Assessing the Effectiveness of Mobile Learning in Large Hybrid/Blended Classrooms

Minjuan Wang[1,2], Daniel Novak[2], and Ruimin Shen[2]

[1] Educational Technology, San Diego State University
[2] E-Learning Lab, Shanghai Jiao Tong University
mwang@mail.sdsu.edu, danielnovak@daniel-novak.com,
rmshen@sjtu.edu.cn

Abstract. This article will describes a method we created to evaluate the impact of mobile learning on a large hybrid/blended computer science classroom of 562 students (about 90% being online). The impact of the mLearning system and learning activities is evaluated through pre- and post-surveys and from four aspects: 1) if student enjoyed the learning experience, 2) how students feel about interacting with fellow learners, 3) how students felt about their relationship to their instructors in the mobile blended learning environment, and 4) mobile blended classroom's effects on students' study habits. Cluster analysis is used to measure the validity of the surveys we used in this evaluation study. The cluster analysis confirms the validity of the survey results and also corroborates the statistical evidence of mLearning's positive influence on learning outcomes.

Keywords: Case study, interactivity in blended classrooms, mobile learning system, active learning, engaged learning, persuasive technology, mobile learning evaluation.

1 Introduction

Chinese classrooms, whether on school grounds or online, have long suffered from a lack of interactivity. Many online classes simply provide recorded instructor lectures to which students listen after downloading. This format only reinforces the negative effects of passive non-participatory learning. At Shanghai Jiaotong University (SJTU), researchers and developers actively seek technologic interventions that can greatly increase interactivity in the blended classes of their Online College. They developed a mobile learning system that can deliver live broadcasts of real-time classroom teaching to students with mobile devices.

The College's core philosophy concerning distance education is "learning anytime, anywhere." All lectures and activities that go on in a campus classroom are digitized simultaneously and broadcasted online, similar to online video programs and vodcasts (video podcast). Students can tune into live broadcasts or view archived videos of lectures online. However, the live broadcast system does not yet provide fully interactive venues. Distance students cannot ask questions or participate in any class

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activities. The mLearning system recently implemented aims to promote active learning in large blended classrooms (more than 1000 students).

The use of mLearning in this college represents an attempt to encourage students' active participation in the learning process, and to engage them in constructivist learning through social and intellectual interactions. For the purposes of this paper, 'mLearning' refers to education and communication during class through mobile phones. Through adapting the current curriculum for interactive teaching and learning, researchers and developers in the E-Learning lab hope to set an example for pedagogic changes in China's system of higher education.

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 [1]. 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.

The experiments reported in our study attempt to discover how much Chinese learners (who likely own cell phones and palm-top 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.

1.1 Measuring Mobile Success

The penetration rates of internet-capable cell phones, personal digital assistants, and other handhelds and the data transmission rates of cellular networks increase with every passing quarter. As such, mobile learning (or, as some call it, mLearning) will play a greater role in classrooms in the coming decade. The question of how to measure the success and utility of this new technology will also appear, especially in today's results-oriented teaching culture.

Yet, how do we measure the quality and success of a program whose learners may never meet face to face? Anticipating this issue, John Traxler [2] identified nine qualities that any evaluation of a mLearning program must possess. Though these qualities do not provide proscriptive solutions to mLearning evaluation, they do offer some guidance. For example, Traxler asserts that evaluations must be consistent with the teaching and learning philosophy all the participants. He also notes that the evaluation must also be rigorous, efficient, appropriate to the specific learning technologies.. Another important factor is authenticity in terms of uncovering what learners really mean, really feel, really want from a learning environment.

However, Traxler [2] appears to mistrust system logs, participant observation, surveys, and questionnaire-based response, and ultimately mLearners as data sources on mLearning. In reference to those means of obtaining information, he notes:

"None of these elicitation techniques were particularly consistent with mobile learning technologies. And all accounts of such evaluations assumed that the evaluators were told the truth by subjects (that is, learners and teachers)…" (9).

