cooperative learning technique. Each learner in a Jigsaw group is regarded as an expert in a particular aspect of the topics under study, and is expected to make unique contributions of knowledge not readily available to the other group members (Aronson & Patnoe, 1997; Aronson, 2005). Lai & Wu (2006) exploited handheld devices which permit mobility, while maintaining communication between peers as platforms to support Jigsaw cooperative learning in a traditional classroom. Their findings showed that students' attitudes and performance can be enhanced by this type of learning.

To date, much research has been done on the successful use of the Jigsaw method in traditional classroom. However, some issues have not been fully addressed in the literature, including the restrictions inherent in a classroom environment, the emphasis on special education, and the scarcity of expert resources. Hence, the need for the development of a ubiquitous cooperative learning environment to address these issues is increasing gradually. Furthermore, studies which have explored use of the Jigsaw method in ubiquitous learning settings are still very scarce. This study describes the implementation of a ubiquitous cooperative learning environment which uses the proposed annotation services, wireless communication devices, and the Jigsaw method.

Although there are many promising indicators regarding the use handheld devices in educational environments, many challenges still remain. Several areas of concern to educators have been identified, including pedagogy and assessment, classroom management, technology management, school purchasing, and contents presentation on the mobile devices (Norris & Soloway, 2004). In addition, Van'T Hooft *et al*. (2004a) indicated that there was a need to conduct more handheld-related research to inform teaching practices. Van'T Hooft and Swan (2004b) also indicated that the investigations in the area of ubiquitous and mobile computing were still relatively rare, and there is a need for more systematic research. Our study presented here is an attempt to address some of these issues.

The objectives of this study were primarily to investigate the suitability and practicality of annotation services in a ubiquitous Jigsaw cooperative learning environment from the learners' perspective, with an emphasis on their attitudes towards the learning activities and the effectiveness of ubiquitous learning. Some other interesting issues are also explored with a view to extend the scope of this study in future research.

Research methodology

Jigsaw learning activities are performed in a traditional classroom with four essential steps: topic assignment, individual study, the expert group meeting, and the Jigsaw group meeting. Therefore, we first considered how to carry out these four steps in a ubiquitous learning environment, with the additional step of knowledge sharing through the use of annotated materials. The procedure is shown in Figure 1. The four phases Jigsaw method adopted in this study are described in more detail below.

