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Can Lean Media Enhance Large Group Learning? An Empirical Investigation of Mobile Information and Communication Technology

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Abstract

A mobile information and communication technology, namely the Mobile Interactive Learning System (MILS), was used to enhance large group learning in a university setting. Expectations concerning learning outcomes, based on the social construction perspective of media richness and constructivist pedagogical principles, were supported. Under similar study conditions, learners with the MILS system demonstrated better (perceived) understanding than those without. Furthermore, learning satisfaction among MILS users was significantly higher. The results were drawn from an empirical evaluation of a structural equation model, and from analyses of variance between the two users groups (with versus without MILS). The results support our hypotheses concerning the impact on understanding and satisfaction. They also suggest that mobile technology affects the learning process, leading to more individual practice and peer influenced learning.

Keywords: Mobile computing, ICT, PDA, lean media, social construction, media richness, learning

1. Introduction

Improving learning and instructional effectiveness has long been a research goal and a pedagogical aspiration. Innovative uses of emerging Information and Communication Technologies (ICTs) have been important issues in Information Systems (IS) research. In the education contexts, these issues include using ICTs to better facilitate learner-centered instruction, to increase the ability of instructor in reaching students, and to provide diverse methods of educational delivery, while also reducing knowledge dissemination efforts (Alavi 1994; Alavi

et al. 1997; Lowry et al. 2004). These concerns become even more serious in large group learning environments, where learner-instructor interactions are challenged and learning processes are hampered (Doran and Golen 1998).

With learning being a process of knowledge construction and an enduring behaviour change caused by practice and reinforcement (Kimble 1961), the mandate for ICTs in large classroom learning is clear. The technology needs to provide flexibility for practice, and to signal success or failure (“reinforcement”) to the learners. Meanwhile, it also needs to be informative to the instructor who may wish to adjust further instruction based on the effectiveness of prior efforts. These requirements define the application space for appropriate interactive learning technologies, and among them our Mobile Interactive Learning System (MILS). The MILS (Figure 1) integrates a large number of client-side Personal Digital Assistants (PDAs), connected to a centralized server in a wireless network. The communication component of the system offers the capability for learners to communicate their understanding to the instructor (more precisely, to the instructor’s workstation), and for the instructor to return feedback. The information processing component provides instant reporting capability, such as summary statistics of responses or similar feedback. The device mobility allows learners to reallocate (such as having different seating at different lecture sessions), and still be uniquely identifiable via their PDAs. In addition to PDAs’ small size and light weight, the above features make such a mobile ICT-based interactive learning system potentially possible to enhance learner-instructor communication in a group setting. And, these advantages grow potentially with increasing group size. While small groups can conveniently communicate face-to-face, personal interaction and individual feedback by the instructor becomes increasingly difficult to achieve in larger groups.

