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A Study on the Effects of Collaborative Learning with Mobile Devices

A Thesis

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ABSTRACT

Many mobile learning (m-learning) systems have been constructed to transform traditional classroom or computer-based learning activities to be more efficient and ubiquitous, such as being able to present learners with a shared learning space. The work of learners is increasingly seen as collaborative by nature, and there is more collaboration between learners who have different learning experiences. Although these m-learning systems have promised positive collaborative learning outcomes, there has been little empirical work done to translate them into the learning outcomes which mobile collaborative learning environments can provide, where learners acquire new knowledge by contributing to each member's existing knowledge.

This thesis investigates both mobile learning and collaborative learning, and the focus is on: learning performance in mobile learning, types of knowledge created by collaboration and perceived learning satisfaction from this mobile collaborative learning experience. Several experiments were carried out to understand the nature of mobile-supported collaborative learning against traditional face-to-face (FTF) collaboration. The results revealed that, firstly, the learning performance was enhanced when the participants were learning collaboratively with the mobile device; secondly, mobile collaborative learning with a shared learning space contributed to shared knowledge generation.

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STATEMENT OF ACADEMIC INTEGRITY

I declare that this research study is entirely my own work and that it has not been copied from other people work. If the work and ideas of others have been used in the study, the work has been properly cited in the text.

Jianbo Cui

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CHAPTER ONE: INTRODUCTION AND BACKGROUND

The abundance of mobile devices, particularly for mobile phones, is having a profound effect on the way we use emerging technologies. Indeed, the rapid advancement of mobile devices and wireless networks opens up immense potential for many areas. People expect to be able to work, learn, and study whenever and wherever they want to. As such, people want easy and timely access not only to the information on the network, but to their social networks that can help them to interpret it and maximise its value. The implications for informal learning are profound, as are the notions of “just-in-time” learning and “found” learning, both ways of maximising the impact of learning by ensuring it is timely and efficient.

1.1 Mobile Technology and Education

Emerging mobile technology is changing the nature of education and is very likely to provide us with new experiences of ubiquitous learning. In the past decade, there has been a tremendous increase in research in the mobile learning area. For example, medical students use mobile devices to store and retrieve medical knowledge and manage patients’ resources as they work in the hospital (Hasan, 2002). Law school students can search legal information online, using a “Smartphone” which enable them to access and download legal information and resources at anytime and anywhere (Hasan, 2002). Children can work collaboratively in groups of three or four, communicating through mobile devices, and discover new knowledge by completing a series of tasks together (Schroyen *et al.*, 2008). Other studies (Mohamudally, 2006; Facer *et al.,* 2004; Schwabe and Göth, 2005) also explored the potential of the mobile device to simulate a virtual learning environment through games or field studies. These studies can be summarised in three-fold:

1. How to deliver learning materials to a small mobile device

   Sharples (2006) pointed out that m-learning needs to be innovative not focused simply on delivering information such as lecture notes onto a mobile device. Instead, m-learning should turn away from information access any time, anywhere, to giving learners practical opportunities to achieve experiences that they could not achieve before.

2. How to manage collaborative learning

   Collaborative learning has been frequently seen as a stimulus to enhance social interaction and situated learning. Literature on mobile learning (e.g., Mandryk *et al.,* 2001; Norris and Soloway, 2004) has shown that people often learn better in a collaborative environment than separately. Previous collaborative learning research was focused on computer-supported collaborative learning (CSCL), which relied on the prevalence of personal computers and, laptops and their processing power. As mobile technology becomes increasingly flexible in connectivity, mobility and processing power, it may present new ways to support collaborative learning. For example, mobile devices can create an environment where instant agreement (or disagreement) can take place, and provide effective coordination and negotiation among learners.

3. How to use m-learning to create more engagement with learning activities.

   Previous research has shown that the affordability of mobile devices can extend learner's engagement with learning activities (Schwabe and Göth 2005; Klopfer *et al.*, 2002). As learners become more engaged, it is then possible for them to go beyond the necessary learning activities, and enjoy its extra potential. Facer *et al.*, (2004) pointed out that compared with traditional collaborative learning or CSCL, mobile collaborative learning can create high engagement and motivation. This can be seen in the traditional learning situation, when the student becomes more passive, but mobile learning users have a certain control over the learning.

1.2 Research Questions

As discussed above, there seem to be many perspectives on the benefits of mobile learning, but this study aims to find the benefits or limitations of m-learning through answering the following three questions:

1. **Is mobile learning with collaborative learning activities a good way to enhance learning performance?**

The unique nature of mobile devices, with the mobility and instant connectivity it can offer, enables information retrieval or access anywhere at any time. The benefits of mobile devices thus lead to the assumption that mobile learning would allow a social constructivistic learning, by which learners can collaborate within a supportive community, and build up appropriate knowledge through this active participation. It is thus hypothesised that as learners perform learning tasks through a mobile-based collaborative learning environment, it may enhance a learner's learning performance in social constructivistic learning measures.

2. Is mobile learning with collaborative learning activities a good way to enhance externalisation of knowledge?

As many researchers (Mandryk *et al.,* 2001; Norris and Soloway, 2004**)** suggest that collaboration plays an important role in enhancing learners' knowledge externalisation, this research focuses on whether mobile learning would allow learners to use the knowledge that was generated earlier by themselves or by their peers. This idea is to build up knowledge through collaboration between the learners; in such a process mobile devices can be used as a tool to allow learners to work collaboratively and instantly "in the field", where the required knowledge can be accessed as soon as it is available. Therefore it is hypothesised that immediate collaboration through mobile learning systems may provide better collaborative or social knowledge generation than traditional learning systems do.

3. Is mobile learning with collaborative learning activities a good way to enhance learners' satisfaction?

The portability of mobile devices and their ability to connect to the Internet almost anywhere makes them ideal as a store of reference materials and learning experiences, where they can text, or talk to each other to reach agreement or disagree.

At its core, the notion of collaborative learning is to take advantage of mobile technology as a global dissemination platform for collective knowledge and wisdom, and to design learning experiences that maximise the use of it. Hence it is hypothesised that the adaptation of mobile technology in collaborative learning may provide an enhanced and novel learning experience.

1.3 Thesis Outline

The rest of this thesis is organised as follows. Chapter 2 is a literature review based on the research questions in section 1.2. It includes the current trend in mobile learning and explores different types of mobile learning applications. Chapter 3 explains the research design, experimental method and apparatus. Chapter 4 presents the results collected from the experiments and the brief interpretation of each result. A detailed analysis and discussion of the data are given in Chapter 5. Finally, Chapter 6 describes the limitation of this research and suggests further work.

CHAPTER TWO: LITERATURE REVIEW

2.1 What is Mobile Learning?

Many researchers and communities work in the m-learning area, and they all have rather different perspectives. The following summarises three main perspectives of the current m-learning studies: *Techno-centric, Related to e-learning, and Learner-centred* (Sharples, 2006).

Techno-centric Definitions

This perspective describes m-learning as learning by using mobile devices, such as mobile phones, PDAs, laptops or any portable devices. Traxler (2005) put m-learning in the techno-centric view as "*any educational provision where the sole or dominant technologies are handheld or palmtop devices*" (Traxler, 2005, p. 262). Another techno-centric definition is "*the ability to enjoy an educational moment from a cell phone or personal digital assistant (PDA)*" (Hashim, 2007, p. 11). However, any such definition of m-learning is hardware-dominated and does not allow for new uses, so a wider definition is needed, for example, the concept of e-learning could be included.

Relationship to E-Learning Definitions

The second perspective translates m-learning as a part of e-learning, thus using mobile devices to offer learning experiences blended with e-learning. Traxler (2005) supported this perspective, maintaining his techno-centric definition to put mobile learning on e-learning's spectrum of portability. However, this lacks consideration of learning in the contexts that mobile learning makes possible. Learning in such contexts includes the mobility of the learner, and this cannot be described by existing learning methodologies, such as e-learning.

Learner-centred Definitions

It seems that the recent focus of mobile-learning is on the mobility of the learner. In this sense the learner should be able to perform learning activities without the constraint of having to do so in a certain location. For example, learning outside a classroom, on a train or bus, or learning while working in an office. Sharples (2006) hence defined mobile learning as:

> *"Any sort of learning that happens when the learner is not at a fixed, predetermined location, or learning that happens when the learner takes advantage of learning opportunities offered by mobile technologies"*
>
> (O'Malley *et al*., 2003, p. 6)

2.2 Why Mobile Supported Collaborative learning?

The previous section described diverse definitions of m-learning, from techno-centric to user-centered. In this section, we explore why collaborative learning has recently attracted the m-learning community.

Many features of mobile devices suggest that they have the potential to support more ubiquitous collaborative learning. In this light, Klopfer *et al.* (2002) have analysed features which could be fully exploited in m-learning as follows:

- Portability – allows the learner to carry mobile device around anywhere at any time.
- Social interactivity – allows collaboration with others through mobile devices, face-to-face or both forms at the same time, and sharing information.
- Context sensitivity – allows context-based real or virtual activities, such as location-based service, current environment or time.
- Connectivity – allows compatibility with other devices or through networks, and increased information access.
- Individuality – allows unique scaffolding that is personalised to the individual's path of investigation.

This research focuses on collaborative learning through mobile devices. Mobile collaborative learning activities would support instant knowledge sharing between learners. Hence learners can work together to accomplish shared objectives, especially if they have difficulty in learning on their own (Olguin *et al.,* 2001). When learners are able to share common learning goals, it would be of great value if they were able to share doubts, agreements and disagreements, so that they could understand other perspectives that they have not thought of. Previous results confirm that collaborative learning fosters more creative ideas, strategies and solutions than working individually (Johnson and Johnson, 1989). These benefits imply that mobile technology is particularly suitable for presenting enhanced collaborative learning experiences.

A practical example of a mobile-supported collaborative learning system is the *Savannah project* (Facer *et al.,* 2004). It aims to encourage the development of children's understanding of animal behaviour through collaborative activities. In the *Savannah project*, mobile technology was used to enable conversation between students, equipped with a GPS–enabled PDA (see Figure 2.1), playing the role of a lion or other creatures in the Savannah.

Figure 2.1 Personal digital assistants (PDAs) and headphones – with image, energy bar and sight, send and smell buttons (Facer *et al*., 2004)

For instance, when they move around the simulated play field, the mobile device allows them to hear the simulated sound, and see the related images of a specific area of the Savannah. At the same time, players can communicate with each other and coordinate collaborative activities by using their PDAs. For example, players can coordinate their movements in the virtual Savannah and work as a team to perform attacks on prey, as in the following example:

Player 1: A baby lion, do we attack it?

Player 2: Yeah.

Player 1: 1, 2, 3 attacks (Facer *et al*., 2004, p. 406)

The findings indicated that learners were highly engaged while interacting with the mobile learning activities. More importantly, they found that working in a group rather than individually were more likely to lead to greater success, and thus they were encouraged to work more collaboratively.

Arrigo and Chiappone (2004) carried out a richer collaborative learning project, focusing on collaborative knowledge building. They created a system called *mobile Collaborative Learning Tool* (mCLT), which allows students to participate in knowledge building by accessing subscribed courses from a mobile device. When a student logs onto the system, a list of courses is shown, each of which contains content related to the course, each one is a discussion on a topic which is created by the course authors. These discussions are of different categories (e.g., problem, comment, working theory), which helps distinguish between the concepts in the discussion. Students can contribute their opinions by creating notes or images. Others may read then reply to the previous notes, the content of which naturally forms contextual collaborative knowledge while they use the system.

These examples show that mobile supported collaboration can construct a learning environment in which shared knowledge can be generated from the content by the cooperative learners. Reigeluth (1999) believed that these mobile collaborative learning systems could provide a shared knowledge–building environment, which allows learners to explore common ground or shared understanding between them, negotiate to build new knowledge, and facilitate problem–solving (Bonk and King, 1998). This collaborative learning experience is well explained by one of the learning theories, called social-constructivistic learning.