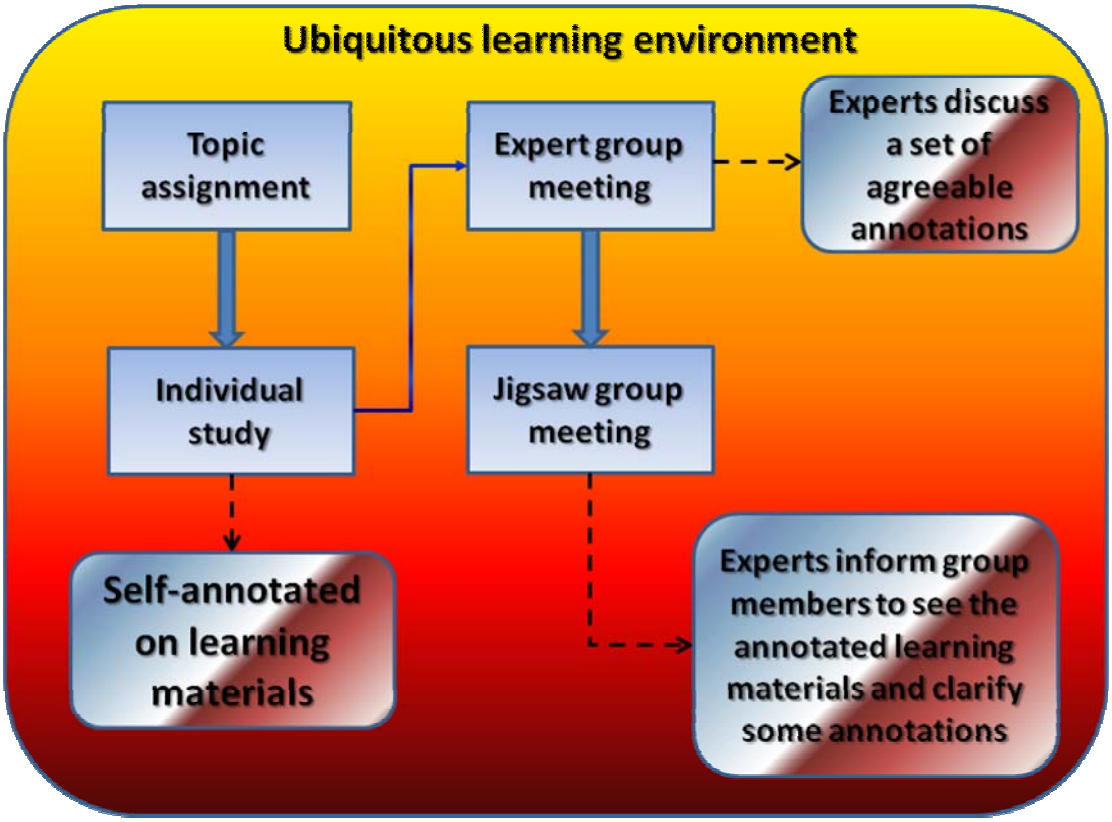

Figure 1. The flowchart of ubiquitous Jigsaw learning activities

Topic assignment

The course instructor assigned topics to each Jigsaw group, and all topics were designated by the instructor beforehand. In each Jigsaw group, each learner studied a different topic with his or her group members. Because of this, when using the Jigsaw method, learners should be divided into equal groups. If the learners cannot be divided into equal groups, two learners may be assigned the same topic. Using a LMS (Learning Management System), a learner working in an e-learning environment can identify the group number he or she belongs to, fellow group members, and the assigned topics. Incidentally, the LMS, called ANTS is the previous study proposed by Jeng et al. (2005), is a platform designed to manage various types of information related to courses of study.

Individual study

Since the course materials are stored in our LMS, learners in our study could download the assigned materials to their own handheld devices. It should be noted that the course materials were presented for appropriate reading on different handheld devices. In order to annotate the areas of emphasis in the course materials, this study created course materials in text-based form. Before moving into the cooperative phases of this activity, learners were required to make an in-depth study of the topic and to make as many reasonable annotations as they could. In other words, during this phase, learners studied individually on their assigned topic and then annotated on the materials to embellish the text with their own reflections, thoughts, and ideas. In order to ensure that learners could effectively obtain expert knowledge from the studying process, the SQ3R (*Survey, Question, Read, Recite and Review*) study method was used to guide students' efforts. This method has been widely and effectively applied in many learning systems (Zhang *et al*., 2001, Zhang *et al*., 2002, Zhang *et al*., 2004). Since e-learning settings are different from the conventional school education, we utilized and extended the original effective SQ3R study method on handheld devices to accommodate those differences. The steps of SQ3R are listed below:

Step 1 – Survey
In step 1, learners quickly survey or scan the material, to get an overview of the assigned topic.

Step 2 – Question
Once students have completed their survey, they use their general understanding of the topic to help generate a list of questions, which should serve to direct their efforts and focus their attention during a more thorough reading of the material.

Step 3 – Reading
In step 3, learners read the material more thoroughly, making a concerted effort to find the answers to questions they generated in step 2. During the reading phase, students can and should utilize the annotation services to make inexplicit annotations (such as highlighting and underlining) on emphatic text or answers to their questions within the text.

Step 4 – Recite
In order to enhance their learning of the course material, students can also write down their impressions, reflections, and thoughts beside the parts of the text they wish to emphasize – that is, learners use explicit annotations based on their own knowledge on the materials. Through repetition of the general concepts and specific details of the course material by making notes students increase the likelihood of being able to recall specific information, in much the same way as a piano player will be able to recall most easily the pieces he or she rehearsed most frequently. By annotating the text with notes based on paraphrasing or summarizing, students not only increase their ability to recall key pieces of information, but also deepen their understanding of the same.

Step 5 – Review
In the final step, in order to consolidate their knowledge, students need to review it thoroughly. This step can also help learners to identify any gaps in their knowledge and to refine any annotations completed earlier.

By using the SQ3R study method learners involved in cooperative learning activities such as the Jigsaw can become experts in their assigned topics, familiar with the assigned materials of topics and possessing the knowledge needed for the expert group discussion that follows the individual study portion of the Jigsaw.

Expert group meeting

Before proceeding with this phase, each expert needed to upload the annotation files that are the form of XML format and then the other experts in the same topic downloaded these files so that the annotation review and discussion process could begin. The purpose of this phase was to validate and extend the knowledge gleaned through individual study via discussions with the other experts. A similar concept has also been mentioned and reported (Yang, 2006). Acting simultaneously as experts in this peer mediated tutorial session, each learner expert had much opportunity to develop a very deep understanding of the annotated material.

