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# Mobile Learning in a Large Blended Computer Science Classroom: System Function, Pedagogies, and Their Impact on Learning

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***Abstract*—The computer science classes in China's institutions of higher education often have large numbers of students. In addition, many institutions offer "blended" classes that include both on-campus and online students. These large blended classrooms have long suffered from a lack of interactivity. Many online classes simply provide recorded instructor lectures to which distance students listen after downloading. This format only reinforces the negative effects of passive nonparticipatory learning. At a major university in Shanghai, researchers and developers actively seek technological interventions that can greatly increase interactivity in blended classes. They have developed a cutting-edge mobile learning system that can deliver live broadcasts of real-time classroom teaching to online students with mobile devices. Their system allows students to customize their means of content-reception, based on when and where the students are tuning into the broadcast. The system also supports short text-messaging and instant polls. Through these features, students can ask questions and make suggestions in real time, and the instructor can respond immediately. This paper describes this system in detail and also reports results from a formal implementation of the system with a blended classroom of 562 students (of whom 90% were online).**

***Index Terms*—Case study, interactive computing, large-scale integration, learning systems, mobile learning.**

## I. Introduction

IN RECENT YEARS, models of distance education have gravitated towards two different poles: the "individual flexible teaching model" and the "extended classroom model" [1]. The former allows students to start the class at any time, study in isolation, and communicate with instructors and classmates through asynchronous tools. The latter organizes students into groups and requires them to meet at local study centers and use interactive technologies such as video conferencing [1].

The Online College detailed in this paper has moved toward integrating the two models via a new mobile learning (mLearning) system. Students can choose either to study alone and asynchronously (on their own schedule), or they can connect to a live class by using portable devices and interact with the instructors and other "ground" or online students. Students who prefer the structure of the classroom can either attend the class in person or use online learning as an extended version of the classroom (by participating in live discussions with classmates and instructors). Equally, students may choose to use the class archives, forums, and "answering machine" to learn on their own. This system helps to create a virtual classroom setting, which enables students to customize their learning experience based on their needs and preferences. Students can tune into live broadcasts or view archived videos of lectures online. All lectures and activities that go on in a campus classroom are digitized simultaneously and broadcast online, similar to online video programs and vodcasts (video podcasts). The college's core philosophy with respect to distance education is "learning anytime, anywhere." Because a majority of the students work full time, the college takes steps to ensure flexibility in terms of course delivery, physical location, and delivery medium.

Indeed, students seem to value the option of learning through a variety of media. The Online College's enrollment has increased from 100 students in 2002 to 16 000 students in 2007. However, the live broadcast system does not yet provide fully interactive capabilities. Distance students can watch and listen to the live classrooms, but they cannot ask questions or participate in any class activities. The mLearning system developed at Shanghai Jiaotong University, Shanghai, China, provides the means for distance students to interact with the instructor and campus students, thus in effect bringing them into the live classrooms.

This lack of interactivity is a long-standing feature of Chinese classrooms, in both online classes and campus classrooms. Many online classes simply provide recorded lectures online or a CD-ROM, to which distance students listen after downloading. Some argue that this noninteractive format is no different from the old format of distance learning through correspondence or by watching televised lectures. Distance learning without interactivity only reinforces the negative effects of passive, nonparticipatory learning. In addition, noninteractivity obliges the instructors to lecture for the entire class session. Even now, teacher-centered presentation dominates many of the higher-educational classrooms in China and across the world. Students, teachers, and instructional designers still see knowledge as an entity that instructors can simply transfer to students. Students are then compelled to listen to the instructor and try to grasp the major "knowledge points" and content of a

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lecture. In the Chinese educational system, knowledge points are similar to learning objectives in that they establish at the beginning of the course the material the students are expected to master.

The use of mLearning in this online college represents an attempt to encourage students' active participation in the learning process and to engage them in constructivist learning through social and intellectual interaction. For the purposes of this paper, "mLearning" refers to education and communication during class through the use of mobile phones. The E-Learning Lab invested in mobile technology because of the devices' high degree of market penetration in all parts of China. The global penetration rates of mobile devices are equally impressive. Worldwide, there are close to 2.7 billion active mobile phones [2]. With their rapid technological development, mobile learning in China and across the world will provide enormous opportunities in the near future. Through adapting the current curriculum for interactive teaching and learning, researchers and developers in the E-Learning lab also hope to set an example for pedagogic changes in China's system of higher education. The use of mLearning also aligns with the "learning anytime, anywhere" philosophy of this college. Students are no longer tied to a classroom; they have the opportunity to study whenever they have time and from wherever they live.