2.3 Mobile Learning implies Social Constructivistic Learning

Recent theories on pedagogy see collaborative learning as a process of social conversation, where students and instructors can interactively build knowledge together. This moves m-learning beyond transmitting knowledge one-way from the instructor to the learner (Jonassen *et al.*, 2003). The construction of knowledge can be seen as the result of mutual understanding of learners' existing knowledge to make meaning to develop new knowledge. However, learners already have their own existing understanding of a problem domain, so they may have different opinions and strategies regarding a particular issue (Dufresne, 1996). Consequently conflicts may occur during collaboration.

Piagetian theory (e.g., Zurita and Nussbaum, 2004) suggests that this social-cognitive conflict could enhance the effectiveness of collaborative learning, by encouraging learners to interactively contribute different opinions through continuing negotiation, to reach an integrated understanding of the issues. In order to support this negotiation, researchers believe that social mediation is important (Brown *et al*., 1989; Vygotsky, 1978), therefore it would be better to situate learning in a real-world environment, where a learner can become a part of a collaborative learning group to address real-world issues and gain knowledge constructively.

Mobile technology can play an important role in achieving this objective. The Arrigo and Chiappone (2004) example described above already showed that mobile technology would support social constructivistic learning, in which people learn by actively creating new knowledge based on current and prior knowledge.

In Zurita and Nussbaum (2004), a constructivist mobile learning environment was designed, in order to allow learners to recognise many words (in Spanish) through collaborative work. Using the mobile devices, each child has to contribute their own ideas, promote discussion, and negotiate with other members to form different words with their syllable. In this experiment, learners worked collaboratively (in groups of three) by using Pocket PCs (Compaq iPAQ). Each handheld displays a syllable that has to be combined with the syllables of the other two children to form as many words as possible (in Spanish, a set of syllables can build different words).

Each child has two options on his or her mobile device to form a word, the "Cloud" button on the top left corner of the mobile device (see Figure 2.2, arrow 1), which allows a child to select the corresponding syllable inside the "Cloud" (each child has different syllable inside his cloud, see Figure 2.2 (b-d)), and the button on the bottom right corner with a face icon (see arrow 2) allows a child to indicate that he or she does not agree to use the syllable to form a word. In order to form a word, all three children have to agree on the syllable on their mobile device.

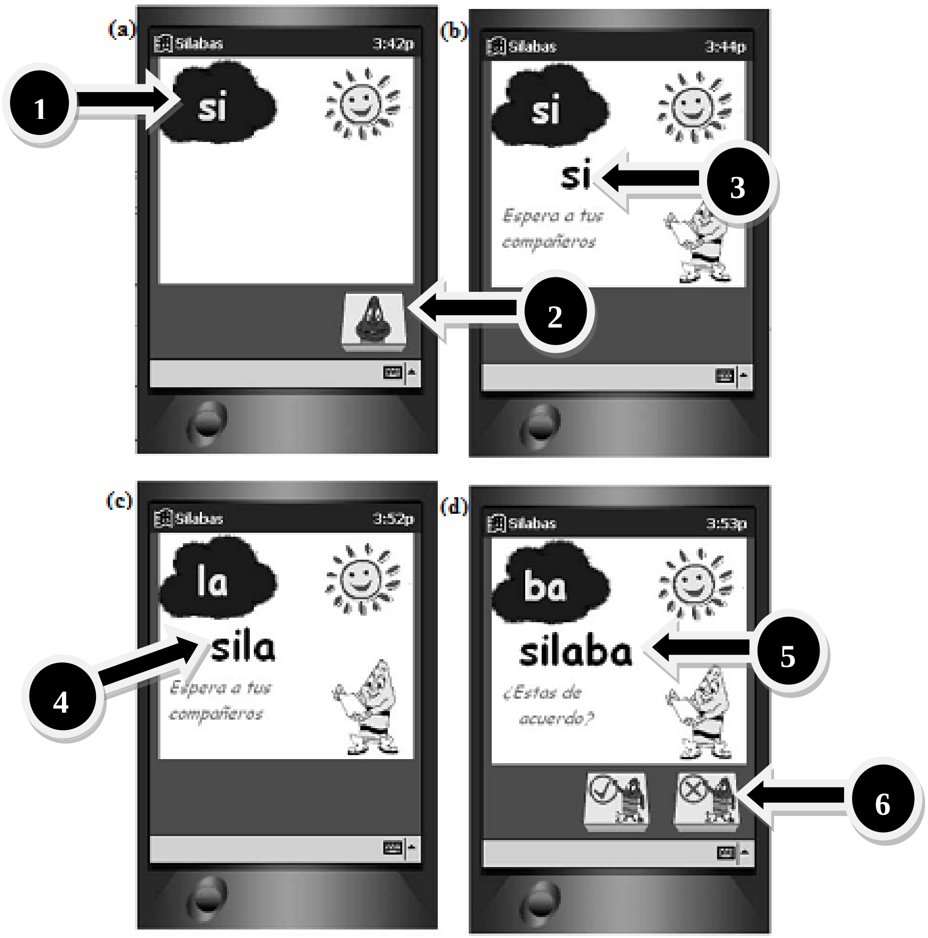

Figure 2.2 Interface snapshots of language activity (Zurita and Nussbaum, 2004)

Figure 2.2 (b-d) represents three views that correspond to one child's screen at a time, but in the three different states. Firstly, one child with *si* (Figure 2.2 a) agrees to use his syllable to form a word by selecting the cloud (arrow 1), and then all the children's screens will show the selected syllable (arrow 3). The next child with *la* (Figure 2.2 c) also agrees on his or her syllable by selecting the cloud, then all the screens update by appending the syllable to the previously agreed one (arrow 4), and the same with the last child as shown in Figure 2.2 d.

After each child selects his or her syllable, a voice message ("Do you agree?") is sent to all the children, to confirm that everyone agrees on the constructed word (arrow 5). If someone in the group does not agree, a voice message ("agree on a new answer") is sent, asking for agreement on a new word.

In such a way, the mobile learning enabled social interaction, and each learner can readily receive the synchronised and shared feedback. The finding of Zurita and Nussbaum (2004) revealed that mobile devices provided a unique experience in constructivist-knowledge building, the social negotiation space of group members, coordination between the activity states, and opportunities to mediate the interactivity.

2.4 Conversation as a Key

In the previous section, we claimed that social conversation could be a major concern of collaborative learning. In modern pedagogy, mobile devices can play important roles in supporting social conversation in collaboration, as the major advantage of Mobile Computer Supported Collaborative Learning (MCSCL) is that it enables instant conversation between learners anywhere at any time. This instant contact can be very important as we apply mobile technology to collaborative learning. A theory that is very relevant to this method of mobile learning is *conversation theory* (Pask, 1967). It describes learning as a form of conversation between different systems of knowledge.

The theory suggests that in order for learning to take place, one must be capable of conversing with oneself about what one knows (Sharples *et al.*, 2002). For example, when a person tries to solve a problem, he or she performs activities in the real world to try out new actions, and make decisions about what to do next based on previous experiences. During the process, the person's thoughts and actions involve a continual interaction and adjustment (see Figure 2.3). In order for the person to gain experience and improve it through future learning activity, he or she must be able to construct understanding and descriptions of the self and its activity, and be able to extend that description with understanding to form further activity.

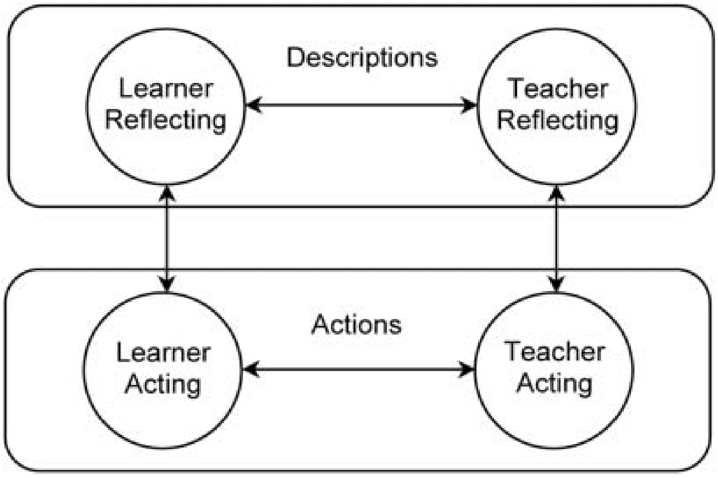

Figure 2.3 A framework for conversational learning (Sharples *et al*., 2002)

Sharples *et al*., (2002) suggested that learning can be more effective when learners are able to converse with each other in collaboration. Learners can share and describe their existing knowledge through continuous conversation, and new knowledge may be created through further discussion or negotiation. For example, when two people are working together to solve a problem, they can converse with each other, and share description of their knowledge. If person A describes something to person B, and it matches person B's expectations, it means the conversation has found common ground. Otherwise, a further series of discussions can be held.

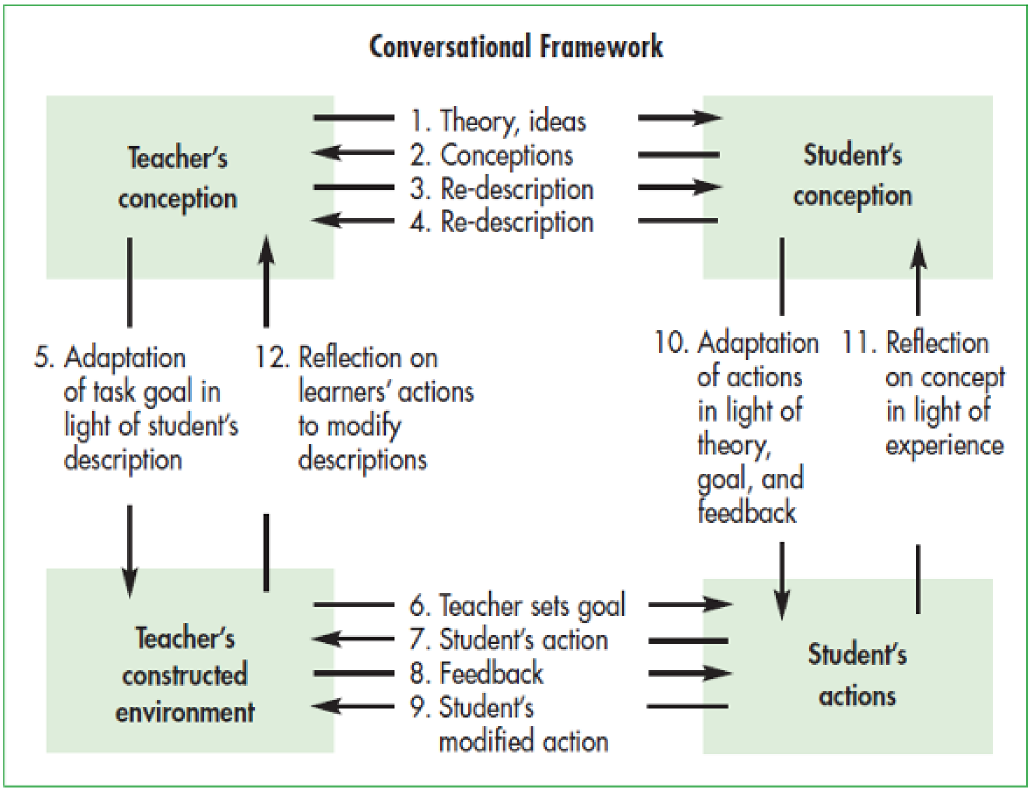

Figure 2.4 Laurillard's Conversational Framework (1993)

When Laurillard (1993) suggested a *conversational framework*, which relates Pask's *conversational theory* to the realm of academic teaching and learning, the focus was on the application of technology to university-level education. Figure 2.4 shows that the *conversational framework* involves a conversational process between teacher and learner, which operates on two levels: *the discursive conceptual level* (see the top two rectangles of Figure 2.4) and *the practical experimental level* (see the bottom two rectangles). The first level can be explained in four steps (see arrows 1 to 4) as follows:

- First, a teacher initiates a conversation by presenting a theory or ideas of a certain topic to a student;

- The student describes his or her understanding of the ideas as feedback to the teacher;
- Then the teacher understands the student's conception, and provides further descriptions of knowledge to the student;
- Finally, the student adjusts his conception based on the teacher's description, and re-describes his or her adjusted understanding back to the teacher.