During the expert group meeting phase, the annotations were classified according to their scope and depth as being either brief, medium, and abounding. The knowledge in brief annotations was information dense, rich in implication and succinct. The knowledge in abounding annotations was more detailed, more fully explained, expansive and would be easier to understand by readers less familiar with the topic. Obviously the degree of difficulty in medium annotations lies between that of the brief and the abounding. All annotations were classified and the annotation discussion process would only proceed after mutual agreement on each item was reached by all experts in the expert group.

In their on-line discussion group, the experts then designed an electronic questionnaire to be completed by the learners in their original Jigsaw groups. Based on each student's performance on the questionnaire, he or she would then be automatically provided with an appropriate set of annotations for use while reading the material originally studied by the expert group. If questionnaire results revealed that a student was already familiar with the topic, he or she was provided with the set of brief annotations. If the results proved otherwise, either the medium or abounding notations would be provided, as required.

The structure of the expert group meeting was comprised of three functional modules and four repositories as shown in Figure 2. The functional modules contained communication mediums, annotation review and discussion, and questionnaire discussion and creation. The four repositories were stored in posted annotations, self-made annotations, classified annotations, and agreeable questionnaires, respectively. The posted annotation repository stored annotations that had been discussed, determined, and presented for the other learners, while annotations stored in the self-made annotation repository were done by student experts on the current course material. The classified annotation repository kept classified annotations determined by expert group meeting and the questionnaire repository collected questionnaires created by the experts.

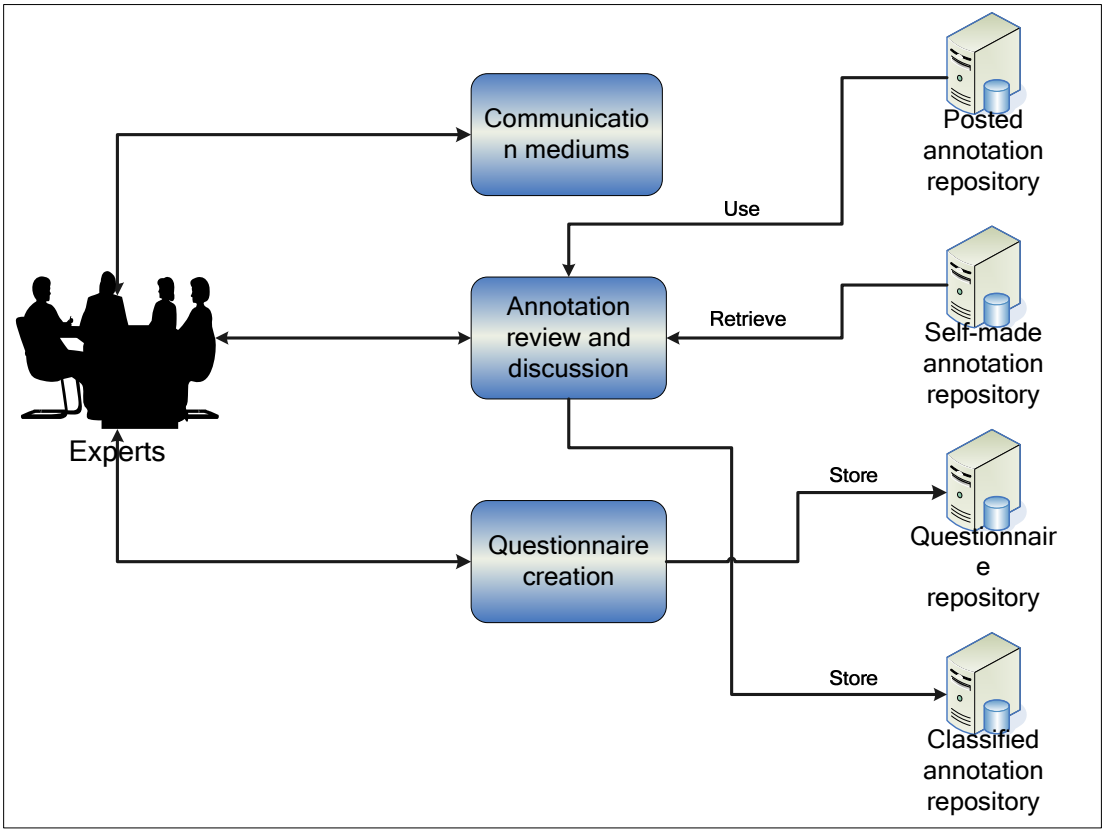

Figure 2. The structure of expert group meeting

Communications among the experts were carried out by the communication medium module which consists of *Instant Message* (IM) software, *Short Message Service* (SMS), *Multimedia Messaging Service* (MMS), *email*, *phone*

