

Exploring the Potential of Mobile Phones for Active Learning in the Classroom

David Lindquist, Tamara Denning, Michael Kelly, Roshni Malani,
William G. Griswold, Beth Simon

Computer Science and Engineering

University of California, San Diego

La Jolla, CA, USA 92093-0404

{dlindqui, tdenning, m1kelly, rmalani, wgg, esimon}@ucsd.edu

ABSTRACT

Research has shown that educational technology can broaden and enhance the use of active learning in large classrooms. An educational technology platform often relies on students to bring laptops or specialized wireless devices like clickers to interact through the system. Mobile phones are an attractive alternative, as most students already possess them, they have more capabilities than dedicated clickers, and yet are small enough to minimize interference with note taking on a classroom desk.

This paper presents the design and use of a mobile phone extension to Ubiquitous Presenter, which allows students to submit solutions to active learning exercises in the form of text or photo messages. In an exploratory study, students found that text messaging worked well for exercises with multiple choice or short answers. Entering symbols common to computer science was difficult. Many problems were more suitable to photo messaging of a handwritten answer, although image quality must be managed. The phone's small size left space for the use of a notebook. The students had concerns about the message charges that would accrue in use. In conclusion, we offer recommendations to instructors and system designers interested in leveraging mobile phones to increase communication in the classroom.

Categories and Subject Descriptors

K.3.1 [Computers and Education]: Computer Uses in Education

General Terms: Human Factors

Keywords

Educational technology, active learning, modality, cell phone, mobile phone

1. INTRODUCTION

As mobile phones have become ubiquitous on university campuses, it is natural to ask whether they can be used to improve education. Mobile phones seem to hold promise for enabling large-scale participatory learning “in the wild”: in most any classroom, with minimal student cost, without Herculean instructor effort to install and

maintain the technology. Especially promising are Short Messaging Service (SMS) and Multimedia Message Service (MMS), which can support text and photo messaging for in-class communication. They are robust, simple, affordable, and familiar to students.

Work with PDAs showed that in-class educational technologies can alter student communications in the large classroom, for example broadening discourse [6]. PDAs are now out of favor because their cost could not be justified by their limited functionality. Multiple-choice Personal Response System (PRS) clickers [4,5] are smaller and less expensive. The scaffolding of other activities around clicker use compensates for their limitations.

At the other end of the spectrum, researchers have been investigating the in-class affordances of pen-based interfaces, like those found on Tablet PCs [1,2,3,7]. Yet, Tablet PCs have just begun to penetrate the typical classroom. Many university students own traditional laptops, but we have found that few use them in class. Students tend to own larger, less expensive, “luggable” laptops. Power plugs are often sparse in the classroom, and on campus. Also, the typical classroom desktop does not support dual laptop and notebook use, and laptops are ill-suited to drawing graphics in real time.

Although it is tempting to draw comparisons between PDAs and phones, they are not comparable. The typical mobile phone is about half the width of a PDA, has a fourth the screen size, a 12-button alphanumeric phone keypad instead of a stylus, a camera, 25x battery life, and a 100x slower network that is nearly ubiquitous and subject to service charges. Most importantly, it makes phone calls, making it an indispensable device for the campus nomad.

In short, despite limitations in the computing, networking, and interface capabilities of mobile phones, they are the most promising technology today for supporting classroom active learning in the wild. But what can the text messaging interface support in terms of in-class active learning activities? Can it perform like PRS clickers? Computer Science notation is rich in symbols and graphics; what types of problems can mobile phones support? Is photo messaging an adequate substitute for Tablet PC ink interfaces, for example supporting the drawing of graphs and diagrams? Is the image quality adequate? What issues arise for students and instructors in mixed-modality classrooms (e.g., laptops, Tablets, and mobile phones)? Are there logistical downsides to the “low-tech” mobile phone option? What do system designers need to know if looking to support mobile phones for the classroom?

We find one previous study on the use of SMS in the classroom [8], and none on photo messaging. This study of one undergraduate and two graduate CS classes focused on asking questions via SMS. The results suggest heightened student motivation, an appreciation for anonymity, slow typing of text on the phone keypad, and concerns about cost. However, question-asking is distinct from solving active

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. To copy otherwise, to republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee.

