TEACHING AND LEARNING WITH MOBILE COMPUTING DEVICES: CLOSING THE GAP

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Abstract

This presentation will report on an ongoing study of the use of mobile computing devices by elementary and middle school students in northeast Ohio. The study employs mixed methodologies to explore students' use of mobile computing devices and its effects on their motivation to learn, engagement in learning activities, and support for learning processes, with a special focus on mainstreamed special needs students. Preliminary data was collected from students in four elementary and two 7th grade science classes in Northeast Ohio. It included usage logs, student work samples, student and teacher interviews, and classroom observations. Findings highlight the personalization of learning afforded by such devices both in terms of individuals and individual classroom cultures, as well as their usefulness in extending learning beyond the classroom, and suggest that increased motivation due to mobile device use leads to increases in the quality and quantity of student work. Findings also indicate that the use of mobile computing devices may help lesson the gap in academic achievement between special needs and regular students.

Keywords: mobile computing, special needs, elementary, middle school

1. Backround

Mobile computers are becoming an increasingly compelling choice of technology for K-12 classrooms because they enable a transition from the occasional, supplemental use of classroom computers and school computer labs to the frequent, integral use of portable computational devices (Soloway et al., 2001; Tinker & Krajcik, 2001). Early evaluations indicate that teachers and students respond favorably to handheld devices, and suggest handheld computers have the potential to impact student learning positively across curricular topics and instructional activities. Teachers, for example, have indicated that students are more motivated, spend more time using technology, collaborate and communicate more, and benefit from having a portable and readily accessible tool (Vahey & Crawford, 2002). Students, in turn, have found handhelds easy to use, fun, and a useful tool for learning (van t' Hooft, et al., 2004).

Perhaps more importantly, some researchers argue that classrooms with handheld computers differ fundamentally from more traditional desktop computing environments in that users interacting with handheld computers can also interact with each other and other computing devices at the same time (Cole & Stanton, 2003; Danesh, Inkpen, Lau, Shu, & Booth, 2001; Mandryk, Inkpen, Bilezkjian, Klemmer, & Landay, 2001; Roth, 2002). Handheld computers thus have the potential to support both personalized and collaborative learning. Roschelle and Pea (2002), for example, highlight three ways handheld devices have been used to increase learning collaboratively – classroom response systems, participatory simulations, and collaborative data gathering – and suggest there are many more such uses (Danesh, et al., 2001; Mandryk, et al., 2001; Roschelle, 2003).

Such fundamental differences may particularly affect students with special needs. For many students with disabilities in inclusive settings, it is quite challenging to remain attentive, stay on task and manage multiple tasks without the use of specific instructional techniques and learning strategies designed to address their specific academic and behavioral needs. The use of handheld technology represents an instructional tool that has the potential to assist these students with managing challenging behaviors and staying actively engaged in their academic settings.

Finally, because of their small size, handheld computing devices no longer constrain users like desktop computers or even laptops do. As such, handheld computers support learning outside the classroom, twenty-four hours a day, seven days a week.. They thus have the potential to support lifelong-learning anywhere, anytime (Tinker, 1997; Bannasch, 1999; Staudt & Hsi, 1999; Inkpen, 2001; Soloway, et al., 2001; Sharples, 2002)..

Research on the effects of mobile computers on teaching and learning, however, is still relatively scarce. This preliminary study was designed to explore the use of mobile computing devices and its effects on student learning. The following questions were addressed:

- How do students use mobile computing devices?
- Does the use of mobile computing devices affect students' motivation to learn and engagement in learning, especially among students with special needs?
- Does students' use of mobile computing devices support learning processes?

2. Methodology

2.1 Subjects and Settings

Data were collected from subjects at two sites during the 2003/2004 school year. The first site was a technology-rich, laboratory classroom at a state university in northeast Ohio where local teachers (who are nominated by their administrators and subjected to a selection process) bring their classes to complete regular units of study in a ubiquitous computing environment.. Classes spend ½ day every day for six weeks in the classroom, with access to to a wide variety of hardware and software to support teaching and learning. Classes and subjects involved at the first site included one sixth-grade class (n = 28), two fourth-grade classes (n = 41), and one third-grade class (n = 16). The sixth grade class's work centered on a biography project; one of the fourth grade classes studied plants and the environment; the other fourth grade and third grade classes, both from the same district, worked on identical projects organized around a study of flight. All students were given mobile computing devices to use and take home for the six-week period their classes spent in the laboratory classroom.

The second site was a suburban middle school in northeast Ohio whose student population of approximately 380 is primarily Caucasian (~ 98%). At the time of the study, about 20% of students qualified for free or reduced lunch. Students (n = 50) in two of five seventh-grade science classes, all taught by the same teacher, were given mobile computing devices to use in science and to take with them for a little over half the school year. Classes given mobile computing devices had a high proportion of mainstreamed special needs students (20%).