call, and even *video phone*. Using these communication technologies with 3G wireless networks, experts in cooperative learning groups can communicate via synchronous or asynchronous approaches at anytime, from anywhere. Since the self-made annotations which were made by student experts during individual study phase were stored in self-made annotation repository, peer experts could proceed with the review and discussion of the annotations. Annotation review and discussion module uses annotations stored in posted annotation repository to refer to the knowledge embedded in the determined annotations, and retrieved the annotations kept in self-made annotation repository to allow experts to carry out annotation review and discussion. The discussion process contained annotation clarification, error correction, and annotation classification. After annotation clarification and error correction have been completed, a set of agreed upon annotations was determined, classified into the three levels mentioned above: brief, medium and abounding.

The questionnaire used was a composite, using both survey type and quiz type questions. The reason for using a composite questionnaire was to accurately evaluate the extent to which learners possessed knowledge and were able to use it to solve the given questions. Additionally, the composite questionnaire can be served as an advance organizer (AO) which describes the structure of conceptions ahead of learning materials. It can be a sentence, an article, a question, or a video clip (Joyce & Weil, 1972). In this study, a question type AO was applied as a stimulus for learning unfamiliar materials so that learning transition can be facilitated (Mayer, 1979). Table 1 shows the descriptions and implied meanings of both questionnaire types.

Table 1. Two types of a composite questionnaire

Type	Description	Implied meaning
Survey	*This type usually asks learners about the definition of terms within a certain topic.*	*This type evaluates whether a learner was possessed of knowledge about a certain topic. It focuses on knowledge possessing.*
Quiz	*This type usually asks learners to solve the questions about a certain topic.*	*This type evaluates whether a learner can apply possessed knowledge to solve the given questions. It focuses on knowledge applying.*

The responses of the survey type questionnaire were classified into one of three groups: *does not understand*, *understands to some extent (medium)*, and *understands fully*. Each group was assigned a score, "does not understand" was worth one point, "medium" was worth three points, and "understands fully" was worth five points. The score of a survey type questionnaire was calculated using the following formula:

$$score\ x = \frac{Not\ understand\ items * 1 + Medium\ items * 3 + Understand\ items * 5}{The\ number\ of\ survey\ items * 5}$$

According to the score x, we can determine which the level of familiarity with a given topic a learner possesses, as shown in Figure 3.

$$\begin{cases} 0.2 \le x \le 0.3 & Learner\ is\ strange\ to\ the\ given\ terms\ about\ the\ topic. \\ 0.3 < x \le 0.7 & Learner\ has\ a\ little\ understanding\ about\ the\ given\ terms. \\ 0.7 < x \le 1 & Learner\ has\ enough\ knowledge\ related\ to\ the\ given\ terms. \end{cases}$$

Figure 3. The classification of a survey type questionnaire

The other type of questionnaire is an exam which contains several questions related to the given topic. The score of an exam type questionnaire can also be calculated. The score is a percentage score calculated by following formula:

$$score\ y = \frac{The\ number\ of\ correct\ items}{The\ total\ number\ of\ items\ on\ the\ exam\ questionnaire}$$

The composite score r which consists of score x and score y is calculated with a weighting value α which can be adjusted by the student experts' criteria. The weighting function is shown as follows:

$$r = \alpha * x + (1 - \alpha) * y$$

According to the result of the score r, the system can determine each learner's exact degree of familiarity with a certain topic and then provide them with the appropriate annotations. Table 2 shows the meanings of the composite score r within each range.

