

A Study in Developing a Mobile Learning System based on Human-Computer Interaction Design Principles

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Abstract

As we know, the learning model of a single instructor interacting with many students that is applied in conventional classrooms forms a passive bottleneck. In this study, we use principles of human-computer interaction (HCI) to construct a usable mobile learning system (MLS) on a personal digital assistant (PDA). The design of the PDA's small-screen will be the critical factor in promoting the MLS performance. The MLS system prototype for a PDA will be very different from a PC or laptop and will effectively enhance learning interest and interactivity in the conventional classroom environment. The results of this experiment show that the mobile-based classroom learning experience provides appropriate mobile tools to help students to become capable, self-reliant, self-motivated and independent. The findings also demonstrate that variations among students' preference or content are associated with differences in the display presentation mode.

Keywords: Human-Computer Interaction (HCI), Mobile Learning System (MLS), Small-Screen Design

INTRODUCTION

The portable offspring of desktop computers are quickly becoming as common as their stationary predecessors. Mobile devices (Pocket PC, Tablet PC, Personal Digital Assistant (PDA), and Smart Phone etc.) will eventually become ubiquitous, and with the increasing use of small portable computers, this emerging communications infrastructure will enable many new internet applications.

While the new technologies open new horizons for personal development, it is with the advent of mobile learning (m-learning) that the true potential of e-learning to happen “anytime, anywhere” has finally started to be realized. The potential value of learning via mobile devices has been widely demonstrated (Leung & Chan, 2003; Naismith, Lonsdale, Vavoula, & Sharples, 2005; Sharples, 2000). Their use has been integrated into various disciplines within high schools, universities, and medical schools (Carlson, 2002).

As we know, the learning model of a single instructor interacting with many students that is applied in conventional classrooms forms a passive bottleneck. Moreover, the instructor cannot effectively record students’ individual learning histories for instantaneous and suitable feedback, the new emphasis in education is on supporting the student, in collaboration with his or her peers and instructor, both within and outside the classroom. When a student’s progress is stymied by the lack of direct contact with his or her instructor and peers, a PDA offers new forms of communication that break down the traditional barriers to education. PDAs have been a popular choice – more so than cell phones – for implementing m-learning in the last few years, likely due to their larger screen size and higher resolution. Both the display capabilities and the data capacity of a PDA are much smaller than those of a desktop. Thus, intelligent presentation of data is required to optimize the layout of the display and the structural presentation of information with minimal loss of information. This is a critical issue to consider for achieving effective communication among the participants.

This paper reported here is to design an adaptive MLS for use as a learning aid that takes into account users’ profiles and device capabilities, in such a way as to create an appropriate interface for content presentation on small display devices.

DEVELOPMENT OF MOBILE-LEARNING

Sharples (2000) identified m-learning, based on mobile devices, as the next generation of e-learning. The main focus of this section is the historical development of m-learning. Relevant issues, such as the features of instructional mobile devices and the m-based classroom, are also reviewed.

Instructional Mobile Devices

Deborah, Roschelle, Vahey, and Penuel (2003) pointed out that many teachers simply used handhelds as portable word processors or other productivity devices, such as calendaring programs. They appreciate the increased access to technology brought by the handhelds, especially for writing assignments. During 2001-2002, SRI International, in collaboration with Palm Inc., conducted a systematic large-scale evaluation of handheld technology for education. The Palm Education Pioneers (PEP) program distributed handhelds through a competitive grant program and examined how the 100 selected teachers used them in the classroom (Vahey and Crawford, 2002). These teachers reported greater student engagement, more effective collaboration, and increased student autonomy on lessons that integrated handheld computer use. They also said that handhelds permitted them to bring more and better use of technology to a wider range of students and circumstances.

The Mobile-Based Classroom

Simply put, the defining characteristic of m-learning is the ability to learn anytime and anywhere. In the context of this work, it is defined as the ability to use handheld devices (such as PDAs) to access learning information in the classroom. The unique characteristics of the mobile wireless classroom environment follow.

- 1) Efficient real-time learning
- 2) Content integration within learning
- 3) Expansion of knowledge acquisition
- 4) Interactive questioning and intelligent help offering

The emerging technology of mobile wireless devices offers a promising tool for helping instructors create a more interactive, student-centric classroom, especially when teaching large courses. To fully appreciate the potential of mobile technologies for assisted learning, we must look beyond the use of individual devices and consider their utility when embedded in classroom practices, or as part of a learning experience inside the classroom. This paper hopes to enhance the effectiveness of learning materials by utilizing mobile devices to increase the accessibility and flexibility of student learning environments.

USER INTERFACE DESIGN

To present information effectively on a PDA interface, the course designer must minimize the inherent limitations of that interface, the most obvious being the restricted size and resolution of the display. In this work, selection of the information and elements to present on the screen is discussed as a major component of the interface design process; we focus particularly on small screen devices. Central factors in designing for small screen devices are highlighted and exemplified. In this section we also describe some of the theories that have influenced m-based classroom interface design.

Mobile Human-Computer Interaction (M-HCI)

Although the PDA has great potential to support a mobile wireless classroom, several studies have shown that screen size does affect performance (Watters, C. J. Duffy, & K. Duffy, 2001). The small screen space can display relatively little data at a given time, resulting in difficulties in using the device for complex tasks. Moreover, research on mobile human-computer interaction (M-HCI) primarily concentrates on presenting information on a small display, with emphasis on user experience, reflection, and collaboration. The design of mobile devices and services cannot be merely technology-driven (as it often happens today), but needs to be prompted by human needs and should properly take into account human abilities, limitations, and preferences.