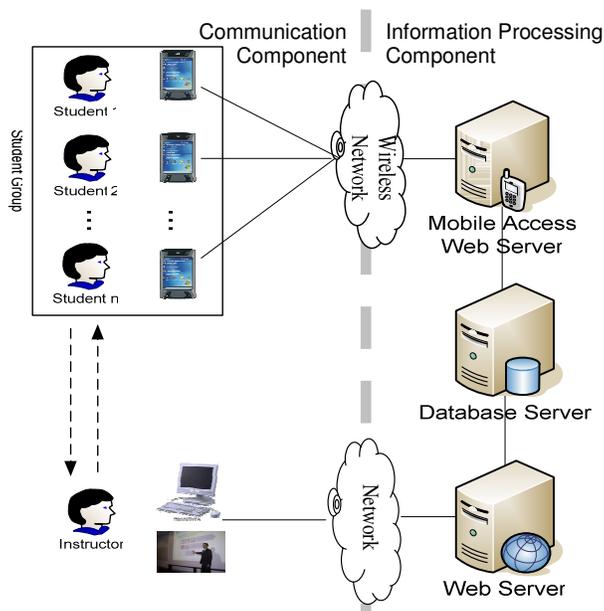


Figure 1. System overview of the MILS

Nevertheless, mobile ICT use for large group classroom learning faces notable problems from technical, behavioural, as well as pedagogical aspects. First, PDA's (or other hand-held mobile devices') constrained input (e.g. stylus or on-screen keypad) and output (e.g. 4-inch or less diagonal screen with 320 x 240 pixels) capabilities limit the medium richness for communication. Second, some negative behavioural aspects may affect the learning process. For instance, learners may grow tired of the technology, or use other technology-enabled features, such as games, to distract themselves from the in-class learning. Third, the teaching styles may not be sufficiently suitable to take advantage of the technology. Consequently, while mobile ICTs hold considerable potential for large group learning, their success cannot be taken for granted and must be empirically validated. Hence, the key research question of this article is as follows:

“Can a lean communication medium, namely mobile ICT, enhance learning when used in a large group classroom environment?”

To answer this question, the article is organized as follows. The next section discusses the characteristics of mobile technology for learning, followed by an exploration of related concepts and theories. Section 4 then introduces our research model and hypotheses, followed by the empirical study in Section 5. Section 6 explains our data analysis and results, with more discussion and limitations in section 7. Conclusions and implications are drawn in the last section.

2. The Characteristics of Mobile ICT for Learning

Advances in mobile ICTs have recently provided the opportunity for educators to apply new use and create new educational models (Chen et al. 2003). With the aid of mobile ICT, learning and instructional practices can be embedded in mobile settings and generate unique characteristics:

- *Scalable ubiquity*: Mobile devices are generally small and portable, enabling their use at any time and any place (provided there is access to wireless communication). By-and-large, they also do not interfere with each other, thus making the use by many within a condensed space (e.g. large group lecture) ideal.
- *One-to-one or one-to-many (hub-like) communication*: Different from group support systems (GSS), whose protocol typically results in many-to-many communication among all group participants, mobile learning can take the forms of person-to-person or hub-like communication, which is more suitable in a large group learning environment, such as a large size university lecture.
- *Frequent interaction*: Learners can communicate with experts (e.g. the instructor), peers, and other learning resources synchronously or asynchronously. Communications can be interleaved, enabling many learners to communicate with their peers or with the hub (“the instructor”) without

disturbing each other. This is contrary to regular voice communication, where one group member has to stop before another one can begin to speak, thus leading to bottlenecks within the communication channel as group size grows.

- *Lean messages*: Constrained by the limited graphical user interface, messages exchanged via hand-held mobile devices, such as PDAs, tend to be short and concise. These messages, for instance, may be answers to multiple choice questions, or short texts to open-ended questions.
- *Knowledge combination*: Many lean messages received from various sources (e.g. students who reply to the instructor's questions) get integrated instantly into meaning knowledge, such as a statistical result of student answers. This process aggregates the explicit knowledge from several sources and develops new explicit knowledge, and can be defined as knowledge combination (Nonaka and Takeuchi 1995). The process of knowledge combination characterizes much of the learning in a school or university setting, and mobile ICT helps to partially automate this process, either through statistical means or other aggregation techniques.