Table 2. The descriptions about the different composite score *r*

Range	Description
0.2$\alpha \le r <$0.3	*The learner is very unfamiliar with the given topic, and needs abounding annotations to study.*
0.3$\le r <$0.7	*The learner has some understanding and knowledge about the topic, and would benefit from medium, rather than basic annotations.*
0.7$\le r \le$1	*The learner fully understands given topic, so brief annotations with complex, rich knowledge succinctly presented would be most appropriate*

Jigsaw group meeting

Upon completion of an expert discussion, each expert was required to upload the annotation files into the classified annotation repository and then inform the members of the original Jigsaw of the location of annotated course materials, indicated by an URL. The communication between an expert and his group members was done using the abovementioned communication medium module. Therefore, group members could see the annotated course materials and then access the knowledge embedded in attached annotations. It is worth reiterating that before a learner could read an annotated material, he needed to reply to questions in the questionnaire designed by his expert peers. Afterward, he was designated as a beginner, expert, or middle learner. If a learner was evaluated as a beginner, the default degree of difficulty offered to him was plain and simple. As the degree of familiarization with the topic increased, the learner could choose other levels of annotation to acquire different aspects of understanding of topics. The group members could also raise questions if they were confused or did not understand the meaning of specific annotations. Experts in the Jigsaw group needed to respond to the questions raised by their group members and then refine the content of the annotations according to their suggestions. Through persistent discussions in the group, eventually, we believe that the materials with these modified annotations were very appropriate for a group study session.

Research experiments

The participants who took part in the experiment were 40 sophomores from the National Cheng Kung University (NCKU) and Hsing Kuo University of Management, and the experiment period was performed for two months, September to November 2007. Two curriculums, named *Data Structure* and *Introduce to Unix*, were adopted as example courses in the experiment. The lesson unit 'Trees' in the course, for example, was chosen to be a studying lesson, and topics contained in the lesson can be regarded as units at the '*Topic assignment*' phase such as "*Representation of Trees*", "*Binary Tree Representations*", "*Binary Tree Traversal and Tree Iterators*". Before conducting the experiment, subjects were asked to carry out the SQ3R study method during the individual study phase. During the expert group meeting phase, student experts discussed a set of agreeable annotations and created the questionnaires. And then, students obtained learning materials with annotations during Jigsaw group meeting phase. The experiment process lasted one semester. Following the experiment, the subjects' degree of satisfaction about the effectiveness and suitability of using annotation services with handheld devices in a ubiquitous Jigsaw cooperative learning environment was solicited as was information about limitations of this study. A Liker-type scale

method was adopted to check learners' satisfaction degree, ranging from strongly approvable to strongly opposing. Each response was assigned a corresponding score shown as follows: 5 for strongly approvable, 4 for approvable, 3 for neutral, 2 for opposing, and 1 for strongly opposing. In addition, the using frequency of different wireless networks and communication ways were also investigated.

The handheld devices chosen to be the testbed should possess variant wireless communication technologies, including *GPRS*, *WiFi*, and *3G*. Therefore, learners' opinions about different wireless environments should also be evaluated. They used touch pens attached with handheld devices to highlight and underline words and phrases. For simplicity and consistency of presented annotation, only two colors were applied to highlighting (with yellow color) and underlining (with red color) tools. Naturally learners could erase annotations in order to make modifications or corrections. Figure 4 shows the annotations presented on an experimental device. Experts could use a textbox (with green color in Figure 4) to write additional knowledge with respect to certain terms. In Figure 5, a questionnaire used to evaluate learners' familiarization degree in terms of the given topics is shown. According to the results of the questionnaire, the default presented annotations were classified into three levels, simple, middle, and complicated. Learners could manually adjust the appropriate annotations in accordance with their own learning style and pace of learning by using a drop down list.