These dialogues can form an iterative process between them, until the teacher and learner's descriptions meet each other's expectations or reach a consensus. Then the teacher can construct a learning environment on the experimental level, and allow learners to practice in light of their understanding (see arrow 5 of Figure 2.4). This process can be explained in four steps as follows:

- First, a teacher can set learning tasks and goals or a student in light of their conversation on the conceptual level;
- The student engages in a learning process according to the teacher's instructions;
- The teacher monitors the student's learning process and provides feedback;
- The student modifies his actions based on the teacher's feedback.

These dialogues can form an iterative process among peers, until the learning task or goal is reached. In the end, these two levels are linked by each participant practicing the theory (see arrows 5 and 10), and reflecting on the theory in light of the practical experience (sees arrows 11 and 12) (Laurillard, 1993).

The ‘conversational framework’ (Laurillard, 1993) and the ‘conversational learning’ (Sharples *et al*., 2002) looks at the on-going teacher-learner or learner-learner interactions, at the process of negotiation of different knowledge, so learners able to modify their perceptions. From this, the study develops a mobile supported collaborative learning system, setting a series of learning objectives, encourage learners to talk with each other using their mobile devices, and finding more meaningful information relate to their personal context.

The capabilities of mobile technologies imply that they are more suited to adapting the *conversational framework* activities mentioned above, and provide a more progressive collaborative learning experience. This can be summarised in four presumed statements:

- Mobile technology can support effective negotiation mechanisms, where a learner is able to contribute his opinions in a shared learning environment quicker than before. For example, a learner may use his or her mobile device to raise a specific theory or ideas in a shared learning space, and then others can contribute with their own ideas to the same topic. Mobile devices can easily support this kind of conversation, as a learner receives opinions from different perspectives instantly, so they can then continuously adjust their understanding and actions, consequently providing an enhanced learning experience.
- Mobile devices can be used to coordinate collaborative learning activities for classroom learning as well as for outdoor learning (Aleahmad and Slott, 2002;

Bick, 2005). Therefore they can provide more opportunities for learners to practice the concepts, either for real or experimentally. More importantly, learners can converse with their peers to share ideas, theories and problems as they practice the related theories and concepts, so the adaptation (see arrows 5 and 10) and reflection (see arrows 11 and 12) processes can be done instantly.

- Interactivity among learners can be crucial in collaborative learning, as successful collaborative learning requires learners to converse with each other, and exchange ideas, problems and theories. The "any time, anywhere" characteristic of mobile devices can support instant interactivity between learners in many ways, such as the exchanging of knowledge and information, the giving and receiving of help and feedback and the ability to challenge and encourage learners (Curtis and Lawson, 1999). Moreover, mobile devices allow the learner to be in control of their device and activities (Zurita and Nussbaum, 2004), taking the initiative in accessing or acquiring information (Pincas, 2004).

In this sense, our study focuses on using mobile devices to provide an instant collaborative learning environment, where knowledge can be generated through instant knowledge sharing between learners. We want to explore the learning effects of the instant knowledge sharing supported by mobile collaborative learning, and compare these effects with forced collaborative learning.

CHAPTER THREE: EXPERIMENT

The main purpose of this research was to explore whether collaboration via mobile devices could be effectively associated with learning experiences. If this is the case, then we seek to answer how this would best serve knowledge building in collaboration.

To do so it was necessary to examine a collaborative learning activity in a natural learning situation. This would allow one to identify how mobile technology achieves a critical collective learning experience in mobile learning, and eventually how the mobile learning may be accepted. The purpose of this evaluation was to determine under what circumstances this sample of participants found the collaborative learning activity useful.

The experiment was designed to investigate collaborative learning activities using mobile devices from three perspectives: learning performance, knowledge building and learner's satisfaction. Based on the previous literature review, we built research questions and null hypotheses as follows:

Question 1: Is mobile learning with collaborative learning activities a good way to enhance learning performance?

Hypothesis 1: As learners perform learning tasks using the mobile-based collaborative learning environment, it might enhance learning performances.

Question 2: Is mobile learning with collaborative learning activities a good way to enhance externalisation of knowledge?

Hypothesis 2: Immediate collaboration through mobile devices may facilitate better collaboration or social knowledge creation than what traditional learning can.

Question 3: Is mobile learning with collaborative learning activities a good way to enhance learners' satisfaction?

Hypothesis 3: Compared with traditional collaborative learning, mobile computer-supported collaborative learning might give positive user satisfaction in terms of usefulness, activeness, effectiveness, "in-time" collaboration, and ease of learning.

3.1 Experimental Design

To empirically investigate the research questions above, a realistic learning program was developed to train security guards. This program was aimed to allow participants to patrol several physical locations, to find as many security issues as they could, and collaboratively learn from each other. Two types of learning system — mobile collaborative learning, and face-to-face (FTF) collaborative learning — were developed to see the differences in learning performance, knowledge generation and learning satisfaction. Both systems allow the trainee guards to participate in a security patrol mission by using a mobile device, encouraging them to act on their own and collaboratively, and construct their own knowledge, as well as sharing knowledge with other trainee guards to complete the patrol. Six patrol locations were selected from Massey University Albany campus, each patrol location associated with an instruction for the trainee to learn. The same locations were used for both settings (i.e., Mobile collaborative learning and FTF collaborative learning), and each subject patrolled three areas, and learned three instructions of each location.

The experiment was a between-subjects design. The two types of learning system (mobile collaborative learning, and face-to-face collaborative learning) given were the between-subjects independent variable, while the dependent variables are:

- Learning performance – represents how well a participant has learned the patrol instructions from both their visit to three of the locations, and their partner's visit to the other three locations.
- Types of knowledge generated – represents the number of different types of knowledge (e.g., *Problem*, *Theory*, *Suggestion*) that was generated through the collaboration between two participants.
- Personal satisfaction – represents the ease of learning, the efficiency of learning, the usefulness of learning, the "in-time" collaboration, and the activeness of the participants for both systems.

3.2 Participants

A total of 40 participants (20 pairs), aged between 20 and 28, voluntarily participated in the study, and around half of them were female. They were assigned at random to one of the two experimental settings (ten pairs to mobile collaborative learning, and another ten pairs to FTF collaborative learning). The participants were recruited from Massey University and none of them had any experience of security patrol duties.

3.3 Apparatus

Each subject was equipped with a mobile device installed with the patrol system, called "*Online Patrol Training System*" (OPTS). Table 3.1 shows the details of the functionalities for each system.

Functionalities	Mobile CL	FTF CL	Description	Note
View patrol Instructions	Yes	Yes	View and learn the patrol instructions of a patrol location.	
View campus map	Yes	Yes	View the name and the location of each patrol location on a campus map.	
Take photo of a patrol location and submit to the system	Yes	Yes	Take a photo using mobile device and submit it to the system.	
Adding a Problem/Question to the system	Yes	No	Create and submit a question to the system, such as problems or enquiries. Also take a photo using the mobile device and attach it to the question.	Used for generate instant knowledge in mobile CL, in contrast to a late generation in FTF CL.
Adding a Theory to the system	Yes	No	Create and submit a theory to the existing problems. The participant is required to provide something they think is useful to the system, and could also take a photo with the mobile device and attach it.	Used for generate instant knowledge in mobile CL, in contrast to a late generation in FTF CL.
Reply to a previous knowledge in the system	Yes	No	Create and submit a post (e.g., problem, theory) as a reply to existing information in the system.	Used for instant collaboration and knowledge sharing, in contrast to a late collaboration.
Search for existing knowledge	Yes	No	Search for related knowledge in the system by entering keywords.	Used for instant knowledge generation in Mobile CL, in contrast to a late generation in FTF CL.
Collaborative wrapping-up	No	Yes	Join a FTF wrap-up to enable discussion and collaboration. The participant is required to externalise and share the knowledge they gained from their individual learning.	Used to enable a late collaboration and knowledge sharing in FTF CL, in contrast to Mobile CL.

Table 3.1 Functionalities for Mobile collaborative learning system and Face-to-Face collaborative learning system

The difference between the two systems (e.g., Mobile collaborative learning and FTF collaborative learning) is that the Mobile collaborative learning system supports instant communication, so that subjects could readily perform collaborative learning. On the other hand, the FTF collaborative learning only allows a subject to take photos and store them for the time-delayed collaborative session later.

The Mobile collaborative learning system allows participants to use their mobile device as a mediating tool to communicate and then externalise what they have found and learned about their patrol locations, into a knowledge table. This is done by adding text-based information or images to the knowledge table. When new knowledge is added to the knowledge table, it instantly notifies the new information to the other learners.

By contrast, the FTF system does not allow instant collaboration, but they can take photos, upload them to a server, and later on view them together in the wrapping-up session. Because the subjects did not collaborate during the patrol, this time-delayed collaboration was performed to give them the opportunity to externalise any issues or build up knowledge they wanted to share with their partners.

Figure 3.1 Mobile Devices with the Patrol Application Interface

The mobile application was installed on Nokia E71 and E66 handsets (see Figure 3.1) with 3G network connections, and subjects could choose their preferred keypad in order not to interfere with their existing experiences. The six patrol locations are shown in Figure 3.2.

(a) Postgraduate Lab (b) Gate 3

(c) Sushi Shop (d) MBA Kitchen

(e) Student Club (f) IIMS & Library Car Park

Figure 3.2 Photo of Patrol Locations

3.4 Experimental Scenario

Firstly, all the participants attended a tutorial which introduced necessary information to carry out the experiment task, such as:

1. Six locations to be patrolled;
2. Online Patrol Training systems (OPTS);
3. Form groups and assign patrol locations;
4. Practice the OPTS

In the main experiment session, they decided the patrol sequence by themselves.

When mobile collaborative learning was used, the subjects were required to perform the following series of tasks, but not in a sequential way:

- Go to the location;
- Learn instructions of each patrol location, and inform their group member of those instructions;
- Search for related knowledge (from database) of the patrol location;
- Patrol the location by carefully observing the environment;
- Raise questions or build theory related to the security of each patrol location;
- Take photos that relate to the issues raised, submit the photos and add comments to the knowledge table;
- Provide something they think useful to share, for a future use.

For their first job to do, he or she was required to go to each location and to gain sufficient knowledge of the environment by either visually examining the location, or accessing the knowledge table. If they found some security issues, they were required to take a photo of the site, describe the issue and then submit it to the knowledge table. To ensure the good quality of the knowledge added to the knowledge table, they were encouraged to think creatively and act collaboratively during the patrol, externalising their knowledge by proposing questions and theories. For example, when a trainee described an issue such as "the car barrier bar at Gate 3 is visually too weak", then he or she took a photo of the barrier bar and submitted the problem together with the photo to the knowledge table. Then the other trainees received this information instantly, and could reply to it by contributing their opinions such as "Gate 3 requires backup plan when incident occurs". However, this free style description would make adding knowledge to the knowledge table much onerous. Hence they were asked to use some "*scaffolding*" words (Clowes and Morse, 2005) for adding knowledge to the knowledge table.

[Subject A's Problem]	*There are not enough security cameras at the student car park A.*
[Subject B's Theory]	*Car park A is frequently patrolled, so it is relatively safe.*
[Subject A's Disagreement]	*I disagree. As the car park is completely open, it is hard to secure the entire area.*
[Subject B's Agreement and Suggestion]	*I agree with subject A. The student car park needs more security cameras to cover the entire area.*

Table 3.2 Subjects externalise opinion as Theories

Table 3.2 shows two subjects contributing their opinions by using the scaffolding words. Subject A patrolled the student car park, and he thought there were not enough cameras installed in the car park, therefore he externalised his opinion as a

‘*Problem*’. When Subject B saw this post, he or she also replied with his opinion as a ‘*Theory’*. If Subject A agrees with B, he or she may externalise an opinion as an ‘*Agreement’*, otherwise a ‘*Disagreement’* can be generated. Subject can also generate a ‘*Suggestion’* to an existing issue raised by others.