3. Theoretical Foundation

3.1 Rich Communication through Social Construction

The definition of communication richness in electronic media has been an important theoretical basis for IS researchers in their studies of ICT adoption. One of the influential definitions in both IS research and practice is the media richness theory. It indicates that communication richness (or leanness) is an intrinsic objective property of ICT, which can describe and explain the adoption and use of ICT as a communication medium (Daft and Lengel 1986). According to Daft and Lengel (1986), media have a range of "richness" from "very rich" to "very lean" [see the "media richness continuum" in Daft et al. (1987)] depending on "the ability of information to change understanding within a time interval" (p. 560). This line of research focuses on the technical characteristics of information processing, such as medium capacity, communication cues, and feedback speed, in determining communication richness of a medium. Recently, a growing number of scholars have taken on the more general social construction perspective into the study of electronic media, arguing that media in use may exhibit different characteristics than media as conceived (Trevino et al. 2000; Yoo and Alavi 2001). Among them, Ngwenyama and Lee's (1997) critical social theory suggests that richness or leanness is related not only to the material properties of the communication medium, but also the interactions between people in the social context. Based on the critical social theory, communication richness is determined by "whether or not mutual understanding (person's coming to understand what another person means) occurs" through social interaction (Ngwenyama and Lee 1997). Kock and Davison's (2003) study also shows that a lean communication medium, such as email conferencing, could support building of a shared understanding among group members when

combined with appropriate social processes. Taken together, these studies point out that the richness of communication via a so called “lean” medium can be increased in certain socially constructed conditions.

Yet, what is important for this study is the question whether a mobile ICT-based communication medium is rich enough to (1) permit timely and unequivocal transmission of learner responses and instructor feedback to reach understanding, and (2) generate sufficient social influences that shape individual behaviour in terms of learning. As we know, learner-instructor interaction is bi-directional. In a classroom, messages exchanged are often in the form of, either a learner’s questions followed by the instructor’s answers (“questions-answers”), or the instructor’s questions followed by students’ answers, followed by the instructor’s comments/feedback (“questions-answers-feedback”). A successful communication, according to Te’eni (2002), means that both the sender and receiver reach mutual understanding through the cycle of communicative actions. However, reaching understanding in the classroom environment does not simply mean shared understanding between the instructor and the specific student(s) who participated in the cycle of actions, but also most (if not all) other students in the classroom. In a large group classroom, mobile ICT, such as the MILS, provides only a narrow channel with lean messages (via PDA devices) for learner-instructor interactions. However, the unique characteristics of mobile ICT (as discussed earlier) adds new capabilities for learners and the instructor to reach understanding and also gain satisfaction through frequent interactions, aggregated lean messages of learner responses, instructor’s timely feedback, and peer influenced (shared) understanding.

3.2 Supporting Constructivist Learning Process

Leidner and Jarvenpaa (1995) link the cognitive and collaborative constructivism (e.g. Bruner 1960; Piaget 1928) into the IS context through an examination of the learning models and of the impact of ICT on learning. They postulate the existence of a variety of opportunities for implementing ICT to support business and management education. To clearly understand the impact of mobile ICT on large group learning, we also need to examine the effectiveness of learning process in detail.

Based on constructivism, which considers learning as a process of constructing knowledge by an individual rather than being taught by others, methods of teaching should be designed to stimulate students’ learning involvement (Wittrock 1978). Students continuously develop new knowledge and improve understanding through constant engagement in mental exercises and social sharing to analyze and interpret knowledge and information. The constructivist models of learning stresses cognitive construction of knowledge through *individual practice* and social construction of knowledge through *peer-influenced activities* in the process of learning (Du and Wagner 2005). Hence, to support

effective learning processes and to reach a good learning impact, we need to increase the learning process gains and reduce process losses.

Similar to the mobile ICT supported learning environment, peer-support and peer-influence (in the context of GSS) provide either explicit or implicit reinforcement (“process support”) by allowing individuals to exercise and improve their mental models through interaction and information sharing (Alavi 1994). Further, to achieve process gain, parallel communications (enabled by both mobile ICT and GSS) reduce airtime fragmentation and maintains permanent learning records (or memory), such as comments, feedback, questions and answers (Nunamaker et al. 1991). In addition, these interactive group computing technologies, alleviates process losses by encouraging participation with electronic identity (e.g. nick name) that is less intimidating than direct face-to-face. Previous studies suggest that GSS support learning by enhancing communication among group members, particularly in a small (10 or less members) to medium (20 or less members) size group (Dennis et al. 1998). However, when the group size increases to a fairly large number, for instance, a group of about 100 students in a large lecture, communicative actions can result in dramatic process losses. While the communication of GSS is constrained by group size, mobile ICT with its unique characteristics, on the other hand, is easily scalable without much process loses. Even given the narrow mobile transmission channel via client devices (e.g. PDAs), mobile ICT can provide aggregated rich content from numerous lean messages with its hub-like (single instructor and many students) communication mode and knowledge combination capability.