In spite of this concern, researchers at SJTU decided to experiment with existing data about user experiences while participating in an mLearning project. The research

team generated the questions for the questionnaire from 'common sense' concerns about the user's experience and from surveys used in past distance and e- learning surveys. This resulted in a focus on the end users' happiness and comfort in the virtual learning environment created by the mLearning classroom. The statistical consistency of the responses (indicated by a Cronbach Reliability Alpha of .95) indicates that either all learners lie equally, or that they have responded with some reasonable degree of 'truth.' From a positivist standpoint, this data proves statistically consistent and valid, and therefore provides a glimpse into the users' learning experience.

Using cluster analysis, a valid and oblique observational technique, researchers from San Diego State University collaborate with SJTU's E-Learning Lab to turn this data into a series of evaluative dimensions that measure student reception of the mLearning intervention. This responds to Traxler's concern about the inability of current techniques to describe mLearning phenomena. Cluster analyses often reveal obscured patterns of response that may not appear in more direct modes of statistical analysis. These evaluative dimensions, statistically valid but generated by mLearning data, will prove useful as researchers, administrators, and teachers gauge the usefulness and quality of their forays into the world of mobile learning.

There is still a dearth of mLearning use in formal teaching and learning. Using mobile learning in large blended classrooms is even less. The researchers designed the surveys by following Traxler's principles about being consistent, rigorous, efficient, appropriate, and authentic. Also, the survey questions conform to some of the recognized methods in evaluating online or distance learning [3] (Simonson, 1997). The survey collected both quantitative ratings and qualitative feedback, and thus balanced the traditional quantitative method [4] and the more "modern" qualitative evaluation method [3].

The survey questions are organized around the core issues that arise when evaluating distance learning: a) measures of activity, b) measures of efficiency, c) measures of outcomes, and d) measures of organization. In addition, the researchers also measured a few important constructs that don't fall into the aforementioned categories, such as student satisfaction, level of interaction (student-student, student-instructor), and sustainability of student participation in mLearning activities. Ample literature supports the idea that satisfaction is an important factor that affects learner choice of distance programs, as well as the high dropout rates associated with distance learning. Researchers also studied interaction because the mLearning systems at SJTU were designed to increase interaction in large classrooms.

2 M-Learning System and Its Implementation

2.1 System Function and Architecture

In a hybrid classroom at SJTU that is equipped with the mLearning system, instructors carry out multimedia instruction via a specialized station that supports handwriting on the computer screen, SMS messaging, and guided Internet use. 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 sub-system, records all of these media components and relays them in customizable combinations to students.

During the class, the instructor station displays messages from campus and online students. It also reports their learning progress, their questions, and their feedback to the instruction. These messages are delivered as mobile phone text messages through a SMS (Short Message Service) protocol. To address these messages, the instructor can give oral explanations or reply through text-messages. In addition, this mobile learning system can also display the screen of any students' mobile device that are tuned into a live broadcast on a larger screen, allowing the instructor to supervise students' learning. The instructor can also take an instant poll on any aspect related to the instruction, including pace, clarity, content, and structure.

When the students connect their smart phones to the network, they can choose to view a live broadcast of the classroom. They can view it from 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). During the class, students can send short text messages to the instructor and participate in polls and other in-class activities. Thus, the instructors, students, and system administrators cooperate to create a blended classroom with real-time communications.

This model of mobile-supported hybrid learning can be used in many other classes. Students can use their mobile phones to send short text-messages to communicate with the instructor. The instructor can address these messages either by typing on the screen or giving an oral explanation that the entire class can see or hear.

2.2 Use of Mobile Learning in a Computer Science Class

This introductory computer science class teaches students a basic knowledge of computer science, Internet technologies, and the application of software in the business world. In this class, the instructor presented to both campus and online students at the same time. The computer system also archived videos of the course on the class's website for students to review at their convenience.

'Knowledge points,' or small, clearly defined units of knowledge or skills organize the class content. Knowledge points are an endemically Chinese mode of instructional design. While in some ways comparable to the American concept of instructional objectives, knowledge points do not necessarily require performance or demonstration of skills on the part of the learner. Rather, students listen to the knowledge points as delivered by the instructor, and are expected to remember them in detail at a later date.