SIGCSE '07, March 7–10, 2007, Covington, Kentucky, USA.

Copyright 2007 ACM 1-59593-361-1/07/0003...\$5.00.

learning exercises. The weaker frame of reference for asking a question may result in more typing. “I don’t understand” is ambiguous for a question, but not for an assigned exercise. Questions might also have very different content than answers. The study did not address how effectiveness is impacted by technical content, a key question for the present study. The one undergraduate class studied was Computers & Society, possibly diminishing the amount of CS technical content in questions.

Using an extension of the Ubiquitous Presenter (UP) system [3] (Section 2), we report on an exploratory single-lecture active-learning experience in which most participants used mobile phones for student submissions (Sections 3-5). The limited input interface for text messaging was fast and convenient for short answer and multiple choice problems, but cumbersome for other common types of computer science problems. Photo submissions were suitable for these problems. The phone fit well in the ecology of the classroom desk. Some students raised surprising concerns regarding cost, as well as a preference for using laptops or Tablets if they were available. We conclude with recommendations for instructors and designers.

2. SYSTEM USE AND DESIGN

2.1 Ubiquitous Presenter

UP is an extension of University of Washington’s Classroom Presenter (UWCP) [5] that is both web-enabled and supports both pen-based and typing-based student submissions [3]. Web support provides student access and control: Should the instructor so choose, nearly any computing device can view the instructor’s replayable inked slides, in any order, at any time, in the classroom or out. Student submissions permit students to author solutions to in-class exercises and submit them anonymously to the instructor. Both pen and keyboard inputs are available. (A student with a normal laptop can use the mouse to draw; a student with a keyboardless slate Tablet can use the virtual pop-up keyboard to type.) Additionally, a row of lettered buttons is provided in the browser interface to support multiple choice questions. The instructor can display student submissions and multiple-choice bar graphs for discussion, and students can peruse them on their own.

The UP system utilizes a web-server architecture. The server acts as a bridge and data repository for instructor-student interactions. Instructors lecture with UWCP itself. For use in UP, it is enhanced to communicate its slides and ink to the server using SOAP. Student submissions created by students are relayed from the server to the instructor in a similar manner. UP employs personal accounts, allowing students to enroll in their UP-hosted classes and customize some settings.

2.2 Mobile phone Submissions

A mobile phone submission (See Figure 1) is initiated by sending an SMS text or MMS picture message to an e-mail address for UP (See Figure 2). In our experience, all phones and carriers provide a mechanism for sending an SMS/MMS to an e-mail address, and the interfaces for these services are well developed due to their long availability in the marketplace. Leveraging these avoids complications such as developing a native application for each of the many phone/carrier platforms, or requiring students to purchase the additional data service required to use the web browser. A potential downside is that the SMS/MMS interface is not specifically designed for use with UP. To mitigate this, students are not required to name the exercise being solved; this is inferred as discussed below.

Our approach to processing a mobile phone submission is to massage it gradually into the form of a regular web submission via a proxy, thus avoiding changes to the core of UP. When e-mail is sent to the UP server, a procmail “recipe” automatically routes it to the mobile phone submission proxy, written in PHP. Creation of a submission is split into three tasks: parsing, routing, and rendering.

To parse the raw e-mail message into its basic components (i.e., sender e-mail and phone number, subject, and body), we use EZ components, an open source MIME parser for PHP. Next, if the body is a multi-part MIME attachment (e.g., text and photo), its content is extracted. Finally, the source address of the e-mail is normalized and the subject and body of the message combined.

A student submission is always destined for a particular classroom, lecture, and slide. For a phone submission, we assume that the submitting student can be enrolled (and physically present) in only one class for a given day and time. Additionally, we assume that the submission is for the slide being displayed at the time of its submission. Thus, the student’s identity (determined by using the sender’s phone number to retrieve their profile) and the time of submission (extracted from the e-mail header) are sufficient to unambiguously identify the appropriate classroom lecture slide.