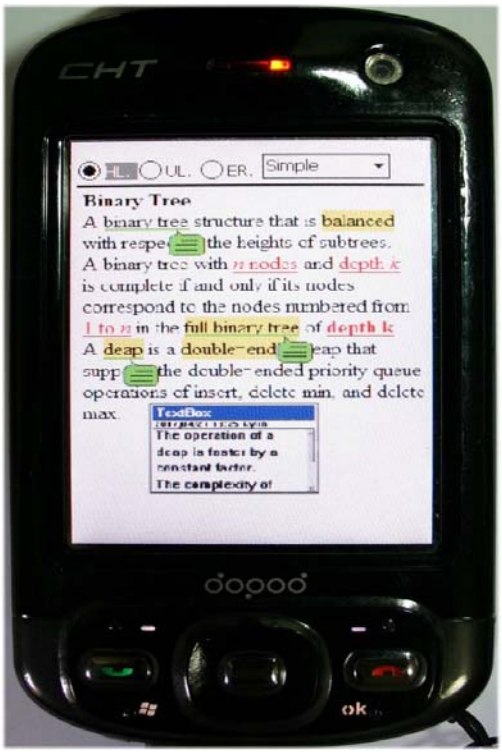

Figure 4. The presented annotations on a handheld device

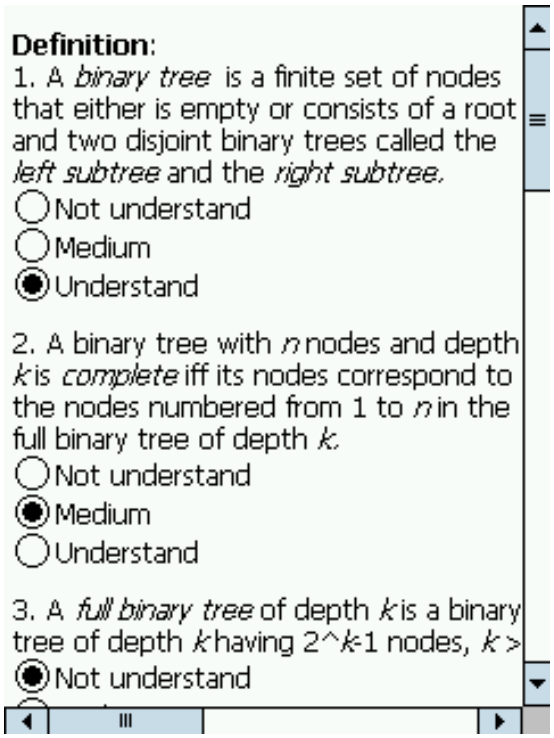

Figure 5. A questionnaire presented on a handheld device

Results and discussions

We first discuss the attitudes of participants in the study towards the learning activities and their perceptions about the use of handhelds. Afterward, the usability of different wireless networks and learners' perceptions of different communication tools are investigated and discussed.

Attitudes towards learning activities

Table 3 shows learners' attitudes towards Jigsaw learning activities. The evaluation indices were divided into three phases: individual study, expert group meeting, and Jigsaw group meeting which are three primary learning activities

in Jigsaw method. 70% of learners endorsed the efficiency of the use of the annotation services while 20% of learners disagree with this point (Question 1). Most learners indicated that annotation services offer a viable interface for making annotations on digital materials. 20% of learners thought that the services should provide a greater variety of annotation styles, such as graphic and vocal annotations. We believe these preferences reflect the learners' cognitive styles, which indicates a potential area of further research and development on the part of software designers and developers. Most learners felt that annotation services helped them use SQ3R reading method more efficiently (Question 2). In the expert group meeting phase, 75% of learners agreed that extended discussion about their annotations increased their familiarity with the materials (Question 3). Although 25% experts thought that the discussion process was a time-consuming task, the assistance of wireless technologies indeed facilitates the discussion process. In particular, the process is carried out in a distributed environment. Over half of learners disapproved of undertaking self-evaluation with classifying annotations (Question 4). Some of them indicated that they saw no need to do the self-evaluation, and some learners stated that they had no intention of doing so. The question of determining a proper time for self-evaluation and self-reflection is primarily the responsibility of a moderator whose role is usually filled by a teacher or instructor. The intervention of a moderator should occur at an appropriate time to remind learners to complete their self-evaluation and self-reflection about the classifying annotations. In the third phase, the Jigsaw group meeting, the composite questionnaire and interaction with experts were the two main factors evaluated (Question 5-7). 40% of learners agree that the composite questionnaires helped them get appropriate annotations embedded within the materials (Question 5). They said that the annotations provided did indeed correspond with their prior knowledge. Learners in disagreement with this said that classified annotations were insulting, in particular those students who expected to get higher level annotations. On this point, the classified levels of annotations should be redesigned and the composite questionnaires should also be under constant revision and changes in order to be improved. Question 6 evaluates whether or not composite questionnaires provide an adequate advanced organizer of the topics. 60% of learners responded positively, while 40% could not get the point of the composite questionnaires. As mentioned in research methodology section, the composite questionnaires were served as AOs, which have been shown to be effective in helping learners grasp the main points associated with course materials. However, 40% of learners thought that text-based AOs are not adequate to give them a deeper understanding of the materials. In the further study, therefore, multimedia AOs such as graphs, sound, and video need to be considered in order to thoroughly investigate the effect of AOs.