In class, the instructor presented about the major knowledge points for that session. She then showed 10 multiple-choice questions on the computer screen. These questions allowed students to review the essential knowledge points that they should have learned from the instructor presentation. The instructor encouraged the students to answer these questions by sending text messages. She also presented real-world problems related to these knowledge points and encouraged students to discuss them through text messages.

3 Preliminary Survey

Researchers conducted a series of analyses to help determine how students respond to four major facets of the mobile learning system. 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. The survey's fifteen questions (translated into English from Chinese) appear in Table 1.

Table 1. Survey Questions (Translated from Chinese)

Question Number	Likert Scale (X-Y)	Question Text
1	1-4	Overall satisfaction with this class
2	1-5	The mLearning class was well organized
3	1-5	The course's activities were engaging
4	1-5	The activities strengthened my connections with my classmates.
5	1-5	The activities strengthened my connections with the instructor.
6	1-5	I had more opportunities to ask questions.
7	1-5	I had more opportunities to help my classmates.
8	1-5	I had more opportunities to practice what I learned.
9	1-5	Mobile learning helped me a great deal in studying the content of this class.
10	1-5	Mobile learning helped me grasp the course's main points.
11	1-5	Mobile learning changed my habit of studying alone
12	1-5	The modality of mLearn (words, audio, video) fits my learning style
13	1-5	I felt that my social skills have improved through the use of mobile learning.
14	1-5	I would like to recommend mobile learning to other students.
15	1-5	I would like to participate in future mLearn activities.

Researchers composed the survey to gather data relating to a number of practical questions. First, researchers wanted 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, researchers hoped to gain insight into how students felt about interactions with fellow learners via the mobile classroom. This sought to address the concern that students may feel isolated or disconnected from one another. Third, researchers asked a number of questions concerning how students felt about their relationship to their professors in the mobile learning environment. In the Chinese classroom, students sometimes feel distanced or separated from their professors.

The Researchers wanted to know if the mobile environment affects student-instructor interactions. Fourth, researchers asked questions about the mobile classroom's effects on students' study habits and their ability to learn from the online system.

The survey yielded 245 unique responses from mobile learning students in this hybrid computer science course. This sample constitutes an adequate number of responses to represent a given university's population, and presents a rich source of data to mine. This data presents an opportunity to create a high quality metric system that can help future students, researchers, administrators, and faculty determine if mobile learning meets their needs.

4 Methods

Researchers determined that, by excluding demographic data, they could use the above survey to create a high-quality metric that could be used to generate future surveys and evaluations of mobile learning. A cluster analysis was conducted (based on the Pearson Correlation) to identify patterns amongst the scores. These similarities confirm that the constructs incorporated into the survey emerge in the results, and can therefore be measured in future surveys. The analysis that follows identifies some (though not necessarily all) of the important features of the mobile learning experience, and establishes ways to test them consistently. Ideally, future researchers will use the constructs identified in this paper to design surveys and evaluations that target mobile learning courses. These tests can also help future researchers determine if mobile learning performs as desired. Further, it represents a step towards the creation of a targeted and specific evaluation system for mLearning courses.

4.1 Cluster Analysis

Typically, researchers use cluster analysis to look for trends within large, unstructured surveys. This is an ideal strategy if one is looking for patterns amongst potentially linked ideas. The survey discussed in this paper is a Frankenstein's monster assembled from several different survey methodologies of varying ages and from varying media The questions and constructs were valid in their original contexts, but one cannot assume that they are valid when assembled into a different framework and applied to a different medium (mLearning). Therefore, a central concern of this study is confirmation that students responded to the *a priori* constructs that the researchers chose at the outset.

After this confirmation, the researchers hoped to identify new constructs by examining the clusters for patterns or missing features. This involved taking a close look at the patterns of response, and looking for larger patterns within the Finally, researchers hoped to identify ill-defined clusters or over-tested clusters, and thus refine the survey for future use. Table 2, generated by the statistical analysis software SPSS, clusters the questions into as few as 4 groups and as many as 9 using the Pearson Correlation method.