Finally, the submission is rendered as a regular UP student submission for the identified slide as follows:

1. If the submission contains text that starts with a single letter, A-H or a-h, it is added to the multiple choice tally.
2. Any text of a submission is superimposed on a copy of the slide, just like a regular submission, except the text is centered, since no placement is specified (Figure 1). There is no rendering for a multiple-choice submission that has no explanation of the choice.
3. If a photo is present, for simplicity it is superimposed on a separate slide, with needed adjustments such as downsizing.

Write a loop in Java or C to print out all the odd numbers between 3 and 33 inclusive

```
For(i=3; i<34; ++i)
    If(i%2!=0) System.out.println(i)
```

Figure 1. A typical mobile phone submission (cropped).

3. METHODOLOGY

Our research questions directed us towards an *exploratory* study. In particular, we sought to discover issues of mobile phone use in a traditional classroom setting with desk-chairs, thus serving as a guide for future experimenters, designers, and instructors.

We conducted a one-hour “mock” lecture led by one of the authors. It largely comprised active learning exercises, submitted and displayed via UP for discussion among the students and instructor. The exercises were cast as formative assessments, thus giving students freedom on how to answer the questions, if at all.

Twelve upper-division undergraduates majoring in computer science participated in the class. Several were familiar with UP from recent classes. Ten students used mobile phones and two used Tablet PCs for purposes of comparison. A few of the phone users also had a laptop or Tablet PC on their desk. Two of these abandoned the phone after the first submission, one because of concerns about the per-message service charge.

The phone users were shown how to submit answers via SMS text messaging. In the last exercise, students were also spontaneously asked to resubmit their solution using an MMS photo submission. The Tablet users were asked to use UP's ink and text submission features. For the last exercise, where it was suggested that students take notes, blank notepaper was provided to all participants.

We adopted a problem set – with minor modifications relevant to our focus on mobile phones – from an earlier study on the difference between the modalities of typed text and Tablet PC inking [3]. The study found that the input modality could affect the approach to solving the problem and writing down the answer, as well as the amount of elaboration beyond the basic answer.

The session was videotaped: one camera captured the whole room, another roved capturing individual's positions and interactions with mobile phone interfaces. At the end, an open-ended group interview was conducted to help us understand the phenomena we had observed, as well as gather opinions and feedback. To derive our results, we reviewed and analyzed these tapes, our research notes taken during the lecture, the students' notes written on the provided notepaper, and the electronically submitted materials.

4. OBSERVATIONS BY PROBLEM TYPE

4.1 Set-up Logistics

Some preparation was required before starting the exercises. The classroom chosen for the experiment initially had weak phone reception. We opened the door and raised the metal blinds, dramatically improving the reception. One student still could not get reception. About a minute was required for a student to login to UP via a web browser and update their profile to include their phone number. Normally this would be completed outside class.

4.2 Selection problems

Instructors often ask questions that are expressly limited to a range of answers – perhaps to guide discussion or limit the time spent on an exercise. We posed two multiple-choice exercises, each with a request for an additional free-form explanation.

The students had little problem submitting a one-letter answer. One student entered “DDDD” rather than “D”, confusing our simple vote parser. Only one student on each of the problems submitted an explanation. This is in part explained by students often neglecting to answer the second part of a two-part question. However, with this low conformance, it must be that the convenience of just voting, combined with the awkwardness of text entry, encouraged the students to provide a minimal answer. One explanation was six words, the other four. The explanations were written out in full, except for one use of “n” for “and”. The four-word explanation neglected to say which choice it was explaining, although the descriptor “cheap” clearly referred to the low-tech bicycle on the slide.

The ink submissions were typical of the previous study [3]. Answers were indicated by drawing around the selected item. Most explained the answer, often with humorous pictographs and text.

4.3 Short-answer problems

Sometimes instructors ask questions where the expected answers consist of a short phrase or a list of words. There was one fill-in-the-blank exercise (what year are you?) and one listing exercise (what would be your three favorite and least favorite places to visit?). An explanation a multiple choice problem also fits in this category.