In contrast, for FTF collaborative learning, each participant performed an individual patrol without instant collaboration. Since no instant collaboration was made in FTF collaborative learning, the patroller only learned half of the locations during the patrol, and received no information relating to the other locations. Subjects were required to perform the following tasks, but not in a sequential way:

- Go to the locations;
- Learn the instructions for each patrol locations;
- Patrol the location by carefully observing the environment;
- Raise questions and issues related to the security of each patrol location;
- Take a photo that relates to the raised issues, and submit the photo to the knowledge table;
- Participate in FTF collaborative learning.

The first three tasks are the same with Mobile collaborative learning tasks; however when questions and issues have been raised, subjects are only allowed to take photos, no immediate collaboration was allowed during the patrol. As a compromise, when they finished their patrol, they attended a wrapping-up meeting with their teammate. The FTF collaborative meeting was carried out in a sequential way:

- Share photos taken earlier during the patrol;
- Externalise and discuss questions and issues raised during the patrol by others;
- Document all the discussions, problems and theories

The photos stored on the system could be accessed through a simple web page. In the meeting, the subjects worked together to externalise their knowledge and a computer was used to motivate this process with all the photos taken. The subjects were then asked to use the scaffolding words (same to mobile CL in Table 3.2) to assemble their knowledge into a document, for example:

[Subject A's Problem]	*Postgraduate Lab is insecure, because the door was unlocked.*
[Subject B's Theory]	*Anyone can access the lab as the door was unlocked.*
[Subject A's Disagreement]	*Postgraduate Lab requires better security measure, for example, install a security camera.*

Table 3.3 Subjects Document Their Knowledge

3.5 Experimental Procedure

Figure 3.3 shows the details of experimental procedures for each system.

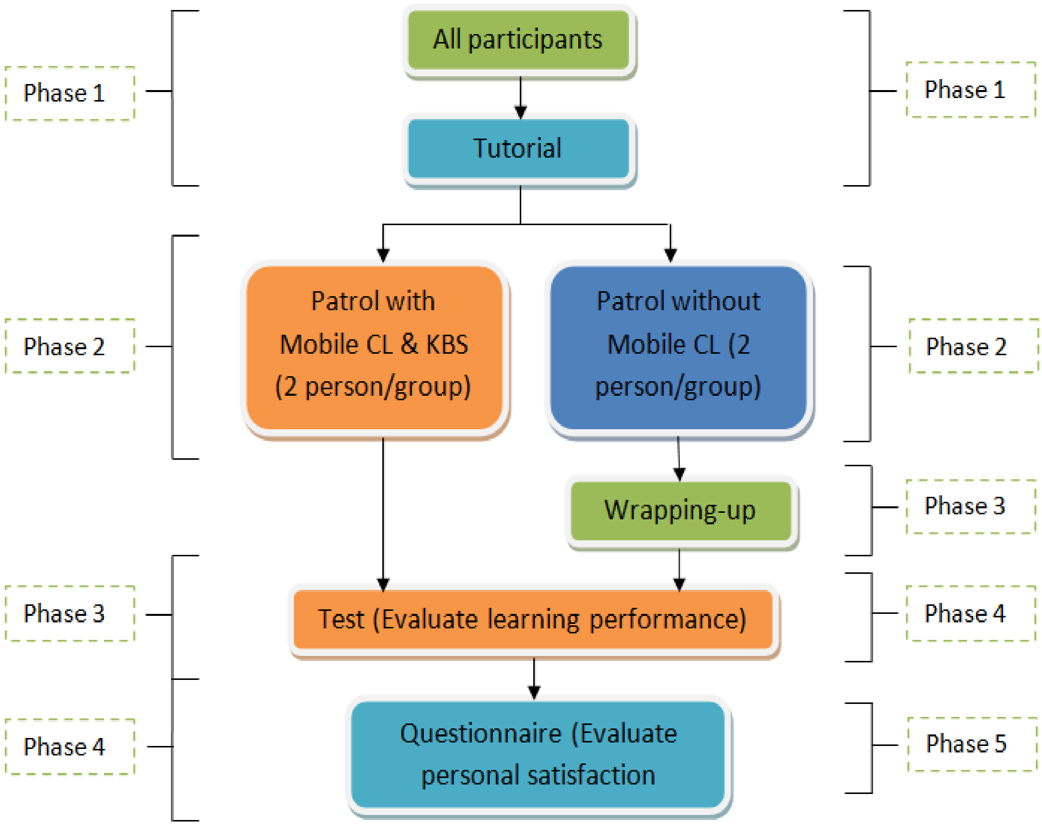

Figure 3.3 Experiment Procedures

(Four phases in Mobile collaborative learning and five phases in Face-to-Face collaborative learning)

3.5.1 Tutorial Session

In the tutorial session, all the subjects were told about the locations to be patrolled. There were six locations to be patrolled, all of which are in Massey University Albany campus. Both table 1 and Figure 1 in Appendix 4 show the name of each patrol location, and the patrol locations on the campus map. All the subjects were required to learn this information in the tutorial. The subjects then received a short tutorial on how to perform basic tasks by using OPTS. In order to obtain quality data from the main experiment, participants were required to get familiar with the system before they started the patrol. They were required to practise the system by performing the following tasks until they became familiar with it:

- Add a sample problem to the knowledge table;
- Add a sample theory to the knowledge table;
- Search for related knowledge by entering the keyword “library”;
- View all the patrol locations’ names and the locations on the campus map;
- View instructions related to each patrol location

3.5.2 Patrol Tasks

Our participants were assigned groups with two people in each, and each subject patrolled only three locations. They were required to learn the following patrol procedure for Mobile collaborative learning and FTF collaborative learning.

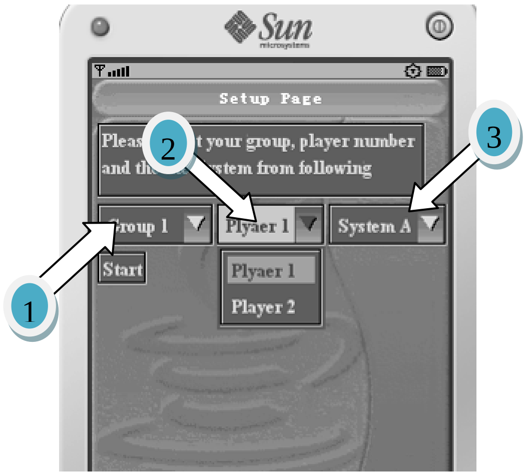

Figure 3.4 Setup Screen

For the Mobile collaborative learning system, firstly the subject sets the system by selecting the group number (Arrow 1), player number (Arrow 2) and the system they are using (Arrow 3), which were given to the subject before the patrol, then they pressed the *Start* button (Figure 3.4).

(a) (b)

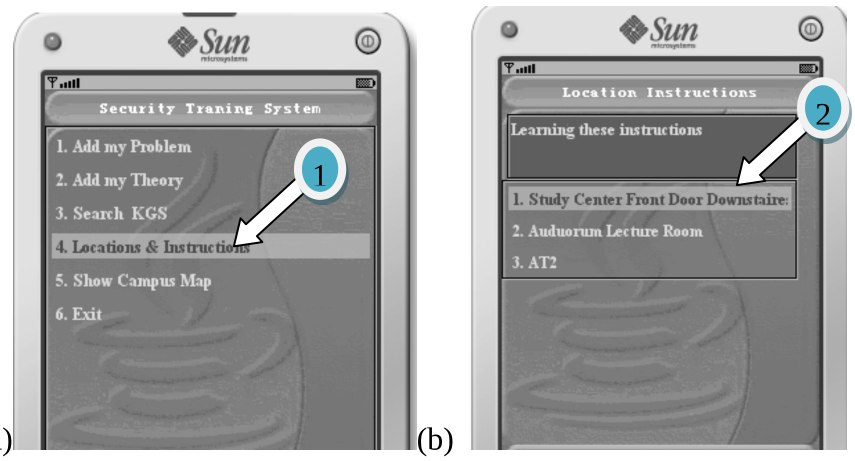

Figure 3.5 Location & Instruction Screen

After setting up the Mobile collaborative learning, the subject chose a place to patrol by selecting *Location & Instruction* option (see arrow 1 in Figure 3.5), then a list of patrol locations is shown (Arrow 2).

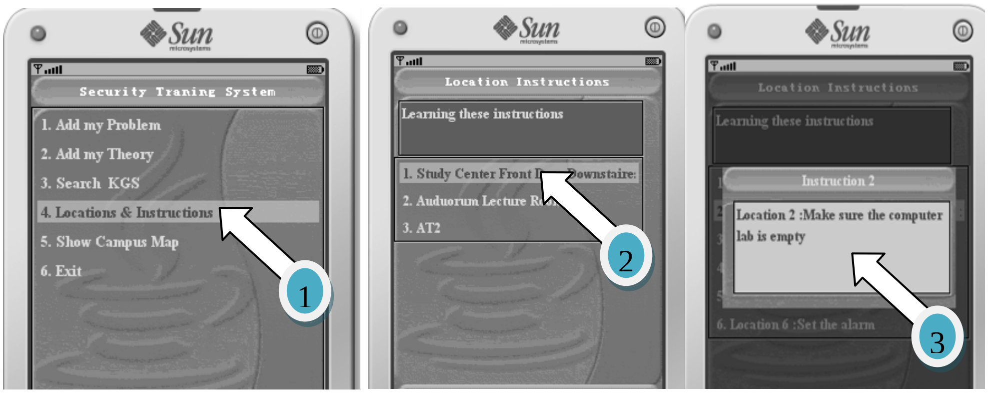

Figure 3.6 Instruction Screens

The subject learnt the patrol instruction (Arrow 3 in Figure 3.6) associated with each location by selecting the *Location & Instruction* menu (see Arrow 1), then the location name (Arrow 2). The subject needed to teach their partner about the instruction (Arrow 3) by sending a theory to them.

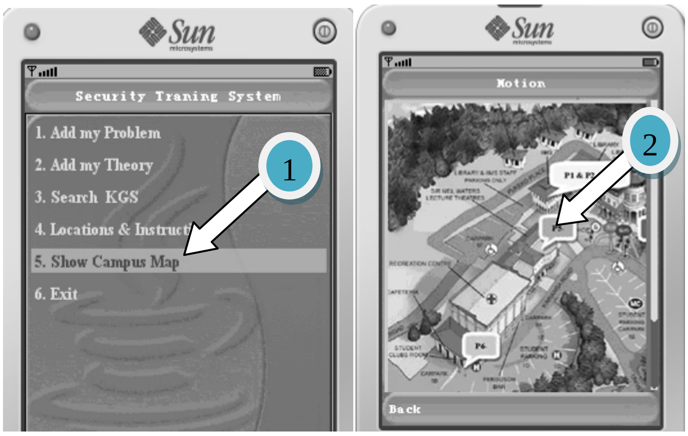

Figure 3.7 Show Campus Map Screen

Then the subject could find the patrol places on the campus map by selecting *Show Campus Map* menu (arrow 1 in Figure 3.7), and the locations, marked *P1* to *P6* (Arrow 2).