This study seeks to examine three essential questions regarding the mLearning experience in a computer science course. First, researchers conducted preintervention student surveys to determine how students felt about mobile learning. Second, researchers conducted a post-intervention course evaluation to determine if students benefited from interactivities supported by the mLearning system. Third, researchers compared the students' final course grades with their use of mobile technology to determine how mobile learning affects students' learning. In essence, the researchers asked: 1) Will students use it? 2) Did they like it? and 3) Did the intervention work?

## II. Theoretical Framework

Although mobile learning has been used around the world, a review of extant literature reveals dissent about the proper use and utility of mobile technology as learning tools. For example, Harris [3] promotes a view of mobile learning that values the dual benefits of distance learning and constant connectivity. Wagner and Wilson [4], on the other hand, advise that mobile learning should not be viewed as "e-learning" transferred to mobile devices. Instead, they contend, the value of mobile devices as tools of learning is found in the storage capabilities that enable people to connect to previously downloaded materials at any time.

Foremost in the minds of educators and researchers at this stage, of course, are the limitations imposed upon learners by the size restrictions of mobile devices. The small screen size impacts the effectiveness of viewing content [5]. Moreover, the small keypads do not promote ergonomically satisfying input methods. These limitations restrict the primary functions of mobile devices to brief textual communications and the viewing of small chunks of data [6]. Considering all these constraints, researchers must consider how mobile devices can be used in large

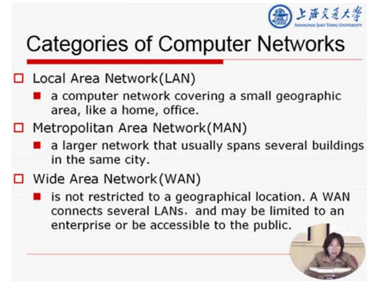


Fig. 1. The course content displayed on a mobile phone.

classrooms (especially classes that include both campus-based and online students), as well as how the current curriculum can be adapted for mobile delivery.

Successful trials indicate that the potential benefits of mobile learning will change the nature of the classroom, providing that instructional designers implement the devices effectively. For example, mobile learning currently enables researchers and students to bring the classroom into the field by enabling easy note-taking and audio/video recordings [7]. The ubiquity of mobile devices themselves further promises to accelerate the use of non-PC-based digital learning, and to free students from the traditional classroom/field model. Penetration rates of mobile devices (especially cellular telephones) surpass that of home computers in many parts of the world.

In China and many other countries, mobile phones have the potential to expand the accessibility of learning opportunities [1]–[4]. However, the best practices for using mobile devices in teaching and learning are still unknown. Systematic studies are needed to investigate students' and instructors' experiences with mobile learning. Researchers must study and examine existing mobile learning programs to highlight their strengths. Designers must capitalize on these strengths to further develop new mobile learning opportunities. Future research, however, should also attempt to evaluate any potential obstacles to effective communication, such as the use of text-messaging as a communications medium. In so doing, future learning programs can be designed to minimize this type of problem.

Even at this early stage of development, mobile learning presents a number of opportunities within the context of the American university classroom. Researchers at the University of California at San Diego have conducted a number of valuable experiments that demonstrate mobile learning's ability to increase student-instructor interactivity and provide novel learning experiences. In [8], Ratto and his colleagues designed a mobile learning system (based on palmtop devices) that addresses the divergent requirements of students, teaching assistants, and professors within the same classroom environment. This "ecological" perspective allowed their mobile system (called "ActiveClass") to meet the needs of each group simultaneously. During lectures, for example, the ActiveClass software allowed students to anonymously ask the professor questions about the lecture material. This feature increased the volume of classroom participation by allowing large groups of students to access the professor without interrupting the lecture. At the same time, professors could choose among the questions and select them based on their quality. Instructors could also


Fig. 2. A high-level view of the course delivery system.

deflect specific, off-topic, or tangential questions to the course forums for later discussion by students and teaching assistants.