4. Hypotheses and Research Model

Based on the social construction perspective of media richness and the concepts extended from GSS studies to support large group constructivist learning process, we argue that use of mobile ICT, such as the Mobile Interactive Learning System (MILS), potentially enhances individuals learning process due to the following reasons:

- ◆ *Mobile ICT enables effective learner-instructor interaction, enhancing both individual practice and peer-influenced learning.* The communication component of the MILS system offers individual learners to post and/or answer questions (using PDAs) without interrupting the instructor. Meanwhile, the system’s information processing component is capable of handling multiple inputs simultaneously, allowing the instructor later to either aggregate into a meaningful output or display in sequence. Without mobile ICT or a medium of similar kind, these interactions must be done in sequence, and the lecture may have to be interfered from time to time.
- ◆ *Mobile ICT promotes active participation in individual and peer activities.* Although the learners, who use mobile devices may be uniquely identifiable with their electronic identities, they experience less evaluation apprehension (Gallupe et al. 1991) as compared to direct face-to-face communication. They

are, therefore, encouraged to be more active and confident in idea generation and sharing, even in a face-to-face classroom situation.

- ◆ *Mobile ICT provides instant feedback for individual practice.* With the use of MILS system, students get to know the result of their in-class exercises immediately after submitting answers. They not only practice what they have just learned during the lecture, but also receive instant feedback of their knowledge about the subject matter, i.e. whether their answers to the exercise questions are correct or not.
- ◆ *Mobile ICT provides an additional channel for peer-influenced learning.* In the networked learning environment with the MILS system, information sources can be aggregated into meaningful knowledge. For example, all answers from students can be displayed on the instructor's lecture screen, statistically aggregated across the number of participants, with average score, ranking of scores, or similar measures. Further, students can assess their level of understanding among their peers, for instance, by knowing the ranking of other learners, or by comparing their own answers to instructor question with other students' answers (even without actual participation in the Q&A). They not only can compare and compete (implicitly) with their peers, but also can broaden learning from the ideas of others.

Hence, we formulate the first two hypotheses as follows:

- H₁:** In a large group learning environment, individual practice with a Mobile Interactive Learning System (MILS) will be perceived as better than without it.
- H₂:** In a large group learning environment, peer-influenced learning with a Mobile Interactive Learning System (MILS) will be perceived as better than without it.

Drawing on the cognitive and collaborative constructivism, we further assume that effective learners should be, actively engaged in constructing knowledge through individual practice and socially reinforced in the interactive learning process ("peer-influenced learning"), in order to reach understanding and gain satisfaction. Based on these insights, we formulate four more hypotheses as follows. And, the research model is shown in Figure 2.

Individual Practice:

- H_{3a}:** More individual practice in the learning process will result in higher perceived understanding.
- H_{3b}:** More individual practice in the learning process will result in higher satisfaction.

Peer-Influenced Learning:

- H_{4a}:** More peer-influenced learning in the learning process will result in higher perceived understanding.
- H_{4b}:** More peer-influenced learning in the learning process will result in higher satisfaction.