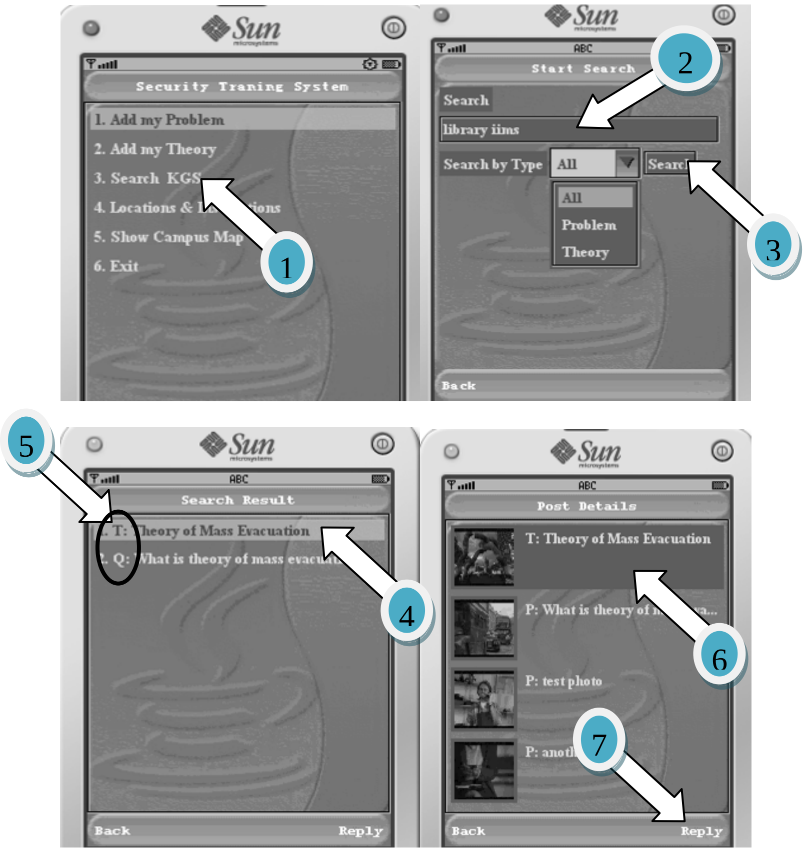

Figure 3.8 Search knowledge table by keyword

Figure 3.8 shows the screen shots for searching the knowledge table by entering a keyword. Arrow 1 shows the *Search knowledge table* option on the main menu, Arrow 2 shows the text box for entering the keywords, by pressing the submit button to start searching (Arrow 3). Arrow 4 shows the search result in relation to the keyword. The results are displayed as a list of items and categorised into '*Problem*' *and* '*Theory*'. Arrow 5 shows two categorised search results ('*P*' represents a '*Problem*' and '*T*' represents a '*Theory*'). A list of '*Related context*' is displayed after selecting an item from the list as Arrow 6, this '*Related context*' includes information in the knowledge table that are contextually related to the selected item. Arrow 7 shows the reply button to reply to the selected item.

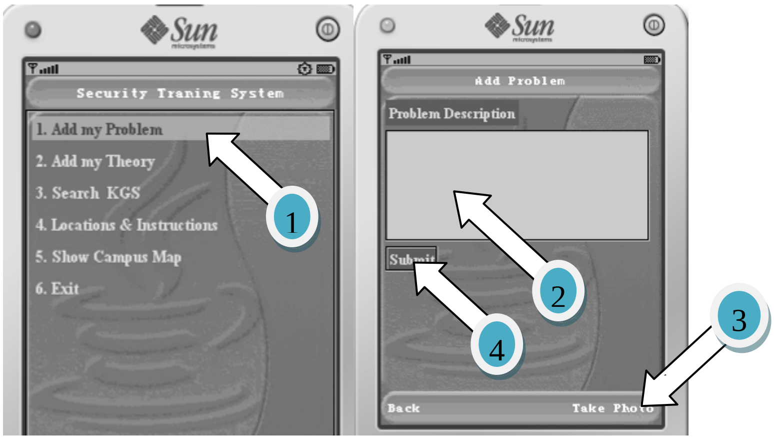

Figure 3.9 Add Problem Screen

To add a problem to the knowledge table, one can select the *Add my Problem* option (Arrow 1 in Figure 3.9), then describe the problem in the *Problem Description* (Arrow 2), and choose the *take photo* option to take and attach a photo to the problem (Arrow 3), finally pressing the submit button (Arrow 4) to submit. The "*Add my Theory*" procedures are the same with *Add my Problem*.

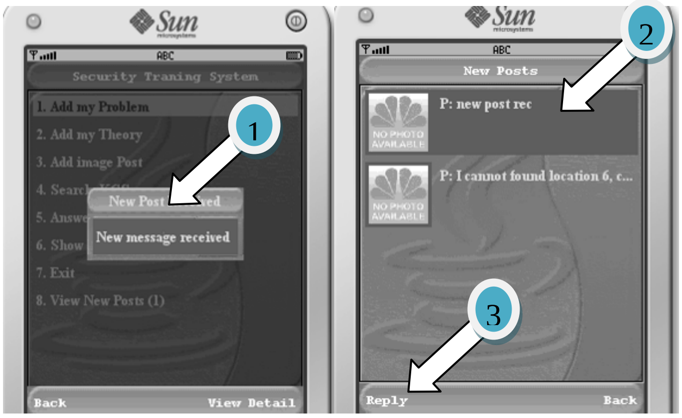

Figure 3.10 New Post Screen

When a subject adds a new content to the knowledge table, his or her partner instantly receives a notification (Arrow 1 in Figure 3.10), and he or she must reply to the newly received content by first selecting it as Arrow 2, and then selecting the reply option as Arrow 3.

Figure 3.11 Add Image Post Screen

Figure 3.11 shows the steps for submitting an image post. First the subject selects the *Add image Post* option (Arrow 1), then chooses the *Take photo* option to take a photo of the place (Arrow 2), after which they can view the photo by clicking on *View Attached Image* option (Arrow 4) and submit it to the system (Arrow 3).

3.5.3 Wrapping-Up session

Just after each face-to-face group completed the patrol, they joined a FTF wrap-up to enable discussion and collaboration. In the beginning, they were told the procedures to carry out the wrapping-up session. Since each subject only visited half of the six locations, they were required to externalise and share the knowledge they had gained from their individual learning, so they needed to talk about the places they had patrolled and discuss any issues they thought were necessary. The subjects presented their ideas, problems and issues raised during their own patrol, and their partner also needed to contribute their opinions. That is, a subject could propose specific security issues related to a place, and the other group member could provide feedback by using his or her existing knowledge.

The session was conducted group by group, and each session lasted about 30 minutes. During the session, subjects needed to recall the knowledge they had gained from each location, and verbally externalise the knowledge to their partner, so they could learn from each other. They also presented the photos taken earlier during the patrol, and used them as references to motivate discussions of the related issues. The related knowledge and discussion were manually documented with the scaffolding words, see Table 3.3 for details.

3.5.4 Retention Test

The next day, all the participants were asked to answer the questions listed in Table 3.4, which was given to see whether the participants had obtained certain learning outcomes.

Questions
For how long does the Library & IIMS Staff Car Park need to be patrolled?
Which alarms do not need to be set for the Student Club?
How many doors need to be locked at the MBA Kitchen?
Which location only allows authorised people to access?
For how long does Gate 3 need to be patrolled?
How many doors need to be locked at the Sushi shop?

Table 3.4 Test Questions

The six multiple choice questions are related to the six patrol locations. That is, the subject must answer half of the questions based on their own visit, and the other half from the collaborative knowledge with their partner. Thanks to this difference in the retention test (i.e., half from their own learning, and the rest from someone else), it is expected to show the benefits between mobile collaborative learning and FTF collaborative learning collaborative knowledge, if there are any differences of them.

3.5.5 Questionnaire

Finally, a questionnaire was presented which included seven questions (See Table 3.5) used to measure the subjects' learning satisfaction. The questions were focused on the ease of learning, the efficiency of learning, the usefulness of learning, the "in-time" collaboration, and the activeness of the participants for both systems. The questions were answered on a Likert-scale of five points.

Question
1. It was easy to learn how to patrol by using the system
2. It was efficient to learn how to patrol by using the system
3. The collaboration was useful to learn about the places that **you haven't visited**
4. The collaboration was useful to learn about the places that **you have visited**
5. The collaboration was in time in the experiment
6. I was willing to be active during the collaborative learning
7. In the collaboration, I found others had been collaborative actively

Table 3.5 Questionnaire Questions

3.6 System Design

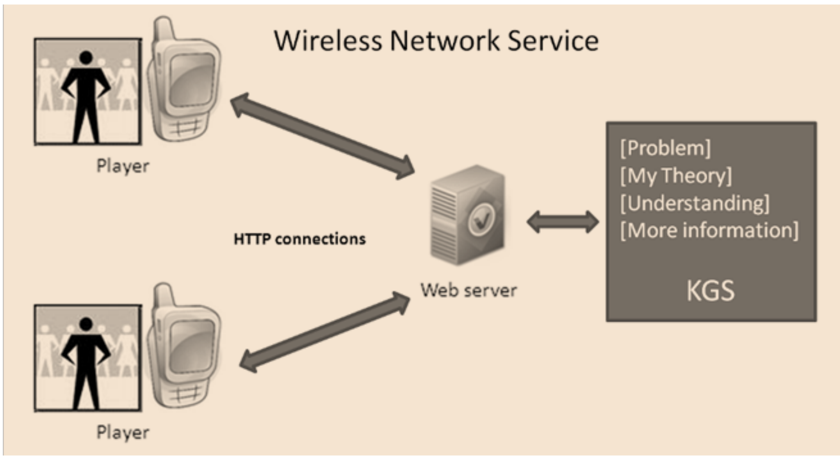

Figure 3.12 Mobile CL Architecture

Figure 3.12 shows the architecture of the system prototype. The system is basically client-server architecture, which includes two components: the client-side application on a mobile device, and the web-based application on the server-side, which connects to a database application. The client-side application was written by j2me, and runs on a K Virtual machine on the mobile phone. It communicates with the server-side application via HTTP connection via Wireless G3 Network Service.

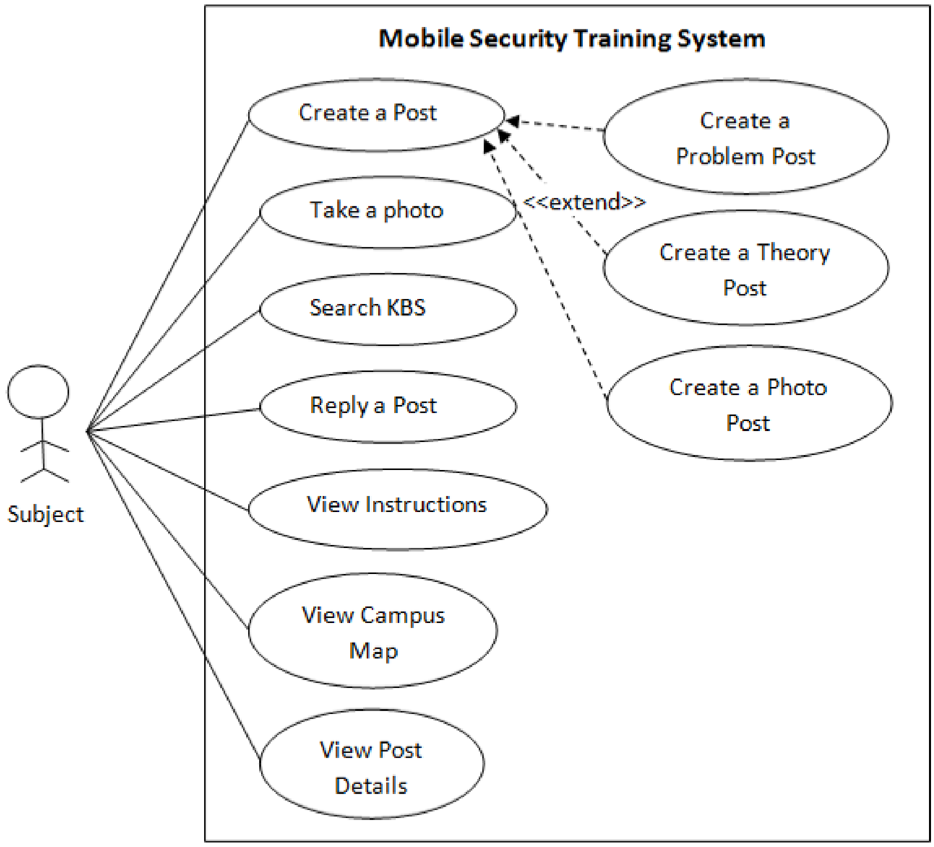

Figure 3.13 Use Case View

Figure 3.13 shows the use case view of the subject, explained as follows:

1) Create a Problem Post: this function allows a subject to describe a problem that is related to a patrol location and submit it as a post;

2) Create a Theory Post: this function allows a subject to describe a theory that related to a patrol location and submit it as a post;

3) Take Photo: this function allows a subject to take a photo by using the application and attaching it to a post;

4) Search knowledge table: this function allows a subject to search for related knowledge in the knowledge table by entering keywords;

5) Reply a Post: this function allows a subject to create a problem or theory post as a reply to an existing post;
6) View Instructions: this function allows a subject to view and learn the patrol instructions for each location;
7) View Campus Map: this function allows a subject to see the labeled patrol locations on a campus map;
8) View Post Details: this function allows a subject to select a single post, and view all other posts in the knowledge table that are related to the selected one.