Mobile device designers face five main challenges (Dunlop and Brewster, 2002):

- 1) designing for mobility;
- 2) designing for a widespread population;
- 3) designing for limited input / output facilities;
- 4) designing for potentially incomplete and varying context information; and
- 5) designing for users to multitask in ways unfamiliar to most desktop users.

Mobile services will not be successful if we do not understand and design for the needs of the end-users, which are very different from those traditionally studied in HCI research. Users will not enthusiastically adopt mobile computing devices if we are not able to prevent the pains and complexities of interacting through very limited input and output facilities. Recent papers presented at HCI conferences and published in journals illustrate the growth of the field of interface

design. Examples of emerging research in this field include mobile interaction with enhanced physical objects (Kindberg et al., 2002; Rukzio, Schmidt & Hussmann, 2004; Rohs & Gfeller, 2004), environmental sensing for awareness of the context of the user (Hinckley, Pierce, Sinclair & Horvitz, 2000; Gellersen, Schmidt & Beigl 2002), mobile interaction with public and semi-public displays (Ferscha, Kathan & Vogl, 2002; Greenberg, Boyle & Laberge, 1999), mobile interaction in smart environments (Shahi, Callaghan & Gardner, 2005), mobile annotations (Smith et al., 2003), and using the mobile device as a universal remote control (Myers, 2002).

Information Display on a Small Screen

Wireless technology is rapidly being introduced throughout the world for education, business, and commerce. Wireless technology, however, like any other technology, is not in itself a panacea (Clark, 1994). Reflection on how it can be used to support and encourage the teaching / learning process through the enhancement of interaction, socialization and engagement is required (Bleed, 2001). The multitasking nature of student behavior requires m-learning interfaces designed to support users' limited attention span. As mobile technology improves, the available features of mobile devices will resemble those of desktop computers in every way except for screen size. The tiny screen sizes of mobile devices have been previously deemed "unsuitable for learning new content but effective for review and practice" (Thorton & Houser, 2002). Thus, the m-learning interface should be carefully designed to compensate for limited visual display. Jones et al. (1999) suggested that users did not want to use the conventional page-to-page navigation as it was interactively very costly on the small screen. Rather, a much more direct, systematic approach requiring less scrolling was seen as appropriate. As developers are learning to tailor content to the unique characteristics of wireless devices, quick and easy access is the main concern.

Guidelines for Small Screen Design

The present study specifically examines introduction of a PDA into an educational setting. Interface designers should think about how the interface should be organized to best present the information clearly, what information should be

presented, what guidelines exist for designing interfaces, how to design for usability and how the users perceive the information that is presented. As Tufte (1990) states: “Clutter and confusion are failures of design, not attributes of information.” Certainly the influence of human interaction on knowledge construction is so pervasive that a proper understanding of learning cannot be achieved without taking into account its social dimension. Since much of learning is done within a social context, it becomes important to understand how dialogue between an instructor and students, and among students, can be used to enhance student learning. To develop an effective m-learning interface, we need a reference framework that informs us on how user interfaces are shaped. Thus several design guidelines were identified to help ensure that the handheld applications for the student were designed appropriately.

1) Information Selection

The information communicated through the screen is of primary importance for performing tasks on handheld devices. With respect to information content, Nielsen (1993) states, “Less is more,” implying that user interfaces should be simplified as much as possible. The ideal case is to present exactly the information the user needs at exactly the time and place where it is needed. Another ideal goal presented by Nielsen (1993) is that information that will be used together should be displayed closely together, and preferably on the same screen.

2) Screen Layout

When text is used on the screen, it is important that it be legible. A MLS operates within a width of 240 pixels and a height of 320 pixels. Darroch, Goodman, Brewster, and Gray (2005) indicated that a font size between 10 and 11 is preferred for reading text on a PDA. Götz (1998) suggests that text on the screen should be at least 10 points, but at best between 11 and 14 points. The corresponding title type size should be between 14 and 20 points. Regarding the font type, Bernard, Chaparro, Mills, and Halcomb (2003) focused on the readability and legibility of varying 10- and 12-point sizes of both Times and Arial font types on computer monitors. Of note, screen designs are improving; some screens can now accommodate up to seven lines of text (Clyde, 2001). Furthermore, it is important that the letters on the screen are properly spaced. Interlinear spacing is an important element in making text easy to read, and

spacing allowances should be more generous for screens than for text on paper. The recommended line spacing by Götz (1998) is 150% or more.

3) Interface Element Design

Not only must the presented information be carefully selected, but attention should be given to every element that is to appear on the screen. Scrolling (both horizontal and vertical) should be avoided. Otherwise, the user will be occupied with keeping track of the changes on the screen rather than paying attention to the information they are trying to attain. However, Skogen (2004) stated that when unavoidable, deeper hierarchies are preferable to long scrolling pages, indexes can provide direct access to content in lieu of shortened hierarchies. General guidelines for interface design also concern the use of type and color. Color use should be limited to between 5 and 7 different colors since it becomes difficult to remember and distinguish the implications of each color when larger palettes are used. Moreover, owing to the percentage of people being colorblind, the interface should be able to be used without the color coding. Color should only be used to categorize, differentiate, and highlight, not to give information (especially quantitative information).

Generally speaking, good interface design of mobile devices ensures that they are effective in communicating information, are tolerant of error, need minimum physical effort, and are a convenient size. Furthermore, their designs should ensure that they can be used by people with diverse abilities, and are flexible and simple to use. Overall, much progress has been made in adding human factors to the interface design process.