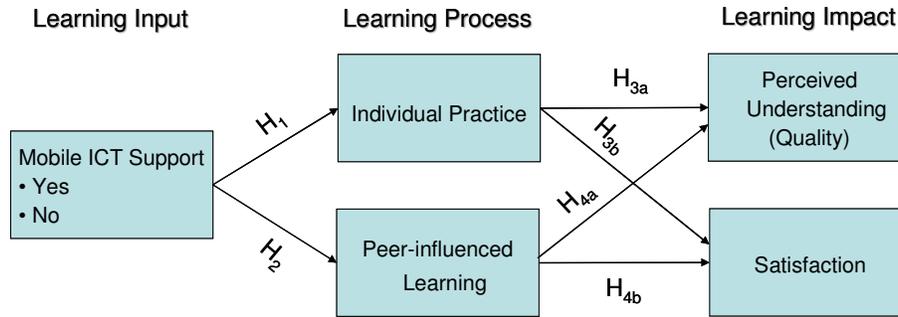


Figure 2. Research Model

5. Empirical Study

5.1 Study Design

To assess the expected benefits of mobile ICT supported large group learning, we examined the learning processes and learner perceptions in a field study of two large lecture sections (groups) of an undergraduate course on Management Information Systems. One of the student groups used MILS system in the class, and each of them had received a PDA at the beginning of the semester in the pilot project. This difference in treatment, while not chosen by us, nevertheless provided a unique opportunity to examine the learning process and outcome differences. Appendix A contains two photos illustrating students using PDA client devices to do exercises and the instructor receiving aggregated results on the computer screen.

Both groups were taught by the same instructor, in the same format, with same exercises, same learning materials, and differing only in the use of MILS system (with PDAs) to complete in-class exercises and quizzes. Lectures for both groups lasted 2 nominal hours each week. The PDA group had 126 students enrolled in it; the non-PDA group consisted of 114 students. Both groups were composed of first year business school students with similar backgrounds and comparable range of university entrance scores. As majority students (in both groups) graduated from the local high school, their learning and computer experiences were following the same local standards (only very few had used PDAs). Thus, the potential influences of these demographic variables should be indifferent.

5.2 Processes and Measures

To enable mobile ICT-based interactive learning, MILS system was developed with the client software operating in the PDA's Web browser. The PDA group used this system for quizzes, exercises, and other in-class interactions, while the non-PDA group received the same class materials and completed the same quizzes and exercises on paper-form, but had to ask or answer questions orally in class. For the PDA group, the instructor was able to assess the students' answers to the quizzes and exercises, and to provide feedback

based on the aggregated online results produced by the system. For the non-PDA group, the instructor assessed students' understanding and gave feedback according to the number of arms raised and (few) students' oral answers.

In-class exercises were held throughout the 13-week long semester. At the end of the semester, a teaching evaluation survey questionnaire (see Appendix B for the measurement scales) was distributed among all 240 participants. The survey guaranteed confidentiality, and stated the purpose as to "determine the usefulness of the in-class exercises". A total of 182 responses were obtained, 90 from the PDA group and 92 from the non-PDA group. The overall response rate was 76% (71% for the PDA group and 81% for the non-PDA group).

5.3 Construct Operationalization and Validation

A carefully-designed questionnaire was developed based on established scales, and review of prior IS research and education literature (see Table 1). The validation of these constructs was subjected to a two-round conceptual validation based on procedures prescribed by Moore and Benbasat (1991) with the help of two groups of four graduate students. The first-round (unstructured) sorting yielded an average hit rate of 84%, while the second-round (structured) sorting received 98% average hit rate, supporting the conceptual validity of the constructs. One item from Satisfaction (S) was dropped since two out of the four judges felt the question rather deterministic, and one item from Individual Practice (IP) and one item from Peer-influenced Learning (PL) were revised for their ambiguous wording.