The short answer problems were easy for the phone users to answer. Capitalization was rarely used, saving effort through default phone behavior, with no apparent ambiguity. The year indications for the fill-in-the-blank question were widely varied (e.g., 4, 4th, fourth, senior). Most answers were one word, one was written as a sentence, and one was clever in the form of providing a range of values (“12345”). In the listing question, there was some abbreviation, some acronyms – “uk” for United Kingdom – but also some shortening – “aust” for Australia (or perhaps Austria). Students used a number of ways to indicate the two halves of the answer. Many led off with “most” and then later “least”. Many used spacing, adding extra horizontal or vertical spaces so that the text would form visual groups. Some used both of these. A couple added punctuation on top of that. Here is a typical solution:

```
Most amsterdam uk berlin      least africa  
djibutti cuba
```

Both the text and ink answers showed modest amounts of elaboration to the basic answer; the ink elaboration was predominantly handwritten text. As another example of non-conformance, one answer was simply “Europe”, not only being five items short, but failing to indicate which category the one item fell in.

4.4 Mathematical problems

Many computing problems are answered appropriately using abstract mathematical notations, such as logic or equations. One problem asked the students to take the complement of two numeric expressions, and provided a number line on which to express the answer, if desired. Most mobile phone submissions simply provided the complemented expression. One student enumerated the values of the number line, but not complemented (a wrong answer); enumerating the complement would have been a much longer answer. Only one mobile answer provided the complement to both expressions, whereas all the ink submissions answered both. Moreover, only 4 of the 8 students provided their answer within the time allotted; 2 additional submissions showed up on the slide for the subsequent problem. We observed that entering the symbols was quite slow.

4.5 Code writing problems

Enabling students to make connections between new concepts and their successful implementation in a programming language is important. We asked the students to write a loop to print all the odd numbers from 3 to 33 inclusive, written in either Java or C. Six of the 10 provided their answer in the time allotted, although one was incomplete. Most were one-line answers, avoiding entry of a special character (return) or because they could not quickly figure out how to enter it. The students employed little abbreviation, though. One student omitted “System” in the print command. In discussion with the students later, it was apparent that they were struggling with the entry of special code symbols, and not so much the plain-text words. For example, the solution shown in Figure 1 answer contains 16 symbols. Figure 2 shows such a submission in progress. Note the uncorrected capitalizations on For and If, as well. The Tablet submissions were similar in solution method, except one Tablet user decided to use the web-based text submission option, and entered exactly correct ANSI C for their answer, which is quite verbose. As observed in the previous modality study, some students enjoy elaborating code answers with complete syntax, good variable names, and documentation [3].



Figure 2. Entering solution for the coding problem.

4.6 Diagrammatic problems

Computer science heavily uses visual notations such as graphs, circuit drawings, and data structure layouts. After instructing the students on how to describe a tree as a linear encoding (to enable answering using SMS), we asked the students to insert a set of values into a Binary Search Tree. After gathering and discussing the submissions, without previously informing the students that UP supported photo submissions, we asked the students to submit, as a photo, any answer they'd written up on their notepaper.

This problem was the only one for which all phone answers were submitted within the allotted time, despite the problem's difficulty in both solution and symbol entry. The answers tended to be shorter, and perhaps by this time all the students were getting comfortable with SMS symbol entry. One submission asked about an ambiguity in the problem rather than solving it (quite appropriate for active learning exercises). Most answers omitted spaces between the one-letter symbols. All the ink submissions provided the answer in both list notation and the standard tree drawing. The instructor noted that the graphical solutions were much easier to check and discuss, since the answer could be explored by navigating through the drawn tree.

When asked to provide photo submissions, several students quickly complied, sending their submission in a matter of seconds. Some submissions contained just the final answer, but a couple showed their work. The resulting submissions, low in contrast, were difficult to read (see discussion in the next section).

5. ANALYSIS AND RESULTS

The above observations, in light of the server data and the collective post-lecture interview, lead to several insights.

5.1 Ease and Speed of Text Entry

Mobile phones are not optimized for entry of symbols, significantly complicating the entry of the symbols used in many types of computer science problems. Overall, text submissions were very brief. Students tended to not elaborate their answers, often desired in active learning settings; it was common to shorten an answer by solving only the first-half of a question. No SMS submission explained the solution, a contrast to the tablet submissions.