MOBILE LEARNING SYSTEM AND OPERATION

A MLS can serve as a catalyst for creating a more interactive, student-centric classroom in the lecture hall, thereby allowing students to become more actively involved in constructing and using knowledge. By facilitating a shift from a passive, instructor-centric classroom, toward an interactive, student-centric classroom, a MLS helps to create a classroom environment that accommodates a wider variety of student learning styles, making the learning of science a much more positive experience for students. As Figure 1 shows, in an m-based classroom learning environment, the student using a handheld device facilitates fast and effective communication with the instructor, peers, and materials. Using

wireless devices eliminates the need for instructors to wait for access to a typically limited number of internet connected computers, and allows them to research web resources or send quizzes (or documents) to students at their convenience. Students can also post questions to the newsgroup without interrupting the flow of the lecture. The teaching assistant can answer questions immediately, or exercise the option of passing questions on to instructor. The teaching assistant monitoring the students' responses during class can signal the instructor when a particularly interesting or frequent question is raised. In turn, the concern can be immediately addressed. Within this environment the instructor can create tasks or questions in a variety of styles, present them to the audience by projection or by downloading questions and/or text to the PDA, and if desired, provide response-specific feedback to the students. Programming contained in the central unit permits the instructor to examine the collected responses, display the results to the audience, and store them for future analysis. The MLS includes facilities for incorporating active learning exercises into the lectures, providing the instructor with instant feedback on student comprehension in the form of quizzes and interactive polling.

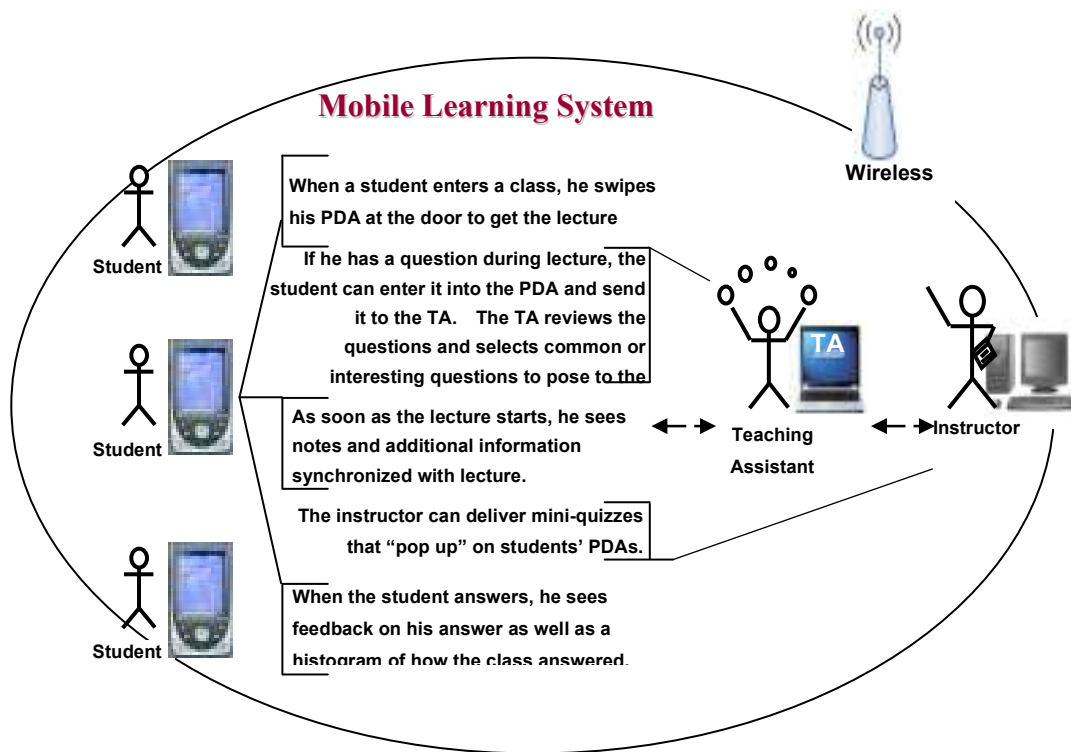


Figure 1 A constructive m-classroom activity for a MLS

DEVELOPMENT OF THE MLS

A MLS-supported interactive lecture offers the opportunity to create a truly active learning environment in a large group format that addresses some of the concerns listed above. In terms of faculty resources, there is an initial time commitment necessary to become comfortable with the system and to design an appropriate interface for student consideration.

Framework of MLS

The constructed MLS has three layers. The first layer is the front page. The second layer has four parts: course content, quizzes, instant message software and a Q&A interface. The third layer is the content of the above. The specific content used here was based on the course design and its objectives. Figure 2 shows the structure of the MLS. English course is as the example of MLS.