Table 1. Operational Definition of Constructs		
Construct (Abbreviation)	Definition	Scale References
Individual Practice (IP)	The degree to which the student participates to learn during the learning process.	Adapted from Kwok et al. (2002-3)
Peer-influenced Learning (PL)	The degree to which the student is influenced by peers during the learning process.	Adapted from Kwok et al. (2002-3)
Satisfaction (S)	The degree to which the student is satisfied with the learning process.	Adapted from Ochoa et al. (2004); Olaniran (1996); Fortune et al. (2001)
Perceived Understanding (PU)	The degree to which the student's perception of understanding about the subject matter.	Adapted from Byrne and Flood (2003); Kordi et al. (2005)

Then, a total of 12 items (4 constructs, 3 items each) were combined into an overall survey questionnaire instrument. Before the full-scale survey, a pilot test was first conducted to validate the reliability using sample subjects conveniently drawn from 11 undergraduate students. For the pilot study, Cronbach's Alphas of all constructs fell in the range of 0.70-0.90, indicating support for reliability of the instrument.

Table 2. Means, Standard Deviations, Internal Consistencies, Correlation of Constructs

		PDA Group (n = 90)		Non PDA Group (n = 92)		Correlation of Constructs			
		M	S.D.	M	S.D.	1	2	3	4
1.	IP	5.10	1.22	4.52	1.36	.83			
2.	PL	4.97	1.10	4.28	1.35	<i>.55</i>	.92		
3.	S	5.28	.92	4.90	1.17	<i>.53</i>	<i>.42</i>	.89	
4.	PU	5.34	.94	5.09	1.20	<i>.58</i>	<i>.44</i>	<i>.55</i>	.90

Notes: Boldfaced diagonal elements are Cronbach's alphas. Italicized correlations are significant at p < .05.

Table 2 shows the means, standard deviations, internal consistencies, and correlation matrix of all the variables used in the full-scale study. The internal consistencies (Cronbach's Alphas) for IP, PL, S, and PU are all above .80, which exhibit high reliability of the measurement scales. Since the scales were modified from a number of prior studies, we first conducted an exploratory factor analysis with varimax rotation to explore the validity of the constructs (Fabrigar et al. 1999). As shown in Table 3, the factors emerged cleanly and each had an Eigenvalue greater than 1.0.

Table 3. Exploratory Factor Analysis Results

Extraction Method: Principal Component Analysis.
 Rotation Method: Varimax with Kaiser Normalization. (Rotation converged in 6 iterations.)

	Factor 1 (PU)	Factor 2 (S)	Factor 3 (IP)	Factor 4 (PL)
IP1	.199	.199	.781	.341
IP2	.253	.227	.864	.253
IP3	.297	.236	.844	.154
PL1	.153	.036	.304	.714
PL2	.152	.200	.160	.862
PL3	.160	.215	.161	.863
S1	.152	.853	.286	.128
S2	.286	.833	.149	.179
S3	.242	.833	.161	.167
PU1	.813	.211	.222	.180
PU2	.846	.260	.233	.190
PU3	.841	.219	.229	.140
Factor	Eigenvalue	% of variance	Cumulative %	
Factor 1 (PU)	6.263	52.191	52.191	
Factor 2 (S)	1.454	12.119	64.310	
Factor 3 (IP)	1.159	9.662	73.972	
Factor 4 (PL)	1.009	8.410	82.382	

6. Data Analysis and Results

Our principal question for this analysis was, whether use of mobile ICT, such as the MILS system, could enhance the student learning process, and therefore result in higher learning impact. To answer the research question with empirical evidence, we evaluated our research model with structural equation modeling (SEM) technique.

Before estimating the structural paths to test the hypothesized relationships between constructs, we assessed and validated the psychometric properties of the measurement model by confirmatory factor analysis (Anderson and Gerbing 1988). The fit indices of measurement model suggested that the model fitted the data well ($\chi^2 = 80.14$, $df = 48$, $\chi^2/df = 1.67$; CFI = .98; NFI = .95; RMSEA = .06). All estimated standard loadings were above .70 ($p < .001$), demonstrated good convergent validity. The average variance extracted (AVE) of each construct was greater than squared correlation between constructs, suggesting good discriminant validity (Fornell and Larcker 1981). The reliability of the model, indicated by composite measure reliabilities of the constructs (all greater than .70), was also supported. (Detailed data results can be provided by the authors upon request.)