Table 3. Learners' opinions about learning activities

			Learners' Choices			
Phase		Question	Strongly approve & approve	Neutral	Oppose & strongly opposing	Mean
Individual study	(1)	Making annotations during this phase helps me study more efficiently.	70%	10%	20%	3.75
	(2)	Using the annotation services can effectively enhance the SQ3R method.	75%	15%	10%	3.98
Expert group meeting	(3)	Discussing the validity of annotations can improve my understanding of learning materials.	75%	20%	5%	4.05
	(4)	Classifying annotations helps me conduct self-evaluation.	40%	35%	25%	3.23
Jigsaw group meeting	(5)	Using the composite questionnaire, I got the appropriate annotations embedded in materials.	40%	45%	15%	3.38
	(6)	Composite questionnaire helps me grasp the main points of the topics.	60%	35%	5%	3.83
	(7)	Raising questions with experts improves my understanding of learning materials.	80%	5%	15%	3.96

Interaction between learners and experts was the last factor evaluated (Question 7). 80% of learners said that they could use variant communication mediums to proceed with clarifying questions and the experts usually responded in useful ways. The results were similar to previous research results (Strømsø *et al*., 2007). 20% of learners thought that these electronic communication media must collocate with face-to-face (F2F) meetings to achieve effective learning. Some questions could not be clarified or solved through the use of communication media in distributed learning environments. Hence, through the redesigned process, consideration must be given to conducting cooperative learning activities in a heterogeneous learning environment which consists of distributed and F2F meetings.

Perceptions about using handhelds and annotation services

Table 4 shows the results of the evaluation about learners' perceptions about annotation services and handheld devices in a ubiquitous cooperative environment. Overall, the results are positive. The reason might be that the participants have the same characteristic, the high acceptable rate of handhelds. Therefore, only the negative responses are discussed below. Almost all learners (95%) in our study agreed that handhelds provided them with the extremely valuable commodity of mobility (Question 1). The variety of communication tools and wireless networks was also appreciated. 30% of learners responded negatively to the **c**ooperative feature of the Jigsaw method in a ubiquitous cooperative environment (Question 2). Spatial separation might be the reason that led to the lack of a sense of cooperation. Perhaps future research could examine the acceleration of social interaction in the ubiquitous cooperative environment in more detail. 15% of learners expressed disagreement regarding the enhancement of the annotation services for learning (Question 3). They indicated that a greater variety of annotation types should be provided so that knowledge retrieval from materials could be more adaptive and individualized. Future research is obviously required to address these software related concerns. The reasons given for disagreement over the usefulness of the annotation feature on handhelds are noteworthy, indicating that size constraints limited the amount of information that could be contained in an annotation , that the services were not easy to use on a small screen, and that there were only a few ways to make the annotations (Question 4). In addition, explicit annotations cannot be compared simultaneously in the annotations services. Generally, the learners were satisfied with the interface of the annotation services, but there is clearly room for improvement. In a future study, we anticipate that the improvements in software design will result in better and friendlier annotations services.

Table 4. Learners' opinions about handhelds and annotation services on ubiquitous cooperative learning

Question	Strongly approve & approve	Neutral	Oppose & strongly oppose	Mean
(1) Handheld devices give full mobility.	95%	5%	0%	4.43
(2) Handheld devices are appropriate for a ubiquitous Jigsaw cooperative environment.	70%	25%	5%	3.98
(3) Annotation services applied on handheld devices enhance my learning.	80%	5%	15%	3.98
(4) The interface of annotation services allow me to make annotations easily	75%	20%	5%	4.05

Usage of wireless networks and communication tools

This section describes the usage of wireless networks and provides statistics about usage frequency of communication tools. Figure 6 shows the usage frequency under different wireless networks. 65% of learners adopted 3G wireless network, whereas 25% of learners chose WLAN as their favorite network. And only 10% prefer GPRS. A one-group chi-square test was used to test for statistical significance. This showed a statistically significant difference for the wireless networks (χ^2 =19.40, df = 2, p< .05).

Afterwards, we analyzed the 40 students' responses on open-ended questions, which provided explanations for the observed phenomenon. The entries indicated that several factors influenced students' preference on different wireless networks. For example, students mentioned that 3G wireless network is the best, due to its wide communication range. Some learners indicated that although WLAN can provide higher data transfer speed, using 3G wireless network could transfer text-based course content with annotations with ease in this study. The reason derives from

complicated configurations which arise when learners want to communicate using WLAN network. First of all, available access points should be searched. Generally, not only one access point could be searched, and users need to select the access point with the strongest signal. Afterward, users need to input account and password to login if the access point is protected by WEP encryption. In addition, they said that they could communicate with others anytime and anywhere via 3G network while they needed to be in specific locations in order to communicate using the WLAN network.