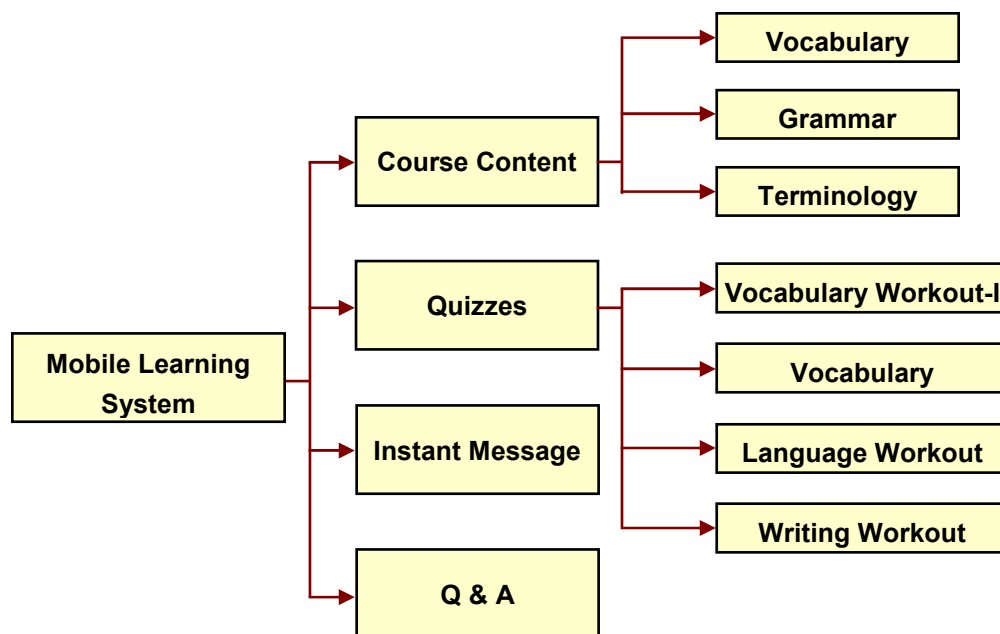


Figure 2 The structure of the MLS

Interface Development of MLS

The interface designs of the MLS are shown in Figure 3 and Figure 4. Figure 3 is the front page of the MLS. The users must input a username and password. It was important that the students log into the server so that we could collect attendance data. Figure 4 lists the function options for this MLS: course content,

take quizzes, instant message, and Q&A. A user can click to enter the selected function area.



Figure 3 The front page of the MLS



Figure 4 The function list in the MLS

As Figure 5 shows, we delivered short mini-lessons to students in discrete chunks so as to be easily readable on the tiny screens. Example content included vocabulary words and idioms, definitions, and example sentences via LMS (Learning Management System) in a spaced and scheduled pattern of delivery. In addition, some mini-quizzes were developed to encourage students to read and answer questions in the target language, while requesting feedback in the form of quizzes and follow-up questions. Students are tested immediately and individual responses are compared to those of others that received identical lessons via the MLS. Figure 6 illustrates the “take quizzes” function in the MLS. For learning evaluation, multiple choice tests on the key concepts of the workouts were administered before and after the lesson. Figure 7 shows three screenshots of the instant message function that illustrate the following options:

- 「Send Message」: send a message to somebody.
- 「Message Box」: review all of the messages received.

The use of mobile devices to gather feedback from students during a lesson via the Instant Message」 function demonstrates the integration of mobile devices into an existing teaching practice, not the replacement of it. The key benefits of the 「Instant Message」 function were timeliness and appropriateness, so that students could be directed as appropriate to either the teaching assistant or their peers. The MLS facilitates whole-class drill and feedback activities by allowing the

instructor to present content-specific questions and gather student responses rapidly. These questions can range from simple content reviews to probing questions at the heart of the subject matter. Student responses are invited by way of multiple choice options on the students' devices. This also aids the teacher in assessing the current level of understanding of the class as a whole.

Traditional education can be enhanced by integrating mobile communication and its related services to increase learning effectiveness. It is obvious that mobile technology is playing a key role in facilitating online learning communities; the dynamics of enhanced expression present an added convenience to traditional learning.

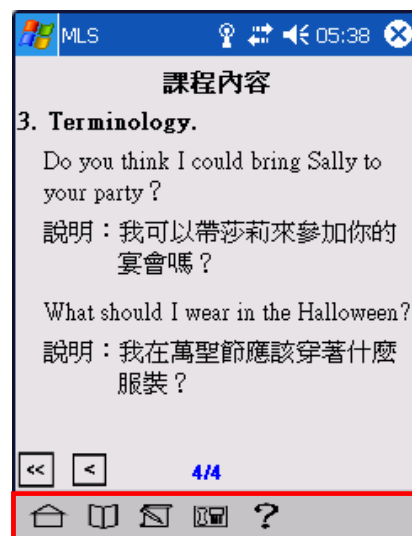
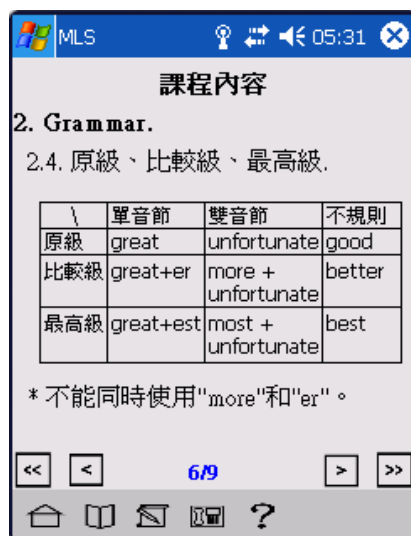
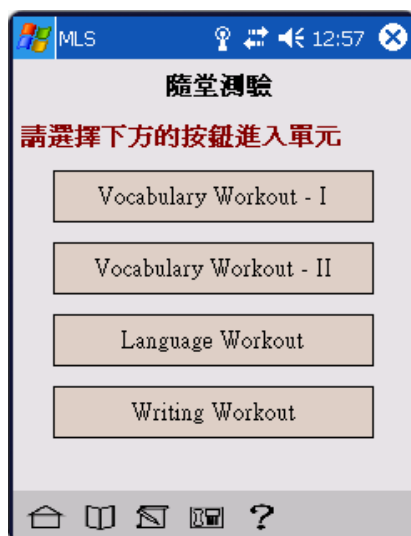