The researchers [8] responsible for the ActiveClass experiment also note that mobile technology is not a panacea. While researchers observed an overall increase in the amount of questions asked ("a broadening of discourse," as they call it), their experiment did not reveal an overall increase in the *number* of students who asked questions. A number of "shy students" refrained from asking questions at all. The researchers advanced the possibility that "shy students" may feel uncomfortable with or uninterested in the new technology. The experiments reported in this study attempt to discover to what extent Chinese learners (who probably own cell phones and palmtop devices, but rarely respond in the physical classroom) benefited from the mobile learning activities, to what degree students accept mobile learning as an instructional option, and how designers and instructors can better involve students in mobile learning activities.

## III. System Function and Architecture

In the mLearning classroom, instructors carry out the multimedia instruction from an instructor's station, which supports handwriting on its computer screen. As they teach, the instructors use either PowerPoint slides or handwriting on the screen. Cameras and microphones that are connected to the computer capture live video of the classroom. A recording program, an integrated part of the mobile phone broadcasting subsystem, records all of these media components (audio, video, handwriting, and PowerPoint presentations) and relays them in customizable combinations to students.

Fig. 1 illustrates what a student sees on his/her computer screen or mobile device when tuning into an online broadcast. Fig. 2 displays the structure of the mLearning course delivery system.

In the meantime, the instructor station displays messages from the students. It also reports their learning progress, their questions, and their feedback to the instruction. The system delivers these messages as mobile phone text messages through a short message service (SMS) protocol. The instructor can address these messages either by typing on the screen or by giving an oral explanation, which the entire class can see or hear. In addition, this mobile learning system can also display on a larger screen the mobile device screen of any of the students tuned into a live broadcast, allowing the instructor to supervise students' learning [9]. The instructor can also take an instant poll on any aspect of the instruction, including pace, clarity, content, and structure. The mobile learning server will generate the poll results and immediately send them to the instructor, who can then adjust her/his instruction on the fly.

Students can choose the format of the live broadcast from multiple perspectives. They can view it from that of the instructor's station (with the teacher's screen, audio, and a small video feed of the real-time classroom), from a "virtual student" perspective (the video of the PowerPoint presentation and audio of the instructor) or from the "front row" (close-up on the instructor's facial expressions and other body language). The first two modalities have the potential to recreate the feeling of sitting in a real classroom with the instructor at the front and other students nearby. When attending class online, students can also use their mobile phones to send short text messages to communicate with the instructor (including questions, suggestions, requests, or other types of feedback).

In summary, the instructors, students, and system administrators cooperate to create a virtual classroom that includes both online and classroom students and the real-time communication between online students and the instructors. However, their cooperation relies on the support of the mobile learning system, which conducts the coding and decoding of the multimedia teaching stream and manages the time delay. The system is quite robust and can be used in many of the large classes offered at this online college.

## IV. Method

This introductory computer science class mainly teaches basic knowledge of computer science, the use of Windows XP and Microsoft Office, and basic knowledge of computer networks and also includes an introduction to the structure of the Internet, computer security, and multimedia technologies. The instructor presented to both campus and online students for 3 h each week. The mLearning system archived videos of the course on the class's Web site for students to review at their convenience. The class content is organized by "knowledge points," or small, clearly defined units of knowledge or skills. As an example, in this computer science, class students completed a presurvey in which they rated their existing level of knowledge on each of the course's knowledge points. The main knowledge points in this class include:

1) the basic concepts of computers such as the development of computers, types of computers, major characteristics of computers, and major uses of computers;
2) use of basic Microsoft Office tools;
3) basic concepts of computer networking;
4) Internet use in Chinese society.

This class is a typical "blended" or "hybrid" class that includes both "ground" and online students. The classroom in this online college is equipped with an instructor computer with two LCD monitors, a microphone, a Web camera, and recording devices that are connected to this mLearning system. The instructor normally sat in front of the computer and presented the major knowledge points for each session using PowerPoint slides. The end of each PowerPoint presentation had 10 multiple-choice questions, which prompted students to review the essential knowledge points that they had just learned from the instructor presentation. "Ground" students who were sitting in the class took notes and were free to hold discussions with their classmates. Online students could tune into the live class through the Internet, the educational TV channel, or via a mobile device (e.g., cell phones). Because of the large number of students in this class (562 total), and in order to make the live class more visible to the online students, the instructor encouraged the students to ask or answer her questions by sending short text messages. The messages were routed through the mLearning system and were displayed on one of the LCD monitors. The instructor would review these messages and address them immediately. Most of these interactions would go on for 10–15 min. Afterward, the instructor presented real-world cases related to these knowledge points and encouraged students to discuss them through text messages. These text messages were also captured and displayed on the instructor's monitor.