Table 2. Cluster Membership, using the Pearson Correlation

Case	9 Clusters	8 Clusters	**7 Clusters**	6 Clusters	5 Clusters	4 Clusters
Overall Course Satisfaction	1	1	**1**	1	1	1
mLearn was organized successfully.	2	2	**2**	2	2	2
The activities were engaging	3	3	**3**	3	3	3
The activities strengthend my connections with classmates	4	4	**4**	3	3	3
The activities strengthend my connections with the instructor.	5	5	**5**	4	4	3
I had more opportunities to ask questions.	5	5	**5**	4	4	3
I had more opportunities to help my classmates.	4	4	**4**	3	3	3
I had more opportunities to practice what I learned.	6	6	**6**	5	5	4
mLearn helped me a great deal in studying the content of this class.	7	7	**6**	5	5	4
mLearn helped me grasp the knowledge points.	7	7	**6**	5	5	4
mLearn changed my habit of studying alone	7	7	**6**	5	5	4
The modality of mLearn (words, audio, video) fits my learning style	8	8	**7**	6	5	4
I felt that my socialzing ability has improved.	9	8	**7**	6	5	4
I would like to recommend mLearn to other students.	8	8	**7**	6	5	4
I (very much) would like to participate in future mLearn activities.	8	8	**7**	6	5	4

After analyzing Table 3, researchers opted to use the seven-cluster breakdown. The four, five, and six cluster analysis created too few groups, and clustered several unrelated questions. The eight and nine cluster analysis created too many groups, and

Table 3. Questions Arranged by Cluster

Cluster – Cluster Title	Question Text (Translated from Chinese)	Likert Scale
Cluster 1 – Overall Satisfaction	Overall satisfaction with this class	1-4
Cluster 2 – Course Organization	The mLearning class was well organized	1-5
Cluster 3 – Course Activities	The course's activities were engaging	1-5
Cluster 4 – Student Interaction	The activities strengthened my connections with my classmates.	1-5
	I had more opportunities to help my classmates.	1-5
Cluster 5 – Instructor Interaction	The activities strengthened my connections with the instructor.	1-5
	I had more opportunities to ask questions.	1-5
Cluster 6 – Relationship to Content	I had more opportunities to practice what I learned.	1-5
	Mobile learning helped me a great deal in studying the content of this class.	1-5
	Mobile learning helped me grasp the course's main points.	1-5
	Mobile learning changed my habit of studying alone	1-5
Cluster 7 – Sustainability	The modality of mLearn (words, audio, video) fits my learning style	1-5
	I felt that my social skills have improved through the use of mobile learning.	1-5
	I would like to recommend mobile learning to other students.	1-5
	I would like to participate in future mLearn activities.	1-5

excluded thematically related questions from certain clusters. The seven-cluster method grouped most of the known constructs together, while revealing new and unexpected patterns in the questions. Table 4 shows the arrangement of questions by cluster.

5 Results

The above table lists the new and differentiated constructs that appeared within the original survey. Researchers noted certain important differences from their original research plan. For example, the questions in Cluster 1 (Overall Satisfaction) and Cluster 7 (Sustainability) were written with the belief that these questions measured related phenomena. The results of the cluster analysis indicate that a student's

satisfaction and their willingness to participate in future mobile learning classes represent two different psychometric issues. Thus, survey researchers and school administrators must test for 'satisfaction' and 'sustainability' separately. Similarly, researchers wrote the survey believing that Clusters 2 (Course Organization) and 3 (Course Activities) represented the same construct. The cluster analysis shows that students consider these two survey questions representative of different phenomena.

Table 5, below, summarizes the evaluative dimensions and constructs that were revealed during this experiment, and their place in future research.

Table 4. Evaluative Dimensions and Explanations

Overall Satisfaction	A student's overall feeling of satisfaction after a course is as important in the mobile learning environment as in the classroom. If students do not feel satisfied, they will not continue taking mobile courses. Researchers and administrators should not ignore or discount the psychological importance of 'enjoyment' or 'satisfaction' in the classroom. These feelings enable learning.
Course Organization	Just as in a physical class, mobile learning students can lose focus if they feel that a course lacks direction. As such, surveys must ask whether students feel lost or confused by the course's direction. Both researchers and administrators stand to benefit from a close examination of students' feelings about course organization. Researchers can use this part of the survey to uncover substantive differences between the pedagogical organization of traditional and mobile classrooms. Administrators can use this portion to ensure that students are happy and are learning effectively.
Course Activities	The design of mLearning activities requires special attention to both the physical limitations of mobile devices (such as cellphones and personal digital assistants) and the psychological limitations and transactional distances of virtual communication. Designers and teachers must pay close attention to how their activities affect students. If one accepts that "the medium is the message," then one must design course activities that make full use of the affordances of the technology. As mobile learning courses develop, designers will need to work closely with administrators and researchers to ask specific questions about learner preferences.