Figure 5 Example course content for the MLS



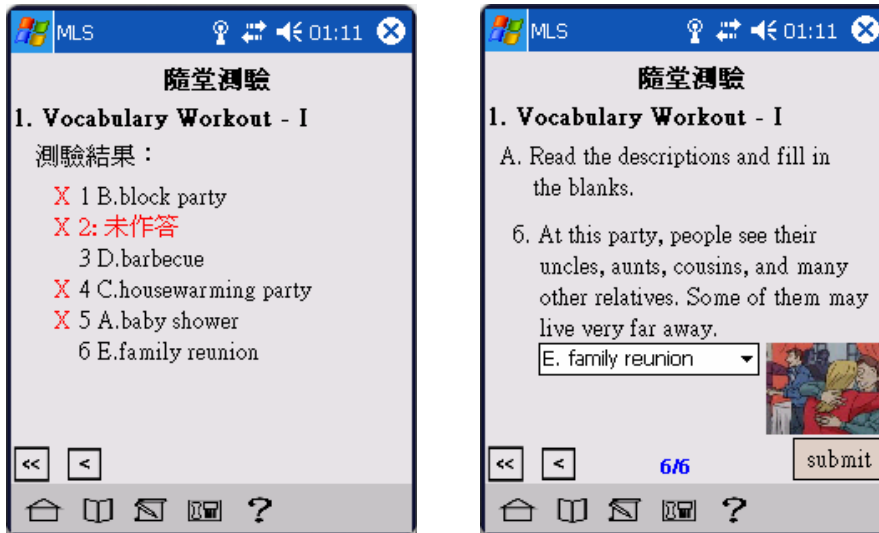


Figure 6 A series of screenshots generated by the “take quizzes” function for the MLS



Figure 7 A series of screenshots from the “instant message” function for the MLS

The development of this interface was based on principles of small screen design (Shneiderman and Plaisant, 2004; Jones et al., 1999; Clyde, 2001), as summarized below:

- Feedback: As shown in Figure 6 and Figure 7, the system should provide positive feedback, and should provide partial feedback as information becomes available.
- Mapping: As shown in Figure 4, metaphors are a possible way to achieve mapping between the computer system and a reference system known to the users in the real world. Icons should often be used to strengthen a metaphor.
- Reduced Short-term Memory Load: As shown in Figure 6, the list was used to suggest the true answer to the question. In this way, one can reduce the memory load to students.
- Short Text Length: All screens contained no more than 7 lines of text.
- Universal Usability: As shown in Figures 4 to 8, a ‘shortcut bar’ was loaded into the button of the displays. Users could jump directly to the desired location even in a large information space.
- Aggregate Data Hierarchies: As shown in Figure 4 to Figure 8, the second level function options presented an aggregate view of the content. Content navigation could be achieved by entering the system through this page.
- Reduced content presentation: Thumbnail sketches may replace full images as the default presentation mode. As shown in Figure 5 and Figure 6, a small illustration (72x56 pixels) was used to assist the students in the language learning.
- Text Format: As shown in Figure 4 to Figure 8, the recommendations for text sizes from previous studies have indicated that a Times font size 10-12 for young to middle-aged adults, and a line spacing of 150% or more is appropriate.

Portrait and Landscape Presentation Modes

Two versions of display orientation to present the information in the mobile learning system were used for the study, as illustrated in Figure 8. We prepared one version of each type of document for the MLS. The content of each type of document remained the same; only the page layout was changed. Each

portrait/landscape page content was composed of text, tables and pictures (e.g. plain text, plain table, plain image, text & table, text & image, text & table & image), in which the landscape mode was redesigned to present the maximum number of lines that would fit on the Palm Pilot without requiring scrolling. The landscape display window was 6 x 8 cm, with a maximum of about 45 characters per line (cpl) and 4~5 lines per page. For the vertical (portrait) orientation, the screen tolerance was 35 cpl and 6~7 lines per page. In this study, we compared user preferences for portrait and landscape modes for a set of tasks performed on the PDA. The preferences were measured via post-experiment questionnaire.

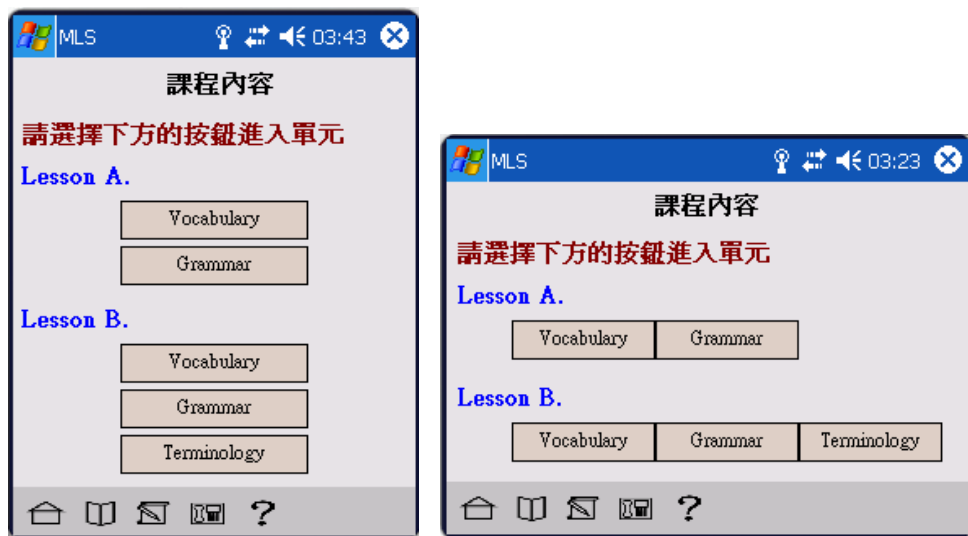


Figure 8 A sample screenshot for Portrait (a) and Landscape (b) display orientations

DESIGN OF EXPERIMENT

In this study a prototype application, written in Visual .NET 2003 and executable on a Pocket PC device (HP hx2400), was developed. The handheld ran the MLS developed for this study, which could communicate with the PC through any available wireless connection—802.11 or Bluetooth. With the HP hx2400 one can easily switch between portrait and landscape modes when choosing the custom resolution. On the PC side, a back-end server (in this instance, the Learning Management System) monitored the communication and interacts with the PDA applications. Our studies showed that the user could place the PDA beside a keyboard for use with the non-dominant hand for various activities. Figure 9 depicts the overall architecture of the m-based classroom.