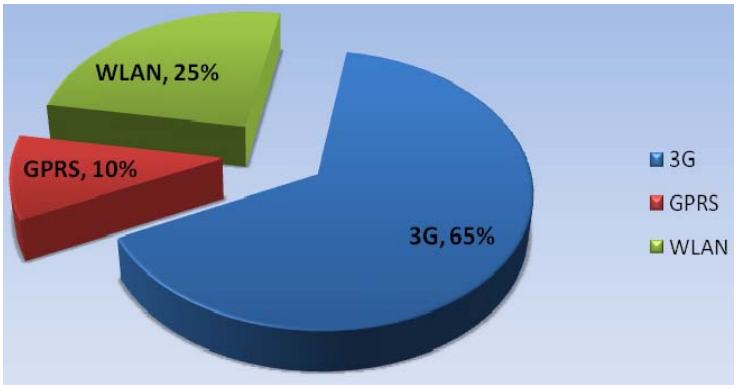

Figure 6. The usage of different wireless networks

Figure 7 shows the statistics related to usage frequency of different communication tools. Synchronous communication tools (*phone call, video phone, and IM*) were used by most of learners (72.5%) while 27.5% of learners chose asynchronous communication tools including, *email*, *SMS*, and *MMS*. According to the open-ended questionnaire, a few learners said that synchronous communications tools require them express their opinions, thoughts, and ideas for discussion immediately. It may explain the existence of high percentage associated with synchronous communication tools. Although the percentage of asynchronous communication tools as a whole is relatively small (27.5%), SMS takes 20% itself. 20% of learners indicated that the SMS campaign was effective due to the quickness of the response, high rates of the response, and the good quality of messages. For example, SMS responses were much quicker than email responses. In conclusion, a common thread in the conclusions of most of learners was that the best communication approach for a given purpose results from the use of the right tools with the appropriate networks.

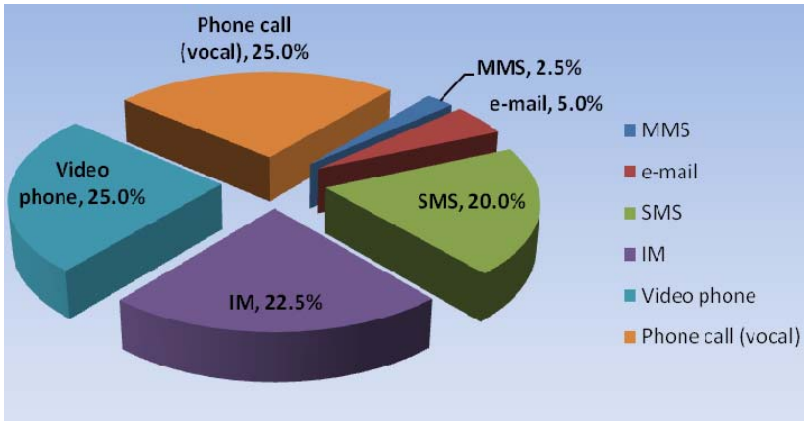

Figure 7. Perceived usage of different communication ways

Conclusion and future research

In this paper, we have described the use of annotation services on handheld devices in a ubiquitous cooperative learning environment. In addition to the implementation of the standard steps of Jigsaw learning method, an auxiliary study method, SQ3R, was adopted by learners to enhance their learning. An expert group meeting produced

classified annotations using three modules (or through three procedures), including communication mediums, annotation reviewing and discussion. The expert group meeting also resulted in the creation of a questionnaire, which served as a type of advance organizer for students, the results of which were used to provide more personalize study helps in the form of annotations attached to each student's assigned reading materials.

The experiment findings could serve as some suggestions for researchers who would like to experiment with ubiquitous cooperative learning in similar contexts. The experimental results revealed that the devised cooperative learning process certainly did help learners both broaden their knowledge of the topics under study and deepen their understanding of the same topics. However, based on learners' responses, deficiencies in software design need to be addressed. We are hopeful that future research will provide a friendlier operational interface and a greater variety of annotation services. The findings also showed that 3G wireless network and synchronous communication tools were the most appropriate network and communication media in ubiquitous learning because of their ubiquity and immediacy of communication they provided. We believe that the coming wireless technology, High-Speed Downlink Packet Access (HSDPA) (3.5G), will provide a great network environment for ubiquitous learning in near future.

In our future research, we intend to expand the variety of course content and conduct the entire experimental learning process in regular educational environments. We also consider applying the proposed method to several on-line courses in near future.

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