Table 4. (*continued*)

Student Interaction	The virtual world created by the mobile learning environment may isolate older learners while simultaneously engaging younger learners. Younger students (often called 'digital natives') feel comfortable in the virtual realities created by instant messaging, cellular telephone, and online games, while older learners (called 'digital immigrants') feel more comfortable in face-to-face environments. These questions can reveal how mixed-generation students feel about the content. Further, demographic information that researchers collect with the survey can reveal whether particular age groups feel alienated by (or comfortable in) the mobile learning environment.
Instructor Interaction	mLearning also carries the risk of distancing students from their instructors. Hybrid learning solutions (such as those employed in mobile learning experiments [5] at University of California San Diego (UCSD) show a distinct increase in learner-instructor interaction. In a series of experiments, researchers at UCSD found that students asked more questions when they could submit their questions via forums and mobile devices. This holds true in the mobile incarnation of the traditionally staid Chinese classroom. However, pure mobile courses may create a psychological distance derived from the lack of periodic, non-virtual interaction. Researchers must carefully study how mobile students interact with their online professors to ensure that students remain engaged and interested.
Relationship to Content	mLearning presents a number of new opportunities for instructional designers to change the relationship between students and course content. Students can access learning materials at any time and from any location. This may well lead to changes in how students study. The above survey included a question that addressed a problem that is prevalent in Chinese classrooms: studying alone. Research (e.g., [6]) shows that periods of group study increase efficiency in a variety of ways, yet Chinese students find themselves spending hours alone pouring over required texts. Mobile learning can increase group interaction if instructional designers and teachers tailor course activities to respond to this problem.

Table 4. (*continued*)

Relationship to Content	Future researchers should determine more specific responses to the problems posed and opportunities created by mobile learning. Asking questions from this dimension can provide valuable data about how students use this technology to interact with course content.
Sustainability	In this context, the phrase 'sustainability' refers to the long-term effects of mobile learning technologies. These include long-term student happiness, willingness to use mLearning tools, and the integration of mLearning solutions into courses. This is especially important as instructional designers look for ways to reduce the high attrition rates associated with eLearning and distance education programs. Administrators and researchers have a vested interest in this dimension. If students are unwilling to use mobile learning in the long run, then public and private sector institutions will not include the technology in their training plans. Non-adoption will further stunt development, and the cycle will continue. Therefore, researchers must study how students feel about the long-term use of mobile learning in their courses.

6 Conclusion and Future Recommendations

The seven dimensions uncovered by cluster analysis may well prove an excellent starting point for the study of mLearning's effects on learners. Future researchers will undoubtedly uncover other dimensions as the technology matures and gains wider acceptance. At this point, however, researchers have identified certain limitations to this study.

Culture and Language: Researchers conducted the original survey at a large Chinese university. The specifics of cultural attitudes towards learning dictate that some variation 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.

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 these dimensions on smaller focus groups.

Population: At present, few mLearning courses are available to students. Even at large-scale testing grounds, such as SJTU's Online College (17,000 students), 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, physical environment, and educational goals. Researchers must work to isolate these variables if they wish to provide a more pure rubric for evaluating mobile learning.

Unaddressed Constructs: Though this study examined a variety of constructs and question styles, it is by no means complete. The context associated with the mLearning intervention may require more specific and tailored questions. Further, evolutions in the technological arena will also lead to the identification of unforeseen constructs in the future. The constructs identified here serve as a starting point for researchers who plan to design surveys for future studies, but by no means exclude other factors. This is an early link in the long chain of research and dialogue that will attend the evaluation of mobile learning programs.

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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