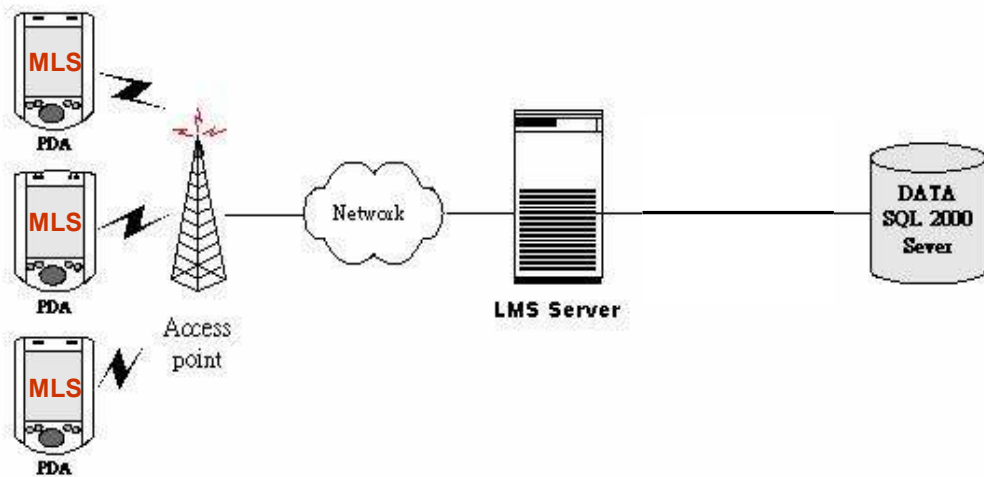


Figure 9 Screenshots of the system architecture

Experimental subjects

Twelve student participants from the Information Management department of National Kaohsiung First University of Science and Technology completed the experiment. Participants had no or very minimal experience with a PDA before the experiment. Each participant was exposed to two simulated scenarios realized in portrait and landscape display orientations. The students were asked to perform two tasks (task A: a workout in lesson A; task B: a workout in lesson B). The tasks were different in both systems. Six of the participants performed the tasks first on the vertical (portrait) version and then on the horizontal (landscape) version (as shown in table 1). The other six participants performed the tasks first on the landscape version and then on the vertical version. All the participants were given a short tutorial of about 8 minutes on both versions. After performing the tasks on both systems the participants were asked to fill out a subjective user satisfaction questionnaire. The questionnaire drew its responses from a post-course questionnaire given to 12 students in an undergraduate course. The questionnaire asked the participants to rate various experiences on a 1-5 scale (1 being poor and 5 being excellent).

Table 1 The experimental task condition for each participant

| Task \ Display | Portrait | Landscape |
|----------------|----------------------------------|---------------------------------|
| | Task A | S ₁ ~ S ₆ |
| Task B | S ₇ ~ S ₁₂ | S ₁ ~ S ₆ |

Research Questions and Hypotheses

A set of questions designed to measure language learning in an “always-online” environment formed a reliable, one-dimensional index for the information sampled from the questionnaires. These questions were tested with Cronbach’s Alpha.

Q1: Can we obtain a measure of language learning from an “always-online” environment that will have high internal consistency?

Q2: Can we devise measures of small interface design that will have high internal consistency?

An independent or contextual variable might influence students’ preference of the MLS portrait or landscape orientation. In our research, the teaching content and the MLS display present mode are considered independent variables. Do the content differences affect the preferences for presentation mode? We present our hypotheses as follows:

Hypothesis 1: The student’s preference in presented orientation will be affected by the nature of the content presented in that orientation.

Hypothesis 2: There is relationship between the content and display mode variables.

EXPERIMENTAL RESULTS AND DISCUSSION

Experimental results

In this study, the performance of all participants was evaluated on the basis of the following: the student experience in an “always-online” environment, assessment of the interface, and the student’s experience using portrait and landscape presentation modes.

As shown in Table 2, reliability analysis showed satisfactory results which had high internal consistency (section 1: Cronbach's α coefficient = 0.861, section 2: Cronbach's α coefficient = 0.845). A Cronbach’s Alpha greater than 0.85 typically indicates high internal consistency for a set of items. Therefore, these results support the following answer to research question 1: this test does provide a good measure of students’ aptitude in language learning in this “always-online” environment. Over eighty percent of the students felt that they found the PDA to be more useful than the study anticipated. Seventy-five percent of the students

thought the MLS improved their learning quality (mean=3.92). Compared to a typical learning environment, seventy-five percent of students thought the MLS made it easier to study the content of the course. Students were also asked about the small interface design for the MLS prototype. Table 2 (see Section 2) shows that over half of the assessable items were “good” by the assessment parameters provided. Therefore, Table 2 (see Section 2) reveals the answer to research question 2. The information from both sections was combined into a single index, which also has high internal consistency (Cronbach’s Alpha=0.845).