The server-side application was implemented in Java Servlet. It receives commands from the client-side mobile device and communicates with the knowledge table. We used the MYSQL database to store all the data including the knowledge table data. The database contains only one table called *Thread*, and it contains the following attributes:

- Id: represents a unique identifier of a thread.
- Thread_contents: Stores the actual content of this thread.
- Thread_photo: Stores the current thread related photos' location.
- Thread_id: this thread id tells where the current thread was subscribed from; it can be NULL or any other thread id, which means it is either a new thread, or it is a child of another thread.
- Thread_type: based on the scaffolding word used in the scenario, the thread type is categorised into two types, Problem and Theory.

CHAPTER FOUR: EXPERIMENT RESULT

4.1 Learning Performance

Question	System	Mean	Std. Deviation
Visited	Mobile Collaboration	89.85	19.27
	Face-to-Face Collaboration	81.40	23.11
Un-visited	Mobile Collaboration	84.70	17.35
	Face-to-Face Collaboration	71.25	22.54

Table 4.1 Summary Table of Group Statistics

Table 4.1 shows the mean test scores of the visited and un-visited places against mobile collaborative learning and FTF collaborative learning. It was expected that the visited places would get higher scores than the places the participants had not visited. In both cases, mobile collaboration seems to be better than face-to-face collaboration.

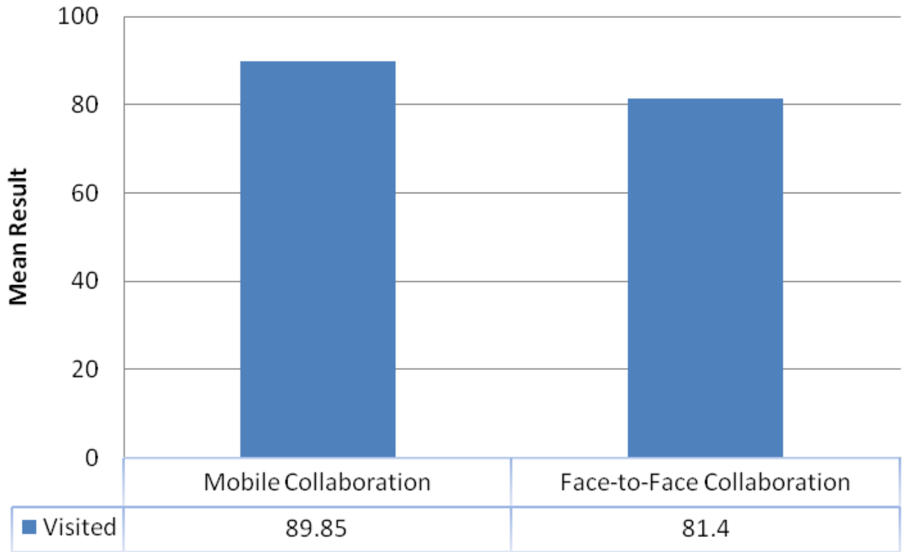

Figure 4.1 Mean Results for Visited Locations

Looking at Figure 4.1, as to the places visited, it can be seen the two means (mobile collaboration 89.85 and FTF collaboration 81.4) were not significantly different. A T-test confirmed that no significant difference was found between the two forms of collaboration systems (t (38) = 1.26, n.s). This can be interpreted that the participants in both systems had visited the places, so they could learn the places in the same context, and thus produce similar learning performances.

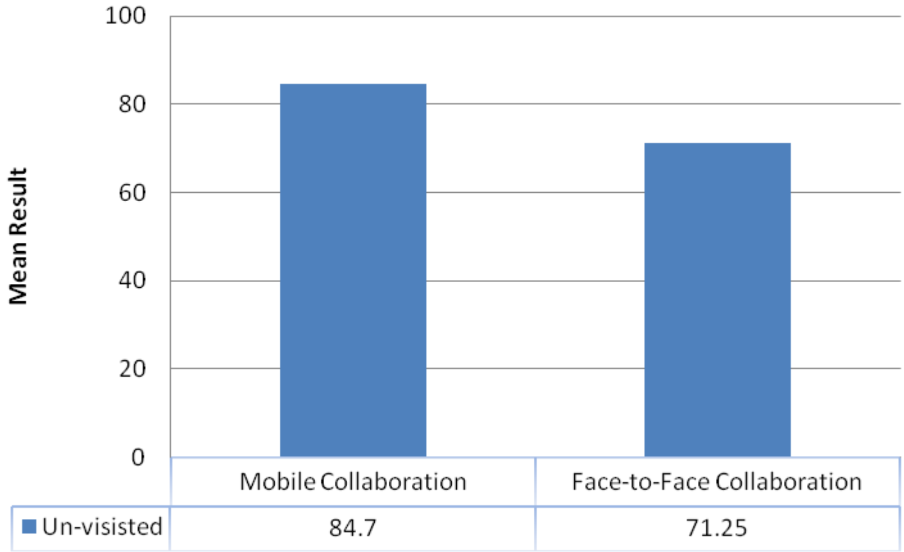

Figure 4.2 Mean Result for un-visited Locations

However, Figure 4.2 shows a somewhat different pattern to Figure 4.1, where a considerable difference can be found between the mobile collaboration (mean = 84.7) and FTF collaboration (mean = 71.25). The result implies that participants learned better about the un-visited locations with the mobile device. A T-test confirmed that the mobile collaboration was significantly different from the FTF collaboration (t (38) = 2.12, $p \leq 0.05$).

This can be interpreted that the participants in the mobile collaboration effectively learned by using mobile devices, together with the support of the knowledge table. However, the participants in the FTF collaboration had to wait till the next wrap-up meeting, and then learn from each other, which could depend on their recall of the event. This FTF collaboration caused significant delay compared with the mobile collaboration; as a consequence, different learning performances were produced.

4.2 Levels of Knowledge Generation

For mobile collaboration the subjects were collaborating by using the mobile application and their conversation were recorded. For FTF collaboration, the subjects collaborated face-to-face after they had completed their patrols, conversation in the wrapping-up meeting was documented and encoded. To explicitly see how the subjects generated their knowledge, the researchers analysed the encoded data by using the verbal protocol analysis method (Michael, 1995). After encoding the raw transcripts into segmented sentences, they were further matched into five pre-defined coding categories:

1. *Problem:* includes sentences/segments which describe an issue that can be identified as a problem, for example, any security issues or safety issues.
2. *Theory:* includes sentences/segments which describe an issue that can provide added value to the patrol location.
3. *Agreement:* includes agreements made by subjects, for example, a subject may agree with existing knowledge in the documentation/database created by previous groups or his/her partner.
4. *Disagreement:* includes any disagreement made by subjects, for example, a subject may disagree with existing knowledge in the documentation/database created by previous groups or his/her partner.
5. *Suggestion:* includes suggestions proposed by subjects with regards to the

patrol locations.

The numbers of cases of this verbal protocol are shown in Table 4.2 and the T-test results are shown in Table 4.3.

Categories	System	Mean	Std. Deviation
Problem	**Mobile CL**	4.20	1.94
	Face-to-Face CL	3.95	2.30
Theories	**Mobile CL**	5.65	2.28
	Face-to-Face CL	5.05	2.21
Agreement	**Mobile CL**	1.40	1.23
	Face-to-Face CL	3.20	1.61
Disagreement	**Mobile CL**	.85	.81
	Face-to-Face CL	1.80	1.36
Suggestion	**Mobile CL**	3.30	1.59
	Face-to-Face CL	4.20	1.64

Table 4.2 Mean Frequency of each Coding Categories

Categories	Levene's Test for Equality of Variances		T-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Problem	2.401	.130	.371	38	.712
Theory	.283	.598	.845	38	.403
Agreement	.970	.331	-3.973	38	**.000**
Disagreement	2.483	.123	-2.680	38	**.011**
Suggestion	.04	.948	-1.76	38	.087

Table 4.3 Two-Sample T-test Result for Mobile Collaborative Learning and Face-to-Face Collaborative Learning

Table 4.2 shows a considerable difference between '*Agreement*' and '*Disagreement*'. For '*Agreement*', the FTF collaborative learning a much higher

‘*Agreement’* frequency (mean = 3.2) than mobile collaboration (mean = 1.4). The T-test result confirmed the mean frequency of ‘*Agreement*’ in mobile collaborative learning was significantly different from FTF collaborative learning (t (38) = -3.97, $p \leq 0.05$).

For the ‘*Disagreement*’, FTF collaboration has a much higher ‘*Disagreement’* rating (mean = 1.80) than mobile collaboration (mean = 0.85). The T-test result again confirmed that the mean of occurrence of ‘*Disagreement*’ in mobile collaboration was significantly lower than FTF collaboration (t (38) = -2.68, $p \leq 0.05$).

In general, the results above show that for the ‘*Problem’*, ‘*Theory’* and the ‘*Suggestions’* categories, mobile collaboration and FTF collaboration had no significant differences. However, significant differences were found between the generated ‘*Agreements’* and ‘*Disagreements’*, where FTF collaboration involved more conversation than the mobile collaboration. A possible explanation may be that participants in mobile collaboration spend most of their time working on collaboratively sharing their knowledge, hence less consensuses is required. While in FTF collaboration, participants spend more time reaching consensus at a meeting, as it could be easily achieved by conversation between participants in the wrapping-up session.

The above contentions have been supported by the pre-defined knowledge types. For mobile collaboration, since participants spend more time collaboratively generating knowledge, it can be assumed that mobile collaboration should generate more knowledge with collaboration than the FTF collaboration. In other words, as participants were using the Mobile collaborative learning system, more useful information might be created by the participants as they were conversing with each other. To further justify the above explanation, we analysed the relationship between *Knowledge with collaboration* and *Knowledge without collaboration*. *Knowledge with collaboration* refers to the information inside the generated transcript, which was created from the conversation between two group members; *Knowledge without collaboration* refers to information that was generated individually, without conversing with another group member. Since participants used the scaffolding words (described in Section 3.5) to build up the transcripts, any context-related information in Question and Answer structure, has been counted and categorised as *Knowledge with collaboration*. All other information has been treated as *Knowledge without collaboration*.

Knowledge Types	**Systems**		
	Mobile Collaboration	**Face-to-Face Collaboration**	**Total**
Knowledge ***with*** collaboration	122	72	194
Knowledge ***without*** collaboration	145	172	317
Total	267	244	511

Table 4.4 Knowledge type of Mobile Collaborative Learning and FTF Collaborative Learning

Inspecting Table 4.4, it would appear that the Mobile collaborative learning system generated more knowledge from the collaboration; where FTF CL generated more non-collaborative knowledge. A chi-square test was employed on the data, revealing a significant difference between the knowledge types and the collaboration systems ($\chi^2_{(1)} = 14.18$, $P \leq 0.01$).

4.3 Questionnaire

Finally, a questionnaire data was used to see their learning experiences. Seven questions were included in the questionnaire; a T-test was conducted on each to analyse the responses to Mobile collaborative learning and Face-to-Face collaborative learning.

Questions	System	Mean	Std. Deviation
Q1. Easy to Use	**Mobile CL**	3.00	1.08
	Face-to-Face CL	3.60	.75
Q2. Efficient to Learn	**Mobile CL**	3.80	.77
	Face-to-Face CL	3.20	.95
Q3. Collaboration was useful to learn *un-patrolled* locations	**Mobile CL**	3.65	.88
	Face-to-Face CL	3.75	.85
Q4. Collaboration was useful to learn *patrolled* locations	**Mobile CL**	3.60	.88
	Face-to-Face CL	3.80	.89
Q5. The collaboration was in time	**Mobile CL**	3.95	.89
	Face-to-Face CL	3.25	.79
Q6. Subject was active in the collaboration	**Mobile CL**	3.70	.92
	Face-to-Face CL	3.50	.89
Q7. Subject's partner was active in the collaboration	**Mobile CL**	3.35	.988
	Face-to-Face CL	3.90	.912

Table 4.5 Mean Frequency of Each Question

An overview of the mean result of each question is displayed in Table 4.5; these data together with the T-test result in Table 4.6 are displayed.