Researchers collected data on this pedagogic strategy through pre- and post-surveys and by comparing the grades of students who were and were not active participants. The presurvey in this class served as a needs assessment. The presurvey also provided informative data about students' professional background, their experiences in taking online classes, their motivation for taking the class, and their perceptions of cell-phone-based mobile learning. A postsurvey solicited participants' perceptions of the mobile learning system, activities conducted using this system, and their learning outcomes (i.e., grasp of the knowledge points).

## V. Pre- and Post-Intervention Surveys

Researchers conducted a preintervention survey to determine if students were willing to use mobile learning technologies in their class. Researchers assumed that a technology that makes students nervous or uncomfortable would actually be detrimental to the learning experience. Researchers also conducted a postintervention survey to determine if students enjoyed mLearning and found it valuable. A technology that students do not like and will not use cannot benefit them, regardless of that technology's sophistication, novelty, or utility.

### *A. Presurvey Results: Mobile Phone Use, Learning Styles, and Sociability Preferences*

Out of 562 students from this computer science class, 447 students responded to the presurvey. According to the presurvey, 87.7% of the respondents consider themselves very good at text-messaging on mobile phones. Only 10.6% considered themselves beginning users, and 1.7% had never used text-messaging before. When asked about their cell phone usage, students replied that they mainly use mobile phones for staying in touch with friends and family (86.9%), for work-related activities (69.8%), and for chatting with friends (84.8%). Only a small percentage (9.5%) used mobile phones for studying and playing games.

Most noted that using mobile phones for course work would be a new experience. However, 52.5% of the respondents have taken a distance education class (via TV, the Internet, or any other media) from this college before; the rest (45.9%) have either participated in distance education at a different institution or had not taken one before (0.8%). A great majority (95%) of those who have taken a distance learning course did so through the Internet (i.e., an online class).

When asked if they were willing to study using their mobile phones, 33.55% said "yes," 48.6% said "no," and 17.5% declined to answer because they were not familiar with this learning format. Students identified the costs associated with mobile phone-based mobile learning as a primary concern, followed by the current technological constraints (hardware and software). Some students expressed concern about the quality of teaching and learning through mobile devices. Some stated that they prefer to use e-mail or the online forum for class communication. The mobile learning research and development team is aware of the problems regarding cost and have found ways to reduce the burden on students. For instance, the development team provided toll-free numbers for students to use for sending in text messages.

As for the length of mobile phone interactivity, 78.2% of the 447 respondents voted for less than 5 min. 87.3% of them would like to receive content in the format of quizzes, 78.2% would like to get interesting stories, and 34% would like to receive real case studies. Students gave convincing reasons to support their choices. For instance, they felt that mobile phone interactivity can help them grasp the basic concepts of computer science. However, students felt concerned about the lack of hands-on learning. From a cognitive science standpoint, kinesthetic learning is a primary means of gaining particular skills (such as computer operation and trouble shooting), so this concern seems worthy of consideration. Thus, mobile learning may lend itself better to short, interesting content that does not require hands-on practice.

Regarding media use in mobile learning, only 281 of the respondents indicated a preference. 46.3% of learners chose audio and video, followed by text as their second choice (45%). Forty percent (40%) said they did not know enough about mobile learning to make an informed decision. Their preference for audio and video seems affected by the prevalence of online multimedia technologies. However, considering the current technological constraints, it will be challenging to provide media-rich content in mobile learning. Just over 54% of learners (54.5%) voted for once-a-day mobile interactions, while 38% voted for once or twice a week. Therefore, mobile learning involving intensive interaction and multimedia should be used in moderation in these classes and should be used as a supplement to other types of class interactions (such as e-mail, forums, and instant messaging).