It was atypical for students to shorten answering time without sacrificing content. Students did not use T9 mode, in which the phone guesses the letter corresponding to each numerical key press in an attempt to make known words. The students noted that many com-

puting terms are not guessed by T9. Some T9 implementations do permit adding words to the dictionary, however. We were surprised at how little abbreviation was used. Abbreviating “System.out.println” with the common “Sop” eliminates 14 characters and 2 symbols. However, some students did chose to answer in C, which is more concise than Java. We hypothesize that students were sufficiently burdened by the cognitive load of text entry (as well as solving the problem and remembering the answer), that additional strategies were beyond their capacity.

For our exercises, the fastest sixth of students was more than twice as fast as the slowest sixth. For these intellectually simple problems, this suggests that some of the observed problems may be due to learning-curve effects. The fastest student answered several problems in well under a minute, a few in just over a minute, with only the coding problem running to three minutes. This student worked two-handed using both thumbs and fingers, whereas most students worked one-handed, using one finger.

Additionally, the symbol-entry interface varies across phones. Some employ a linear scrolling list showing a few symbols at a time, others a complete matrix with faster 2-D navigation (See Figure 2, right). Another early source of delay was in entering the UP server's e-mail address. The students were urged to store the e-mail address in the phone's address book, and complied.

5.2 Photo Submissions

Photo messaging is suited to the complex problems that complicate text entry. Students quickly took and submitted pictures, provided answers in typical forms, and showed their work.

The primary problem with photo submissions is readability. Several answers were written in light pencil. (The students might have written more darkly, if given advance notice.) Some photos were dark because the whiteness of the paper fooled the camera's exposure meter. Others, taken up close, were a bit out of focus. Camera resolution was not an issue. To see whether photo submissions could be automatically improved, we tried several image processing techniques on them. Automatic contrast adjustment worked well (See Figure 3), reliably whitening the background and darkening the writing, without creating flaws like overexposure. Various sharpeners were ineffective, although one designed for graphics was not available.

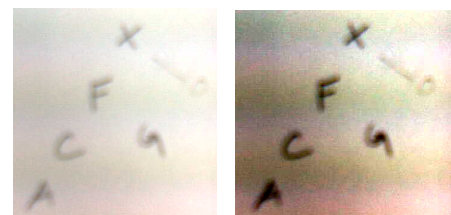


Figure 3. Photo sub before/after auto-contrast (cropped).

5.3 Management of Physical Space

Mobile phones fit naturally into the classroom. Students sat themselves casually, often leaning back while using their phones. Phones were often left on the desk, say on top of notes, and sometimes in the lap. Males often slipped the phone in a pants pocket when not in use. Women's clothes, though, are often tighter fitting (like our one woman participant's) or lack pockets.

5.4 Comparison to Laptops and Tablets

Students indicated a desire to use laptops or Tablets for reviewing students' submissions through the UP web interface, and for accessing resources like Wikipedia. Some noted jealously that the Tablet users worked more quickly, were able to show their work, and contribute more engaging answers (even after performing photo submissions). Yet, the convenience and ubiquity of phones was also noted. Only a few students said they regularly use laptops in class, despite that several bring them to class and most own them (cf. Section 1). Battery life for phones was recognized as key, given the lack of power outlets in typical classrooms. The bulkiness of their laptops was also cited.

5.5 Cost

Students were concerned about the cost of mobile phone submissions. One student switched to a Tablet after the first exercise due to cost concerns (reported to be \$0.25/message); another declined to make a photo submission. A survey on phone services revealed that many students have basic plans.

Students noted that the PRS clickers used in their physics classes cost \$26 new (as low as \$5 used), had no recurring costs, and were used about 5 times per class period. At UCSD, classes meet twice a week for 10 weeks, so the use of a mobile phone would be about \$10 on a \$0.10/message basis or \$15 for three months of 200 pre-purchased SMS messages. MMS costs more, typically \$0.25/message plus airtime charges. Verizon offers 500 SMS/MMS messages for \$10/month, plus airtime charges for MMS. Typically, an MMS can be sent in under a minute.