Questions	Levene's Test for Equality of Variances		T-test for Equality of Means		
	F	Sig.	t	df	Sig. (2-tailed)
Q1. Easy to Use	.824	.370	-2.042	38	**.048**
Q2. Efficient to Learn	.907	.347	2.195	38	**.034**
Q3. Collaboration was useful to learn *un-patrolled* locations	.019	.892	-.366	38	.716
Q4. Collaboration was useful to learn *patrolled* locations	.140	.711	-.712	38	.481
Q5. The collaboration was in time	.078	.782	2.641	38	**.012**
Q6. Subject was active in the collaboration	.005	.947	.698	38	.489
Q7. Subject's partner was active in the collaboration	.820	.371	-1.829	38	.075

Table 4.6 Two-Sample T-test Result for Mobile and Face-to-Face Collaborative Learning

Table 4.6 reveals considerable differences in '*Easy-to-learn*', '*Efficient-to-Learn*' and '*in-time collaboration*'. For the first, FTF collaborative learning has a higher rating (mean = 3.6) than Mobile collaborative learning (mean = 3.0). The T-test confirmed that the mean rating of the '*Easy-to-learn*' in the Mobile collaborative learning was significantly different from FTF collaborative learning (t (38) = -2.04, $p \leq 0.05$), which implies that the FTF collaboration was easier to learn.

For the '*Efficient-to-Learn*', mobile collaborative learning (mean = 3.80) has a higher average rating than FTF collaborative learning (mean = 3.20). Again a T-test was applied, and the result shows that the mean rating of the '*Efficient-to-Learn*' in the Mobile collaborative learning was significantly better than FTF collaborative learning (t (38) = 2.20, $p \leq 0.05$), which means mobile collaboration provided more efficient learning than FTF collaboration.

For the '*In time collaboration*', Mobile collaborative learning (mean = 3.95) has a higher average rating than FTF collaborative learning (mean = 3.25). Then T-test confirmed that the mean rating of the '*In-time collaboration*' for mobile collaboration was significantly better than FTF collaboration (t (38) = 2.64, $p \leq 0.05$), this result implies mobile collaboration was better than FTF collaboration.

Overall, comparing learning satisfaction, the results imply that the mobile collaboration system was better in terms of '*Efficient to learn*' and '*in-time collaboration*', and on the other hand the FTF collaboration system was easier to use. The possible explanations would be: the ability to receive instant responses in the mobile collaboration system may increase participant's learning satisfaction in terms of efficiency and 'in-time collaboration'. However in order to achieve such mobile collaboration, participants have to complete multiple operations on a mobile device that has a small screen and keypad, which makes the mobile system challenging to use.

CHAPTER FIVE: DISCUSSION

Against the pre-defined hypotheses in Chapter 2, this section summarises the experimental findings accordingly.

Research Question	Findings
How does mobile learning with collaborative learning activities affect learning performance?	For learning the patrolled places, the mobile collaboration system was as efficient as the FTF collaboration system. However, the mobile collaboration systems provided better learning performance when participants needed to learn the unpatrolled places.
How does mobile learning with collaborative learning activities affect externalising knowledge?	Mobile CL generated significantly more collaborative knowledge than FTF CL. However, FTF CL generated significantly more non-collaborative knowledge.
How mobile learning with collaborative learning activities affect learner's satisfaction in terms of ease of learning, effectiveness of learning and "in-time" collaboration?	First, it can be seen that FTF CL was easier to use than Mobile CL. Then Mobile CL participants reflected that although the system was not easy to use, they thought it was very efficient to learn by using the system. The data indicates that FTF CL was significantly less efficient than Mobile CL. The result also shows that participants found that Mobile CL provided better 'in-time' collaboration between partners than FTF CL.

Table 5.1 Summaries of the experiment according to the hypotheses

Table 5.1 summarises the findings from the experiments, and detailed analyses are carried out in the following section.

5.1 Retention Test Result

The test result demonstrated the relationship of the learning performances between the two systems. It was clear that when the data from the visited places were analysed, the mobile collaborative learning system did not provide significant benefits to their learning performance. This is because both systems' participants actually visited the places, where they experienced the same learning context, so there seems to be no actual difference while they were learning about the places.

On the other hand, as the subjects needed to learn the places they hadn't visited, the result implies that the mobile collaborative learning system significantly increased learning performance (Hypothesis 1 partially supported). This could be because while learners were using Mobile collaborative learning, the people who visited the places can externalise their obtained knowledge immediately, so the people who had not visited could use the instant knowledge to build and develop more knowledge for sharing (Hypothesis 2 can also be supported). However, for FTF collaborative learning, learners had to first learn about the patrol location by themselves. As no collaboration and knowledge building was instantly enabled, they had to memorise the issues raised, and wait till the FTF meeting to externalise and collaborate with others. Such a process was more complicated and inefficient than immediate collaborative learning. Moreover, as the learners raised more issues, they could easily lose some of them while they were patrolling other locations, since short-term memory capacity is limited (Miller, 1956).

5.2 Knowledge Generation

The second part of the results shows the relationship between different knowledge types generated from the two systems. The original hypothesis was that instant collaborative learning through mobile systems would provide better collective knowledge generation, than traditional FTF collaborative learning systems.

Overall, it can be said that mobile devices (Mobile collaborative learning) are better for knowledge building. This is justified by the result for *Agreement* and *Disagreement* between the two systems, for when people used Mobile collaborative learning, they spend most of their time sharing knowledge, therefore it could lead to more consensus, consequently less *agreement* and *disagreement*. On the other hand, as FTF collaborative learning participants did not collaborate during the patrol, and a significant amount of non-collaborative knowledge was generated, so they needed to use the off-line meeting as an opportunity to reach some consensus rather than generating more knowledge.

To confirm this, in fact, we conducted another small-scale experiment as a control condition to this analysis. In the experiment, five subjects were chosen and each subject patrolled six locations with System C, that was exactly the same as with FTF collaborative learning, but subjects had to visit all the places by themselves throughout the patrol. After the patrol, participants individually documented the knowledge that they had learned, and this knowledge was again encoded into collaborative knowledge and non-collaborative knowledge for comparison.

	Mobile collaboration system	Face-to-Face Collaboration System	System C (Without Collaboration)
Average	7.25	8.6	9.6

Table 5.2 Average Non-Collaborative knowledge for All Three Systems

Table 5.2 shows the average non-collaborative knowledge generated by each system, where the non-collaboration system (System C) had the highest average rating (9.6), and the mobile collaboration system had the least average rating (7.25). Therefore it can be seen that mobile collaboration encourages more collaborative knowledge to be generated, since the least non-collaborative knowledge was generated.

Though mobile collaborative learning can provide a better knowledge generation, further work is still needed to extend mobile collaborative learning to fostering more learning motivation in different circumstances, allowing learners to self-generate learning topics in accordance with their needs.

5.3 Questionnaire Result

In the final questionnaire result, we have seen various differences in learning satisfaction. First of all, participants found that FTF collaborative learning was much easier to use than Mobile collaborative learning. The reason could be that Mobile collaborative learning requires the subjects to perform multiple tasks on a small device while they were patrolling. The small screen and keypad could cause negative satisfaction while they were performing these tasks. However, mobile collaborative learning seems to be more efficient than FTF collaborative learning, because the instant collaboration and access to the knowledge table significantly enhanced their learning efficiency (Hypothesis 3 supported). Lastly, mobile collaborative learning provided better “Just-in-time” collaboration than FTF collaborative learning. Just as the advocates of mobile technology are promising, collaboration on mobile devices enhanced the learners’ satisfaction (Hypothesis 3 supported).

As to the questions related to the learner’s usability and the satisfaction are somehow ambiguous, however they are not the primary focus of this study, and only been used to ensure the minimum learning requirements were meet, and learners able to somehow perform effective learning as they do in other forms of learning. Specifically, the study can only become valid when the above conditions are satisfied.

CHAPTER SIX: CONCLUSION

6.1 Findings of the Thesis

As mobile technology moves to the centre of our society, it is opening new opportunities for education. People rely more on collaborative learning during their work, training and study, and they will need instant knowledge or answers “on-the-fly”, hence, instant collaborative learning outside the classroom is vital. Researchers are looking for ways to take the advantages of mobile devices and technology to overcome the limitations of traditional collaborative learning activities.

From this study, it can be seen that a mobile supported collaborative learning environment provided better learning performance. Therefore a mobile collaborative system can be considered for collaborative learning, especially for outdoor learning activities. One thing that became clear is that the design of mobile computer-supported collaborative learning systems needs to be considered from the learner’s perspective rather than technology. Therefore, we should not simply present a load of information and force people to learn. Instead, we should give learners more freedom, allowing them a choice over what to learn, and learn by themselves with the support of mobile technology and necessary assistance from a teacher.

Secondly, the above conclusion could justify that in a constructivistic learning environment, a mobile collaboration system favours collaborative learning at a distance. The introduction of mobile devices provides a more constructivist authentic learning context during learning activities, where technology mediates instant conversation, allowing learners to work collaboratively and following the constructivistic principles. People can design a mobile supported constructivistic learning environment, where the teacher becomes a guide of the learning activity, allowing learners to take the initiative in their learning. Therefore, the design of mobile computer-supported collaborative learning will become more learner-centred rather than teacher-centred, and this will require less teacher or tutor support than traditional face-to-face collaborative learning.

The results of this thesis also imply that the format of a conversation is a key factor in influencing the generation of collaborative knowledge. Compared with a delayed conversation of traditional face-to-face collaborative learning, an instant conversation of mobile collaborative learning was better in terms of generating collaborative knowledge. In this sense, further improvement of technology supported conversation would offer even more effective collaborative learning and knowledge generation. For example, verbal conversation can be more efficient than a text-based conversation, and video conferencing can be even more interactive, as it allows learners to see each other’s facial and head movements and hand gestures.

Although we have generated the above positive conclusions, it goes too far to say that mobile supported collaborative learning suits all situations. Therefore we assumed that collaborative activities, such as outdoor learning or training activity described in this thesis, are more suited to the support of mobile technology within specific domains.

6.2 Limitations and Further Work

Despite the optimistic conclusions described above, there are still many limitations to be addressed in future research. Firstly, the communication provided in the current mobile system was only text-based. Although we have shown positive results from the mobile collaborative learning system, it is important to gain more insight into other types of conversation methods. For example, considering verbal communication or video streaming, mobile collaborative learning might not be as effective as FTF collaborative learning, and this requires further investigation.

From the experimental perspective, the small number of participants and the subjects' backgrounds were two main limitations. For the first, the sample size was small, and only ten groups used each system, so the result may not provide sufficient proof. The experiment can be improved by testing the two systems with more participants to make the data more accurate. Moreover, all of the participants were chosen from Massey University, and are young people. So this raised the question of whether all kinds of people from different ages with different backgrounds would use mobile devices for collaborative learning. Perhaps a future study could use more participants from different ages, and different backgrounds to test the system.

Another limitation is that the participants were not real security guards, and do not have any training, therefore they may be unable to identify the security lapses as they patrol. Moreover, since the participants were not real security guards, and they saw the purpose of the experiment as different from the real needs, so they used it more, and more collaborative knowledge was generated through mobile collaboration. In a further study, we may need to test the systems with real security guards in a more authentic environment.