We wanted to see if the different interface preferences were equally represented among the students’ choices. First, we present a frequency table for each preference (Table 3). The "Observed N" indicates how many cases are in each group. The "Expected N" shows how many people we expected to find in each group, assuming there was no difference between the groups. Here we see that we expected to find 36 cases in each group. Next, the results of the Chi-Square test show that there is a significant difference ($p=.018^* < 0.05$, $\chi^2=5.556$) between the groups, indicating that the student preferences for each display option are not equal. This result shows that students highly prefer the landscape mode for presentation of the MLS content than the portrait mode.

Table 4.2 Summary of the Measurement Scales

Questionnaire Category: SA=Strongly Agree; A=Agree; N=No opinion; D=Disagree; SD=Strongly Disagree; S. D.=Standard Deviation

Section 1 The always-online environment

| Measure | SA | A | N | D | SD | Mean | S.D. |
|---|-----------|----------|----------|----------|-----------|-------------|-------------|
| It was easy to use the PDA in this mobile-based classroom learning course. | 16.7% | 75.0% | 8.3% | .0% | .0% | 4.08 | .52 |
| Motivate me to do best work. | 25.0% | 58.3% | 8.3% | 8.3% | 0% | 4.00 | .85 |
| Course learning objectives can be met by mobile learning | 8.3% | 66.7% | 25.0% | .0% | 0% | 3.83 | .58 |
| I would recommend the integration of the PDA into the classroom to others. | 33.3% | 25.0% | 33.3% | 8.3% | 0% | 3.83 | 1.03 |
| Overall, I have found my PDA to be more useful than I anticipated. | 33.3% | 50.0% | 16.7% | .0% | 0% | 4.17 | .72 |
| Evaluation and questioning in the mobile learning system (MLS) was effective. | 25.0% | 75.0% | .0% | .0% | 0% | 4.25 | .45 |
| Communication with the instructor / teacher assistant / peers by instant message functioned well. | 41.7% | 50.0% | 8.3% | .0% | 0% | 4.33 | .65 |

| | | | | | | | |
|---|-------|-------|-------|------|----|------|------|
| Do you think that the user interface of the prototype is easy to use? | 25.0% | 75.0% | .0% | .0% | 0% | 4.25 | .45 |
| Does the MLS prototype present to you here show enough evidence that it can be a good complement to the classroom learning? | 16.7% | 66.7% | 16.7% | .0% | 0% | 4.00 | .60 |
| Does the prototype show enough evident that it will bring more convenience to the user? | 33.3% | 58.3% | 8.3% | .0% | 0% | 4.25 | .62 |
| Learning quality is improved by MLS. | 16.7% | 58.3% | 25.0% | .0% | 0% | 3.92 | .669 |
| Compared to a typical learning, did the MLS make it easier to study the content of the case? | 16.7% | 58.3% | 16.7% | 8.3% | 0% | 3.83 | .835 |
| I found the lessons presented through the PDA to be more effective than previous lessons done by note-taking. | 41.7% | 41.7% | 16.7% | .0% | 0% | 4.25 | .754 |

Cronbach Alpha (α) = 0.861

Questionnaire Category: VG=Very Good; G=Good; A=Average; P=Poor; VP=Very Poor; S.D.=Standard Deviation

Section 2 Interface Assessment

| Measure | VG | G | A | P | VP | Mean | S.D. |
|--|-----------|----------|----------|----------|-----------|-------------|-------------|
| Font Size | 33.3% | 50.0% | 16.7% | .0% | .0% | 4.17 | .718 |
| Font Type | 41.7% | 25.0% | 25.0% | 8.3% | .0% | 4.00 | 1.044 |
| Font Color | 25.0% | 33.3% | 41.7% | .0% | .0% | 3.83 | .835 |
| BackColor | 16.7% | 50.0% | 25.0% | 8.3% | .0% | 3.75 | .866 |
| Interline Space | 16.7% | 75.0% | 8.3% | .0% | .0% | 4.08 | .515 |
| Characters Per Line (CPL) | 16.7% | 58.3% | 25.0% | .0% | .0% | 3.92 | .669 |
| Lines Per Page | 25.0% | 58.3% | 16.7% | .0% | .0% | 4.08 | .669 |
| Image Quality | 8.3% | 50.0% | 25.0% | 8.3% | 8.3% | 3.42 | 1.084 |
| Table (font size, column width, row height...) | 8.3% | 58.3% | 25.0% | 8.3% | .0% | 3.67 | .778 |

Cronbach Alpha (α) = 0.845

Table 3 Test results of hypothesis 1

Frequencies of preference (interface)

| | Observed N | Expected N | Residual |
|--|------------|------------|----------|
|--|------------|------------|----------|

| | | | |
|-----------|----|------|-------|
| Portrait | 26 | 36.0 | -10.0 |
| Landscape | 46 | 36.0 | 10.0 |
| Total | 72 | | |

Test Statistics

| | Interface(portrait/landscape) |
|-------------------------|-------------------------------|
| Chi-Square ^a | 5.556 |
| df | 1 |
| Asymp. Sig. | .018* |

We wanted to see if the difference in presented content is related to the students' preference for presentation mode. That is, is different content likely to influence students' preferences? A total of 12 people participated in our study, but there are six presentation content conditions. Thus, our number of cases (Valid N) is 72. Next examine the contingency table. Because more than 20% of the expected values of the participant responses may be rated less than 5, it is necessary to merge the cells and response categories. We search for the best way to merge adjacent intervals by minimizing the chi-square criterion applied locally to two adjacent intervals. Two intervals are merged if they are statistically similar.