The presurvey also asked about students' learning styles and socializing preferences to determine if mobile learning fits their needs and learning preferences. The learning styles of the students were examined from six dimensions. The descriptive analysis of the data collected about their learning styles led to a series of findings that can guide course design and conduct.

1) **Establishing learning goals**: The frequency analysis shows that over 50% of the 447 respondents prefer to let the instructor tell them what to learn, but 43.97% of

students prefer to set their own pace and monitor their own progress of study. The rest of the students (2.3%) prefer a combination of both.

2) **Preferences for ways of learning**: The frequency analysis shows that over 60% of respondents prefer to collaborate with other students to complete course assignments. Thirty percent (30%) of them are willing to participate in discussions with other students. Only 4.23% prefer to study alone.
3) **Preferences for study groups**: The frequency analysis shows that over 89% of respondents prefer study groups. Among them, over 70% of them prefer to be assigned to the group where the knowledge level of group members is higher than their own, and over 18% prefer to be assigned to a group at his or her level. About 10% report no preference for studying alone or studying in groups.
4) **Best ways to study computer science**: Just over 48% (48.63%) of students prefer to study computer science through an online forum, 25% (25.16%) through communicating with the teachers and the students, 21% (20.93%) through watching video, and others prefer the combination of these three ways.
5) **Goals in taking this course**: The frequency analysis shows that 54.44% of the respondents took this course in order to learn new knowledge and skills. Only 3.17% took this course in order to get credits and good grades. Forty-two percent (42.28%) of the respondents choose both.
6) **Preferences for assessment**: The frequency analysis shows that 65.54% of the respondents prefer a final assessment (summative evaluation). Thirty-four percent (34.04%) prefer assessment during the course (formative evaluation). Few students showed no preference on this question.

The results of this survey indicate that a niche exists in the Chinese classroom. Students would like to participate in study groups and work with others on projects, but they refrain from doing so in the physical classroom. mLearning technologies are in a position to realize the opportunities and needs that students cannot realize in their nonvirtual worlds.

### *B. Impact of mLearning on Student Learning Outcomes*

Researchers also performed a descriptive analysis of participants and nonparticipants' grades to determine if mobile learning interventions have a positive or negative effect on learners. A sample of 550 students from the computer science course were selected and categorized into two groups: participants (who used mLearning tools during the course) and nonparticipants (those who did not use mLearning technologies during the course).

Because the grades of both groups (participants and nonparticipants) appear as skewed distributions, researchers used the Mann-Whitney $U$ test (nonparametric test for independent samples) to compare the median differences between the two independent groups. As shown in Table I, the mean rank of nonparticipants is 244.86, while the mean rank of participants is 311.73. $U$ test results show that participants' grades are significantly higher than that of the nonparticipants' ($n = 550$, $U = 46678.5$, $a = 0.05$, $p < 0.0001$).

TABLE I
RESULTS OF THE MANN-WHITNEY $U$ TEST $R$ COMPARING THE PERFORMANCE OF PARTICIPANTS AND NONPARTICIPANTS

| Grades by Groups | n | Rank sum | Mean rank | U |
|---|---|---|---|---|
| Non-participants | 298 | 72968.5 | 244.86 | 46678.5 |
| Participants | 252 | 78556.5 | 311.73 | 28417.5 |
| n | 550 | | | |
| Difference between medians | -3.000 | | | |
| 95% Confidence Mann-Whitney U | 46678.5 | | | |

TABLE II
MANN-WHITNEY $U$ TEST FOR COMPARING THE PERFORMANCE OF PARTICIPANTS

| Grades by Frequency of Participation | n | Rank sum | Mean rank | U |
|---|---|---|---|---|
| All | 144 | 24948.0 | 173.25 | 1044.0 |
| Some | 108 | 6930.0 | 64.17 | 14508.0 |
| n | 252 | | | |
| Difference between medians | 9.000 | | | |
| 95% Confidence Interval Mann-Whitney U statistic | 1044 | | | |

Researchers conducted another Mann-Whitney $U$ test (Table II) to compare the grades of the two groups of participants: those who participated all the time (full participants) and those who participated from time to time (partial participants). A learner's participation status (full versus partial) was determined based on their SMS text-messaging activities recorded by the mLearning system. The mean rank of full participants is 173.25, while the mean rank of partial participants is 64.17. $U$ test results ($n = 252$, $U = 1044$, $a = 0.05$, $p < 0.0001$) indicate that the grades of full participants are significantly higher than partial participants.