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Appendix-1 Questionnaire Data

Q1	Q2	Q3	Q4	Q5	Q6	Q7	System
3.00	4.00	3.00	5.00	4.00	4.00	4.00	1
4.00	5.00	3.00	2.00	5.00	4.00	3.00	1
2.00	4.00	4.00	5.00	4.00	4.00	2.00	1
5.00	4.00	5.00	3.00	3.00	5.00	4.00	1
2.00	3.00	4.00	4.00	4.00	3.00	4.00	1
4.00	4.00	4.00	3.00	5.00	5.00	3.00	1
1.00	4.00	2.00	4.00	3.00	4.00	4.00	1
3.00	4.00	4.00	4.00	4.00	4.00	5.00	1
4.00	5.00	3.00	2.00	5.00	5.00	4.00	1
3.00	4.00	4.00	4.00	4.00	4.00	3.00	1
3.00	4.00	3.00	4.00	5.00	3.00	4.00	1
4.00	3.00	4.00	3.00	3.00	5.00	4.00	1
2.00	2.00	4.00	3.00	4.00	3.00	2.00	1
1.00	4.00	3.00	4.00	2.00	2.00	4.00	1
3.00	4.00	2.00	3.00	3.00	3.00	3.00	1
4.00	3.00	5.00	4.00	4.00	4.00	1.00	1
2.00	5.00	4.00	3.00	5.00	3.00	4.00	1
3.00	4.00	4.00	5.00	5.00	2.00	4.00	1
4.00	3.00	5.00	3.00	3.00	4.00	3.00	1
3.00	3.00	3.00	4.00	4.00	3.00	2.00	1
4.00	3.00	4.00	5.00	3.00	4.00	4.00	2
3.00	4.00	4.00	3.00	3.00	4.00	5.00	2
4.00	3.00	3.00	4.00	4.00	4.00	3.00	2
4.00	3.00	4.00	5.00	3.00	3.00	4.00	2
2.00	3.00	3.00	4.00	3.00	5.00	4.00	2
5.00	4.00	5.00	5.00	4.00	2.00	2.00	2
4.00	4.00	3.00	4.00	3.00	4.00	4.00	2
3.00	5.00	3.00	3.00	3.00	3.00	3.00	2
3.00	4.00	4.00	4.00	3.00	3.00	4.00	2
4.00	3.00	4.00	4.00	3.00	4.00	5.00	2
3.00	2.00	5.00	5.00	4.00	3.00	5.00	2
4.00	3.00	2.00	4.00	2.00	4.00	4.00	2
4.00	1.00	3.00	2.00	2.00	3.00	4.00	2
3.00	3.00	3.00	3.00	3.00	2.00	4.00	2
4.00	4.00	4.00	4.00	4.00	5.00	5.00	2
4.00	4.00	4.00	3.00	4.00	4.00	3.00	2
3.00	2.00	5.00	4.00	2.00	3.00	4.00	2
5.00	4.00	4.00	4.00	5.00	4.00	2.00	2
3.00	3.00	3.00	4.00	3.00	4.00	4.00	2
3.00	2.00	5.00	2.00	4.00	2.00	5.00	2

Appendix-2 Verbal Protocol Analysis Data

Problem	Theories	Agreement	Disagreement	Suggestion	System	Subject
6.00	6.00	0.00	1.00	2.00	1	G1_A
4.00	8.00	1.00	0.00	2.00	1	G1_B
4.00	6.00	0.00	1.00	4.00	1	G2_A
6.00	7.00	3.00	2.00	1.00	1	G2_B
10.00	4.00	0.00	0.00	4.00	1	G3_A
3.00	10.00	3.00	1.00	2.00	1	G3_B
2.00	5.00	0.00	0.00	3.00	1	G4_A
5.00	7.00	1.00	2.00	3.00	1	G4_B
5.00	4.00	0.00	0.00	4.00	1	G5_A
3.00	8.00	1.00	0.00	1.00	1	G5_B
6.00	8.00	3.00	1.00	2.00	1	G6_A
5.00	5.00	2.00	2.00	3.00	1	G6_B
3.00	7.00	0.00	1.00	5.00	1	G7_A
4.00	3.00	2.00	0.00	4.00	1	G7_B
1.00	6.00	3.00	0.00	3.00	1	G8_A
4.00	4.00	2.00	1.00	6.00	1	G8_B
4.00	8.00	3.00	0.00	3.00	1	G9_A
4.00	3.00	2.00	2.00	2.00	1	G9_B
3.00	3.00	0.00	2.00	5.00	1	G10_A
2.00	1.00	2.00	1.00	7.00	1	G10_B
6.00	10.00	2.00	0.00	5.00	2	G1_A
4.00	9.00	3.00	2.00	5.00	2	G1_B
7.00	8.00	4.00	2.00	5.00	2	G2-A
6.00	3.00	5.00	1.00	6.00	2	G2-B
5.00	7.00	6.00	2.00	5.00	2	G3_A
5.00	4.00	2.00	2.00	5.00	2	G3_B
4.00	5.00	4.00	1.00	3.00	2	G4_A
6.00	6.00	0.00	4.00	3.00	2	G4_B
2.00	5.00	5.00	2.00	2.00	2	G5_A
1.00	6.00	2.00	3.00	5.00	2	G5_B
5.00	5.00	4.00	1.00	4.00	2	G6_A
6.00	6.00	3.00	1.00	4.00	2	G6_B
6.00	3.00	1.00	1.00	3.00	2	G7_A
5.00	5.00	3.00	1.00	0.00	2	G7_B
6.00	2.00	4.00	5.00	5.00	2	G8_A
1.00	4.00	3.00	4.00	4.00	2	G8_B
3.00	3.00	1.00	2.00	5.00	2	G9_A
0.00	5.00	2.00	2.00	7.00	2	G9_B
1.00	2.00	5.00	0.00	6.00	2	G10_A
0.00	3.00	5.00	0.00	2.00	2	G10_B

Appendix-3 Test Result Data

System	Visited	Not Visited
1	100.00	66.00
1	66.00	66.00
1	100.00	100.00
1	100.00	66.00
1	66.00	66.00
1	100.00	100.00
1	100.00	100.00
1	100.00	66.00
1	100.00	100.00
1	100.00	66.00
1	100.00	100.00
1	100.00	66.00
1	33.00	100.00
1	100.00	66.00
1	100.00	100.00
1	100.00	100.00
1	66.00	66.00
1	100.00	100.00
1	100.00	100.00
1	66.00	100.00
2	66.00	66.00
2	100.00	66.00
2	66.00	33.00
2	33.00	100.00
2	100.00	66.00
2	66.00	33.00
2	100.00	100.00
2	100.00	66.00
2	33.00	33.00
2	100.00	66.00
2	100.00	66.00
2	66.00	66.00
2	100.00	66.00
2	66.00	100.00
2	100.00	66.00
2	100.00	66.00
2	66.00	100.00
2	100.00	66.00
2	66.00	100.00
2	100.00	100.00

Appendix-4 Patrol Locations

Both figure 1 and Table 1 shows the Massey campus map, and the patrol locations for Mobile collaborative learning. The Campus map only shows the location of each patrol place, numbered from "P1" to "P6".

Number	Player	Locations
1	Player A	MBA Kitchen
2		Student Club
3		Information Technology Postgraduate Lab
4	Player B	Gate 3
5		Sushi shop
6		Library & IIMS Staff Car Park

Table 1. Patrol locations Details

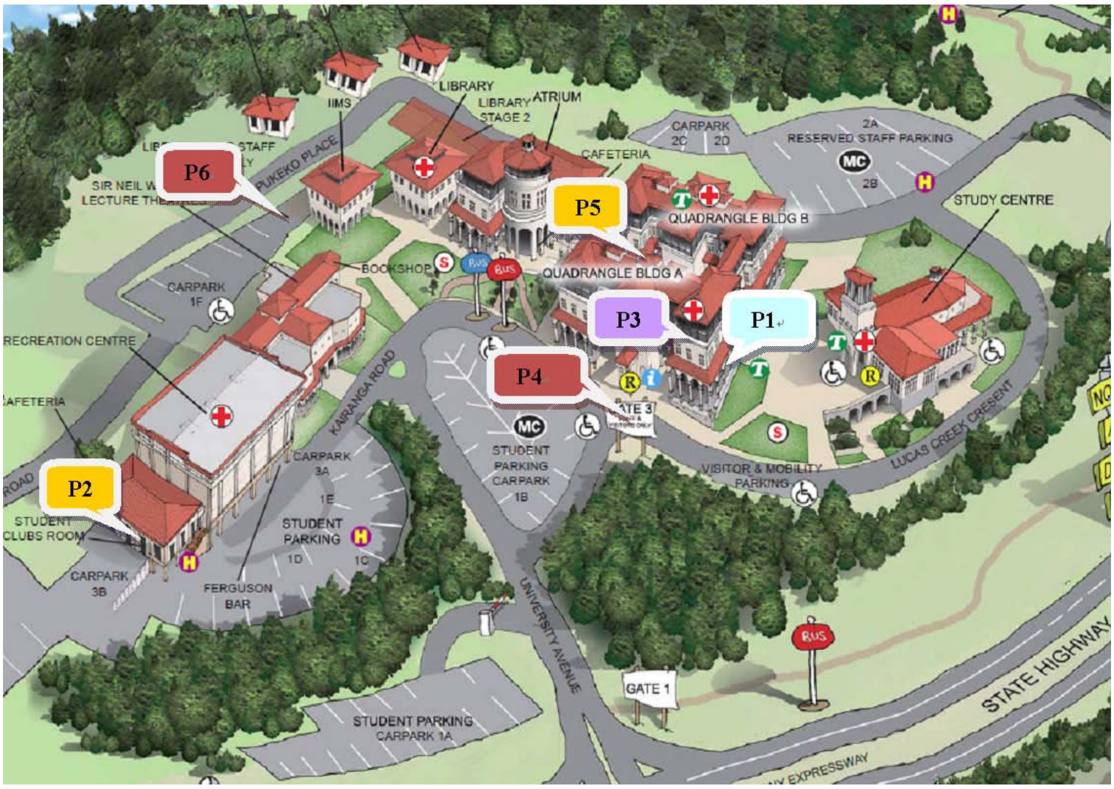

Figure 1. Massey Campus Map and the Patrol locations for Mobile CL

Appendix-5 Instructions

Table 1 shows all the instructions for each patrol location, when the participates reach each location, they are required to memorize each of them, then take a photo or describe them and show to the other group member.

Location	Player	Instructions
1	Player A	Make sure all 4 doors are locked
2		Set the alarm 1,3, 6
3		Make sure authorised people in this room by checking each person's access card
4	Player B	Patrol this area for 2 minutes
5		Make sure all 2 doors are locked
6		Patrol this location for 3 minute, and call your group mate

Table 1. Instruction for each location

Appendix-6 Test Questions

This test is for measuring the learning outcome from your patrol, no personal data will be collected. All the data collected will be used for analysis only and then will be destroyed. There are six multiple-choice questions related to participant's security patrol experience. Participants were required to use the knowledge learned from the patrol to answer them.

Questions	Answer
How long does the Library & IIMS Staff Car Park need to be patrolled for ?	a) 2 minutes b) 3 minutes c) 4 minutes d) 5 minutes
Which alarms do not need to be set for Student Club?	a) alarm 6 b) alarm 1 c) alarm 4 d) alarm 3
How many doors need to be locked at MBA Kitchen?	a) 3 b) 2 c) 5 d) 4
Which location only allows authorised people to access ?	a) Gate 3 b) Student Club c) Sushi shop d) Information Technology Postgraduate Lab
How long does Gate 3 need to be patrolled for?	a) 2 minutes b) 3 minutes c) 4 minutes d) 5 minutes
How many doors need to be locked at Sushi shop?	a) 3 b) 2 c) 5 d) 4

Appendix-7 Questionnaire

This questionnaire contains seven questions related to your feeling during the experiment. All collected data will be used for analysis only and they will be destroyed. Please select from following answer by circle the numbers in the form:

1. Strongly disagree
2. Disagree
3. Neither agree nor disagree
4. Agree
5. Strongly agree

Question	Answers				
8. It was easy to learn about how to patrol by using the system	1	2	3	4	5
9. It was efficient to learn how to patrol by using the system	1	2	3	4	5
10. The collaboration was useful to learn about the places that **you haven't visited**	1	2	3	4	5
11. The collaboration was useful to learn about the places that **you have visited**	1	2	3	4	5
12. The collaboration was in time in the experiment	1	2	3	4	5
13. I was willing to be active during the collaboarative learning	1	2	3	4	5
14. In the collabration, I found others had been collaborative actively	1	2	3	4	5