6. CONCLUSIONS

The low voluntary use of laptops in university classrooms stymies active learning activities in large classes. Mobile phones are a viable alternative. SMS is well-suited for multiple-choice and short-answer problems, a significant extension over clickers, affording open-ended questioning. Yet, the need for brevity hampers creative expression and requires the instructor to work harder in understanding and discussing SMS answers. Photo MMS, on the other hand, affords ease of expression approaching Tablet ink.

Student objections to the recurring service charges incurred by using mobile phones for active learning creates an interesting dynamic. Its practical implications will be best understood through further experimentation in the wild, our next step in this project. It may be that, as juniors and seniors, our participants are just above the "bubble" of the text messaging boom. Carriers, too, continue to restructure their service plans to provide attractive bundles with ample minutes and messages.

The costs for using mobile phones are slightly higher than clickers (and not covered by student aid), but still are negligible in comparison to other recurring costs like tuition or text books. Purchasing a relatively expensive portable laptop just to avoid recurring phone charges seems unlikely, but purchase of additional phone service is possible. However, given the additional benefits of laptops and Tablets (e.g., ability to search web resources, and a better and fully featured interface to UP) many students would apparently take the leap, at least bringing one they already owned to class. Still, if in-class exercises are entirely optional, students might decline to participate at all. One student reported not buying a clicker for his physics class, even though their use was a (small) graded portion of the course.

Recommendations for Instructors. Test your classroom in advance for acceptable service from common carriers. Attempt simple fixes, ask for a new room, or notify the carriers concerned.

Minimize symbol entry and protracted typing with answer scaffolding like multiple choice, fill-in-the-blank, or notational frameworks like a number line. Teach smart text entry by setting up peer discussion forums and setting aside discussion time.

Be cognizant of cost. Motivate why in-class exercises are valuable. Research and suggest add-on carrier services, or buy a free call-in number [8] instead of using an e-mail address. Minimize the need for photo messaging by scaffolding questions.

Recommendations for System Designers. Minimize cognitive load. As example, a student should not have to specify the exercise being solved or be concerned with case-sensitive input.

However, creating special text codes to ease input is dangerous. We allowed either letters or numbers in multiple-choice submissions. However, in our mock classroom we found a numerical submission that was clearly not a multiple-choice answer.

Finally, carrier gateways produce e-mails in a variety of multi-part formats, and change over time. The use of a MIME library and frequent testing is crucial to adaptability and robustness.

7. ACKNOWLEDGMENTS

This work supported by a Calit2 summer undergraduate internship, a gift from Microsoft Research and an equipment donation from Hewlett-Packard. We thank our subjects for their time.

8. REFERENCES

- [1] R. Anderson, R. Anderson, B. Simon, S. Wolfman, T. VanDeGrift, and K. Yasuhara. Experiences with a Tablet PC Based Lecture Presentation System in Computer Science Courses. *SIGCSE 2004*.
- [2] D. Berque, T. Bonebright, and M. Whitesell. Using Pen-based Computers Across the Computer Science Curriculum. *SIGCSE 2004*.
- [3] T. Denning, W. G. Griswold, B. Simon, and M. Wilkerson. Multimodal Communication in the Classroom: What does it mean for us? *SIGCSE 2006*.
- [4] D. Duncan. *Clickers in the Classroom*. Pearson Education, 2005.
- [5] R. Dufresne, W. Gerace, W. Leonard, J. Mestre, and L. Wenk. Classtalk: A Classroom Communication System for Active Learning. *Journal of Computing in Higher Education*, v.7, pp. 3-47, 1996.
- [6] W. G. Griswold, P. Shanahan, S. W. Brown, R. Boyer, M. Ratto, R. B. Shapiro, and T. M. Truong, "ActiveCampus - Experiments in Community-Oriented Ubiquitous Computing", *IEEE Computer*, Oct. 2004.
- [7] M. Kam, J. Wang, A. Iles, E. Tse, J. Chiu, D. Glaser, O. Tarshish, and J. Canny. Livenotes: A System for Cooperative and Augmented Note-Taking in Lectures. *SIGCHI'05: Human Factors in Computing Systems*, 2005.
- [8] C. Markett, I. A. Sánchez, S. Weber, and B. Tangney. Using short message service to encourage interactivity in the classroom. *Computers and Education*, 46:3, Apr. 2006, 280-293.