Although many factors might have influenced students' grades, their performance differences can be attributed to their participation in mLearing activities. The following conditions support this interpretation of the data:

1) Based on the presurvey on students' grasp of the main knowledge points, their preclass levels were similar. The mean rating of their familiarity with the knowledge points was 2.3 on a scale of 1 (not at all) to 5 (very well), with a standard deviation of 0.5.
2) Students' participation in mobile interactions was completely voluntary. Although the instructor gave bonus points as incentives for participation, these points were removed for statistical analysis (descriptive analysis and $U$ tests).

TABLE III
SURVEY QUESTIONS AND DESCRIPTIVE ANALYSIS

| Question Number | Question Text (Translated) | Respondents | Likert Scale (X-Y) | Mean Score | Standard Deviation | Variance |
|---|---|---|---|---|---|---|
| 1 | Overall satisfaction with this class | 242 | 1-4 | 2.79 | .625 | .391 |
| 2 | The mLearning class was well organized | 242 | 1-5 | 3.59 | .708 | .501 |
| 3 | The course's activities were engaging | 242 | 1-5 | 3.53 | .784 | .615 |
| 4 | The activities strengthened my connections with my classmates. | 242 | 1-5 | 3.60 | .845 | .714 |
| 5 | The activities strengthened my connections with the instructor. | 242 | 1-5 | 3.78 | .733 | .537 |
| 6 | I had more opportunities to ask questions. | 244 | 1-5 | 3.84 | .754 | .568 |
| 7 | I had more opportunities to help my classmates. | 244 | 1-5 | 3.59 | .804 | .647 |
| 8 | I had more opportunities to practice what I learned. | 244 | 1-5 | 3.75 | .795 | .633 |
| 9 | Mobile learning helped me a great deal in studying the content of this class. | 244 | 1-5 | 3.69 | .816 | .666 |
| 10 | Mobile learning helped me grasp the course's main knowledge points. | 244 | 1-5 | 3.70 | .835 | .698 |
| 11 | Mobile learning changed my habit of studying alone | 244 | 1-5 | 3.63 | .833 | .695 |
| 12 | The modality of mLearn (words, audio, video) fits my learning style | 244 | 1-5 | 3.59 | .854 | .728 |
| 13 | I felt that my social skills have improved through the use of mobile learning. | 244 | 1-5 | 3.40 | .899 | .808 |
| 14 | I would like to recommend mobile learning to other students. | 244 | 1-5 | 3.71 | .770 | .592 |
| 15 | I would like to participate in future mLearn activities. | 244 | 1-5 | 3.69 | .841 | .708 |

### *C. Findings From an Analysis of the Post-Survey*

Because participation in mobile learning is completely voluntary, 264 students participated in the mobile learning activities; 12 of them withdrew from the class for various reasons. The survey yielded 244 responses from the 252 mLearning participants in this computer science course. Based on the demographic information collected from the presurvey, these 244 students form a representative sample of the student population at this college.

Researchers conducted a series of analyses to help determine how students respond to four major facets of the mobile learning system. Findings corroborate the statistical evidence of mLearning's influence on learning outcomes, and also provide insights into students' learning experiences. Researchers explored these constructs (including satisfaction, interaction with content, social interaction, and effects on study habits) by using the raw data gathered from the survey. Table III gives the survey's fifteen questions (translated into English from Chinese) and a descriptive analysis of the responses.

The postsurvey gathered data relating to a number of practical questions. First, it sought to determine if students enjoyed the mobile learning experience. If students did not enjoy participating in mobile learning activities, then developers may need to consider future design changes. Second, it provided insight into how students felt about interactions with fellow learners via the mobile classroom. This seeks to address the concern that students may feel isolated or disconnected from one another. Third, it asked how students felt about their relationship to their instructors in the mobile learning environment. Due to the large number of students in this class, students might feel distanced or separated from their instructor. This study aims to discover if the mobile environment helps to reduce the psychological distance between students and the instructor. Fourth, researchers asked questions about the mobile classroom's effects on students' study habits and their ability to learn from the online system.