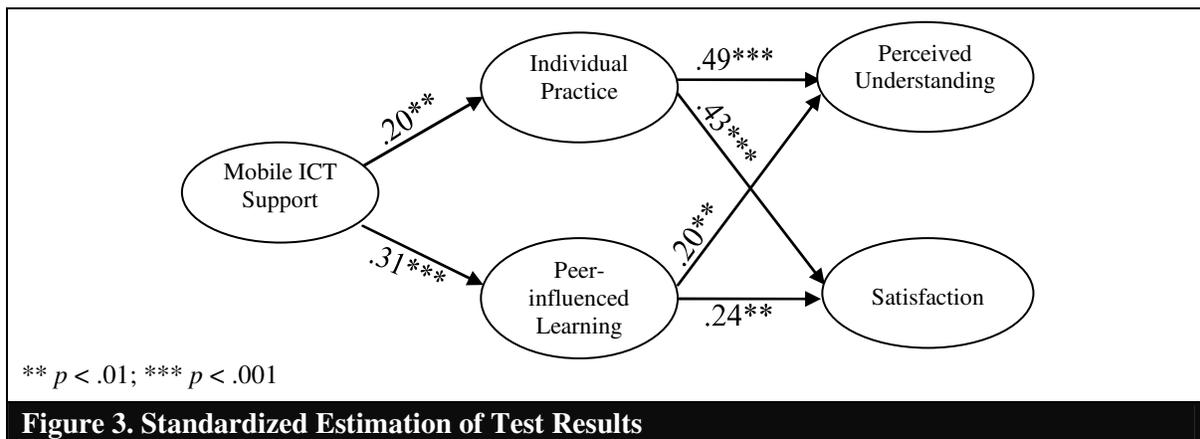


Figure 3. Standardized Estimation of Test Results

To assess the fit of the structural model from the sample, SEM using maximum likelihood estimation method was employed (computed using AMOS 4.0). The model we tested is illustrated in Figure 3. The fit indices sufficiently supported the fit of the structural model ($\chi^2 = 93.98$, $df = 58$, $\chi^2/df = 1.62$; CFI = .99; NFI = .99; RMSEA = .06). Further, examinations of the regression loadings were all significant at the 0.01 level. Accordingly, all hypotheses were supported. In other words, the results demonstrated that in a large group setting, (1) the processes of both Individual Practice and Peer-influenced Learning were perceived better with mobile ICT than without it; and (2) both Individual Practice and Peer-influenced Learning positively impacted learning outcomes. The difference of Individual Practice (Mean = 5.10 vs. 4.52; $t = 3.03$, $p < .01$) and Peer-influenced Learning (Mean = 4.97 vs. 4.28; $t = 3.83$, $p < .01$) were also strongly supported by t-tests between the PDA group and non-PDA group.

7. Discussion and Limitations

Our study offered useful insights to learning processes, identifying that mobile ICT use affected both individual practice and peer influence, and that both in turn resulted in better (perceived) understanding and satisfaction. Consistent with the concepts of cognitive and social construction of knowledge drawn from constructivist learning models, we found evidence for both individual practice and peer-influenced learning

being almost equally relevant to (perceived) understanding. For satisfaction, individual practice mattered more, possibly due to the fact that exposure of one's results to peers was not as desirable to students as being able to privately determine one's understanding. Although perceived learning outcome was not the same as real outcome, given that subjects completed the quizzes week after week, while being able to monitor their learning progress over these consecutive weeks, their own perception of their learning was based on fact (performance in quizzes), and thus should be a good indicator of actual learning.

To further verify these, we randomly selected two lecture sessions for field observations by three observers. The proportion of student responses to in-class questions in the MILS group was observably greater than the group without it, especially for open-end questions. A focus group investigation (with 10 student respondents from the MILS group) was conducted at the end of the semester to discuss their experience of mobile ICT supported interactive learning. All respondents agreed that students would be more willing to ask/answer questions through PDAs as they felt less "shy" or "stressful" not being directly identifiable (or face-to-face). Some also noticed more participation and student-instructor interactions compared to other similar size classes they attended. "The learning atmosphere (of the lecture) was better" and "was more fun". Taken together, mobile ICT use therefore provided better and more enjoyable learning.