Table 4 Test results of Hypothesis 2

Case Processing Summary

| | Cases | | | | | |
|----------------------------|-------|---------|---------|---------|-------|---------|
| | Valid | | Missing | | Total | |
| | N | Percent | N | Percent | N | Percent |
| Format_new * Interface_new | 72 | 100.0% | 0 | .0% | 72 | 100.0% |

Format_new * Interface Crosstabulation (**modify**)

| | | | Interface | | Total |
|------------|--------------------------|----------------|-----------|-----------|-------|
| | | | portrait | landscape | |
| Format_new | plain text & plain table | Count | 4 | 20 | 24 |
| | | Expected Count | 8.7 | 15.3 | 24.0 |
| | | % of Total | 5.6% | 27.8% | 33.3% |
| | plain image & | Count | 15 | 9 | 24 |

| | | | | | |
|----------------|---|----------------|--------|-------|-------|
| Total | text + table | Expected Count | 8.7 | 15.3 | 24.0 |
| | | % of Total | 20.8% | 12.5% | 33.3% |
| | text + image & text + table + image | Count | 7 | 17 | 24 |
| | | Expected Count | 8.7 | 15.3 | 24.0 |
| | % of Total | 9.7% | 23.6% | 33.3% | |
| | Count | 26 | 46 | 72 | |
| Expected Count | 26.0 | 46.0 | 72.0 | | |
| % of Total | 36.1% | 63.9% | 100.0% | | |

Chi-Square Tests

| | Value | df | Asymp. Sig. (2-sided) | Exact Sig. (2-sided) | Exact Sig. (1-sided) |
|---------------------------------|---------------------|----|--------------------------|-------------------------|-------------------------|
| Pearson Chi-Square | 11.679 ^a | 2 | .003 | .003 | |
| Likelihood Ratio | 11.827 | 2 | .003 | .003 | |
| Fisher's Exact Test | 11.310 | | | .003 | |
| Linear-by-Linear Association | .801 ^b | 1 | .371 | .456 | .228 |
| N of Valid Cases | 72 | | | | |

a. 0 cells (.0%) have an expected count less than 5. The minimum expected count is 8.67.

Symmetric Measures

| | | Value | Approx. Sig. | Exact Sig. |
|--------------------|----------------------------|-------|--------------|------------|
| Nominal by Nominal | Phi | .403 | .003 | .003 |
| | Cramer's V | .403 | .003 | .003 |
| | Contingency Coefficient | .374 | .003 | .003 |
| N of Valid Cases | | 72 | | |

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

As shown in the contingency table of Table 4 (**modify**), we can look to the margins, or the ends of each row or column, to find the total number for a given category. For example, a preference for the portrait orientation was expressed in 26 cases. The contingency table also gives the percent of the total responses for each cell. Finally, the results of our Chi Square Test of Independence yield a Pearson Chi-Square value of 11.679. We have 2 degree of freedom, our

significance is .003 (Cramer's V is \sim .403 and significant, $p = .003$), and there is a significant difference because our significance level is less than .05. Therefore, it is clear that the two variables are associated. The data support Hypothesis 2, that the difference in presented content is related to the students' preferences for the content presentation mode.

Based on the results of the users' preferences, the "plain text," "plain table," "text + image," and "text + table + image" content were found to be more appropriately presented in landscape mode, while a preference for portrait mode was expressed for "plain image" and "text + table" content.

Discussion

Portable devices are becoming increasingly important in general education, and it is recognized that "mobile devices can become efficient and effective teaching and learning tools" (Roibas & Sanchez, 2002). This does not mean, however, that the use of mobile devices is a panacea. Significant technological and administrative challenges are still encountered, and the more general question of how mobile technologies can help today's educators embrace a truly learner-centered approach to learning is still ill-defined. Mobile devices share a common problem: while attempting to give users access to powerful computing services and resources through small interfaces, they typically suffer from tiny visual displays, poor audio interaction facilities and limited input techniques. They also introduce new challenges, such as designing for intermittent and expensive network access, and designing for position awareness and context sensitivity. Our project was based on a m-based classroom learning experience, with the assumption that providing appropriate mobile tools would help students become capable, self-reliant, self-motivated and independent. The findings are as follows: (1) students found the MLS beneficial and useful; (2) many students think that the MLS should be continued in future classes; (3) students reported being highly motivated and impressed—particularly by the mini-quizzes and message delivery functions—but expressed difficulty in using pointers and virtual keyboards for data entry. Empirical user-based studies and ethnographical analysis of user needs have been strongly promoted research areas in the mobile HCI community. We believe that this research aids in highlighting the

developing maturity of the field and those topics within the development of mobile systems that need further attention from HCI researchers.

CONCLUSIONS

Contributions

Mobile technologies provide an opportunity for a fundamental shift in education away from the occasional use of a computer in a lab towards more embedded computer use in the classroom and extra-classroom environment. Education as a process relies on a great deal of coordination of learners and resources. The MLS in this study supported the following features:

- instant comparison of individual student responses to those of the group;
- collection and organization of data through the use of a Report Wizard;
- real-time viewing of student responses by demographic type for individual questions;
- automatic accumulation of assessment points, and grading of quizzes and tests - data could be reviewed via LMS reports or exported into campus systems;
- use of comparative links to present questions to students - student responses to a question posed early in the lesson could be compared side-by-side with the responses to the same question posed at the conclusion of the lesson;
- rewarding of quick-responding students.

Future studies

The following directions are therefore appropriate for future work:

- In the present study, one of the major purposes was to design an MLS that could be compared with the traditional classroom learning. Therefore, a future study can test the performance of different small interface designs to assess their effectiveness.
- Deeper analysis of user behavior should be carried out in order to study and improve the learning process.
- The potential effects of newer mobile devices, digital audio, and text-based materials on student participation and perceived learning should be examined.

- We believe that user interaction with the landscape mode-presented content from this study was not optimal. Further study is needed to investigate the design principles affecting content presentation in landscape mode.

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