### *D. Reliability of Student Responses*

For this study, researchers used Cronbach's Alpha test to determine if the survey generated reliable data. Reliability tests help to determine whether a given survey yields a consistent range of answers across the entire data set. While these tests do not reveal whether the survey produces valid results, reliability tests such as Cronbach's Alpha reveal whether students' answers fall within a predictable range.

TABLE IV
STUDENTS' OVERALL SATISFACTION LEVEL WITH THIS CLASS

| *Scale* | *Frequency* | *Percent* |
|---|---|---|
| Unsatisfied | 3 | 1.2 |
| Somewhat satisfied | 69 | 28.3 |
| Satisfied | 146 | 59.8 |
| Very satisfied | 24 | 9.8 |
| Can't answer | 2 | .8 |
| Total | 244 | 100.0 |

For the above survey, researchers determined that a Cronbach Alpha of $A > .90$ would be necessary to label the data as "reliable." The statistical software generated a Cronbach's Alpha value of $A = .948$ (number of cases $=$ 242, number of survey items $=$ 15), indicating that this survey yields reliable results. Researchers also ran a second Cronbach analysis of the data that excluded question number one. Question number one operates on a Likert scale of 1–4, compared to the 1–5 used on the rest of the questions. The results of that test ($a = 0.956$) differ by less than 1% from the original, indicating that the scale itself does not significantly reduce the reliability of the test.

### *E. Findings From the Narrative Data of the Postsurvey*

Out of 562 students, 244 responded to the class's post-intervention survey. Of the 244, 107 (43.9%) reported participating fully in class activities through mobile devices, 60 (24.6%) reported engaging in periodic interactions, and 77 did not participate in any of the activities. The main activities they conducted through cell phones or PDAs included:

a) discussing course-related content with classmates (40.16%);
b) answering questions from the instructor (18.03%);
c) asking questions of the instructor or her assistants (7.79%);
d) asking classmates questions (7.38%);
e) all of these activities (20.49%).

Students provided feedback on five aspects of mLearning: 1) the content used in class activities; 2) the length of each activity; 3) the frequency of mLearning use in class; 4) the organization of mLearning activities; and 5) technical suggestions. Table IV shows students' satisfaction level with this class, and Tables III and IV tabulate their participation information.

Mobile students' felt a high degree of satisfaction with this course, with 28.3% being somewhat satisfied, 59.8% being satisfied, and 9.8% being very satisfied. Existing reports [10], [11] reveal that student satisfaction affects their performance and the drop-out rates, especially in online courses. Close to 70% of the students participated in at least some of the mLearning activities. The remaining 30% of students (the nonparticipants) require close attention to determine why they declined to participate.

As Table V shows, about 56.4% of the students took the initiative in discussing course-related questions with their classmates. Those who had engaged in distance learning in the past were more willing to interact with their classmates through mobile learning. The survey results also point to the need to group students based on their learning preferences and their knowledge and skills. Member exchanges within groups should be strengthened, so as to promote learning- and learner-centered pedagogy, and to encourage students' initiative in learning through peer influence. In the meantime, instructors should learn to change their role from "sage on stage" to coach and facilitator. Therefore, the traditional teacher-centered pedagogy needs fundamental changes better to motivate students and stimulate their enthusiasm.

The following assertions come from students' comments on their experiences with mobile learning and their suggestions for better organizing the mLearning activities. A majority of the students (72.54%) were positive about the mLearning activities used in their class. Students reported liking mobile learning because:

a) mLearning allows students to learn at their own pace and according to their own schedule;
b) mLearning reduces the effects of time and space disjunctions and reduces the transaction distance between the instructor and students;
c) the technology increased their ability to interact and socialize with others;
d) the technology increased motivation and self-regulation;
e) the students grasped knowledge points more effectively through interaction and self-paced review of the archives afterward.

When asked if mLearning helped them learn to interact with others via cell phones, 54.51% of 244 respondents answered "a little," 21.72% said "very much," and 22.95% said "no." This result indicates that students were still acclimating to studying with cell phones. Further efforts are needed to translate students' good learning habits from the classroom to cell phones. These findings have lead researchers to conclude that mLearning content must be made more interesting and engaging in order to encourage both competition and collaboration among participants.