This, like any other study, is not without limitations, and needs to improve in the future. For instance, we could compare the Mobile Interactive Learning System with other type of interactive learning systems, mobile as well as wired. We could also conduct a longitudinal study that examines the learning situation before and after the treatment, rather than a one-time shot. We could compare the actual learning outcomes (e.g. final grades) of the two groups, instead of the perceived values.

8. Conclusions and Implications

Overall, our results confirmed that a lean communication medium, namely mobile ICT, can enhance learning in a large group environment. Learners with mobile ICT support demonstrated better (perceived) understanding and better learning satisfaction than a group without the technology. The technology appears to achieve these benefits by providing rich and effective interaction through social construction, and through its support for constructivist learning processes.

In addition, the study has several important practical implications. First, they demonstrate that large class learning can be better and more satisfying due to mobile ICT use. As the technology is becoming less expensive, it offers the promise of learning improvement with relatively little additional costs, and hence possibly the scalability of classroom enrollment without quality loss. Furthermore, this approach can help students who are shy, or where cultural issues limit their willingness to speak up in a large group. We should also expect that these results would, in part, be generalizable to distance learners who study synchronously, e.g., by all watching an instructional TV program at the same

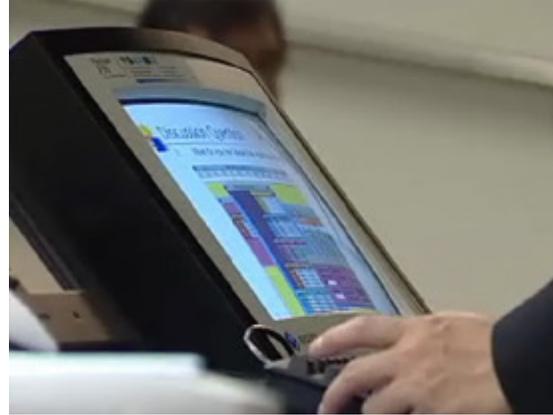
time. In the past, such programs may have had a Q&A session at the very end (outside the view of the TV audience). Using mobile technology (or even a stationary ICT such as a desktop computer) and applying the processes we used, distance learners could complete online quizzes and similar activities, thus adding feedback to a learning mode that traditionally has been mostly one-way. Clearly then, there is great promise for a mobile ICT that is relatively inexpensive, yet can significantly enhance large group learning.

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Appendix A: PDA Learning Photos



Appendix B: Measurement Scales

Individual Practice (IP)

Scale Range: 1 = Strongly Disagree; 7 = Strongly Agree

IP1. I practised what I learnt in the lecture.

IP2. I tested my understanding about the subject matter.

IP3. I assessed my knowledge about the subject matter.

Peer-Influenced Learning (PL)

Scale Range: 1 = Strongly Disagree; 7 = Strongly Agree

PL1. I compared my understanding of the subject matter with that of other students in class.

PL2. I learnt from other students in class.

PL3. I considered the ideas of other students in class.

Satisfaction (S)

How would you best describe the learning process when participating in the Q&A exercise?

S1: Efficiency Scale Range: 1 = Very Inefficient; 7 = Very Efficient

S2: Coordination Scale Range: 1 = Very Coordinated; 7 = Very Uncoordinated

S3: Satisfaction Scale Range: 1 = Very Dissatisfying; 7 = Very Satisfying

Perceived Understanding (PU)

Scale Range: 1 = Strongly Disagree; 7 = Strongly Agree

PU1. I was able to better understand the subject matter of the lecture.

PU2. I learnt more.

PU3. I had a deeper understanding of the lecture topics.