### *F. Suggestions for Improving the mLearning Activities*

In summary, respondents offered several good suggestions for improving the mLearning activities used in this class, including the following.

1) **Increase interactions, especially outside class sessions.** This increase may be accomplished by using artificial intelligence tools, such as the "answering machine," that is connected to the course's learning system. Students type in a question, and the "answering machine" will search its database of answers and provide one that is the closest match to the question.
2) **Design content specifically for mobile learning.** The content should not be limited to textbooks and the instructor's presentations, but should be more extensive (or "should be wider-ranging") to include relevant learning content or even social topics such as problems encountered at work or in their personal lives. In addition, considering the highly technical nature of the course content, the topics being discussed should be displayed on the computer screen to assist students to understand it.
3) **Provide more opportunities for interaction through study groups, etc.** Students hope to take more initiative in learning and to get immediate feedback from the instructor on their participation. Their expectations for feedback pose

TABLE V
MAIN MLEARN ACTIVITIES ENGAGED IN BY STUDENTS

| | Answer questions from the instructor | | Discuss course-related questions with other students | | Ask the instructor or TA questions | | Ask classmates questions | | Other | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Count | % | Count | % | Count | % | Count | % | Count | % |
| No | 147 | 62.8% | 102 | 43.6% | 149 | 63.7% | 137 | 58.5% | 226 | 96.6% |
| Yes | 87 | 37.2% | 132 | 56.4% | 85 | 36.3% | 97 | 41.5% | 8 | 3.4% |
| Total | 234 | 100.0% | 234 | 100.0% | 234 | 100.0% | 234 | 100.0% | 234 | 100.0% |

a great challenge for the instructors since this class has about 600 students. Even though not everyone will attend the live sessions (either in person or online), the average number of attendees is near 500 per class. Developers will need to look into alternative ways to fulfill students' requirements.

4) **Expand the communication tools.** As to the frequency of mLearning interactions, students differ in their expectations. Due to the limited text length on a cell phone, students suggested combining mLearning interactions with other communication tools—such as forums, e-mails, QQ, IMing, the Internet, MP3, and an audio system—so that there can be a better integration of Internet-based communications and media and mobile devices.

## VI. CONCLUSION AND FUTURE WORK

Overall, students felt comfortable and happy with the use of interactive mLearning in their computer science class. Far from rejecting the technology, students want more—more varieties of interaction, more types of content, and more features. Student acceptance of this emerging technology represents a step toward anytime, anywhere learning that brings students together instead of isolating them from their classmates.

The E-Learning Lab in the Online College at Shanghai University has made significant progress toward making mobile learning a reality for students. Though this analysis proves a good starting point for the study of mLearning's effects on students in a computer science class, a great number of pedagogic issues remain. Future research will undoubtedly discover other uses for mobile learning as the technology matures and gains wider acceptance. At this point, however, researchers have identified certain limitations to this study.

*1) Culture and Language:* Researchers conducted the original survey at a large Chinese university. The specifics of cultural attitudes toward learning suggest that some variation in results will occur from one culture to another. As mobile learning gains popularity in Europe, Africa, Australia, and the Americas, researchers may need to ask different questions to uncover how a specific learning group reacts to mLearning courses.

*2) Repeated Testing:* Future researchers must vet their surveys thoroughly before deploying them. Due to time constraints, researchers could not "dry-run" the survey used to generate the cluster analysis on smaller focus groups.

*3) Population:* At present, few mLearning courses are available to students. Even at large-scale testing grounds, such as reported here, only a small percentage of the students learn via mobile technologies. These students may differ from the larger student population in unexpected ways, including learning style preferences, social habits, and educational goals. Researchers must work to isolate and control these variables.

Finally, through pilot testing this system with more classes, future researchers can address a number of troublesome pedagogic issues. For instance:

1) How can the system help build an effective virtual learning environment among large numbers of online students in computer science classrooms?
2) What are the best ways for the instructor to facilitate blended classrooms that include both face-to-face and online students?
3) Do students grasp the computer science knowledge points better after participating in mobile learning activities?

These questions warrant serious attention in the coming years.

Technological and instructional developments in the field of mobile learning are at a tipping point. Only careful observation, repeated testing, and systematic evaluation will ensure that the technology finds a place in the lifelong learning environment

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