2.2 Data Sources and Analyses

Data collected from all six classes included lesson plans, usage data, work samples, student and teacher interviews, and classroom observations, some of which were videotaped.

To answer the first research question, usage data was collected from all students for whom it was available. Usage data for each student was categorized and aggregated by application. Because time periods for which usage data was collected varied among students, the aggregated data was then divided by total time of use to yield average use per week for each student. Averages were compared by classes and gender within classes to provide a detailed quantitative portrait of how students used their mobile computing devices both in and outside of class. Usage data were triangulated with responses from student interviews conducted in all classes during the final weeks of their classroom experiences. Although the question and interview formats varied somewhat according to age and ability level and between instructional contexts, all interviews focused on how students used their devices and likes/dislikes related to the equipment. Interviews were recorded on paper or audiotape for qualitative analysis, using constant comparison to detect emergent themes (Glaser, 1978). Videotaped observations made twice a week of classes in the laboratory classroom were analyzed for evidence of mobile computing use.

To answer the second question, student and teacher interview data related to motivation to learn were also analyzed using the constant comparison method. Student and teacher data were analyzed separately at first, and the results were compared to identify commonalities and differences in response patterns. In addition, single-subject research methodology was used to address the effects of mobile computing devices use on the behavior of students with special needs. Four special needs students from each of the two science classes using mobile computing were identified for participation in the study. Each of the four students were observed for entire class periods during five class sessions prior to mobile computing use and four class sessions during which mobile devices were used. The Behavioral Observation of Students in Schools (B.O.S.S.) was used to quantitatively capture the behavior actually taking place in the classroom through the systematic observation. Since student engaged time is oftentimes a critical variable when students experience difficulty in academic settings, behavior is categorized as active engaged time, passive engaged time, off-task motor, off-task verbal, and off-task passive.

Data for the third research question consisted of student work samples collected via PAAM™ from GoKnow®. PAAM™ transfers all student work to an off-site server whenever individual mobile computing devices are backed up locally. Work was obtained from four students selected in each class as high, medium, and low achieving, and, in all but one fourth grade class, for selected special needs students. Work samples were analyzed for conceptual understanding, based on a framework developed by Newmann (Newmann & Wehlage, 1995; Newmann, Bryk & Nagaoka, 2001), which focuses on evidence of students' use of analytic skills, their depth of conceptual understanding, and their ability to communicate that understanding. The framework provides rubrics for assessing student work, assigning numeric scores for each of three criteria (1 = lowest, 4 = highest, with total scores

ranging from 3 to 12). Scores were computed for all selected student work samples, and averaged and compared within and across classes by ability groupings. Student artifact scores were triangulated with teacher and student interview data, in order to determine whether mobile device usage can enhance student learning processes. Teacher and student data were analyzed separately and then compared to each other as well as the student artifact scores.

3. Results

Results from this preliminary study of the uses and effects of mobile computing devices are outlined in the sections which follow. They are organized by the research questions.

3.1 How do students use mobile computing devices?

All teachers in the study introduced their students to mobile computing, required the use of them for some explicit assignments (Table 2), and encouraged students to use them as needed both inside and outside of class. All teachers required their students to use them for note-taking, and teachers in the laboratory classroom also gave journaling and other writing assignments. Interestingly, only the seventh grade science teacher, the teacher with the oldest students, required her students to use drawing programs.

Table 1: Mobile Computing Assignments by Class

Grade	Mobile Computing Usage
7	note-taking, T-charts, Venn diagrams, drawings
6	note-taking, journaling, first draft of autobiography
4	note-taking, journaling
4/3*	note-taking, journaling, worksheet

*classes worked on same unit

Nonetheless, usage data (Tables 2-4) reveals that all students involved in the study used drawing programs and that youngest students used them the most. Students in all classes also made considerable use of personal information management (PIM) applications such as the Date Book, Address Book, and To Do List, as well as the calculator, although such usage was considerably lower and is not shown in Tables 2-4.

Table 2: Word Processing Usage by Class

Grade	Avg. Min/Week	Range in Min./Week
7	40:24	0:01:16 to 1:17:00
6	1:57:12	0:13:24 to 8:07:48
4	1:29:12	0:03:12 to 3:10:36
4*	3:34:42	2:09:18 to 7:29:36
3*	2:46:24	0:50:18 to 4:48:48

*classes worked on same unit

Table 3: PIM Applications Usage by Class

Grade	Avg. Min/Week	Range in Min./Week
7	7:12	0:0:00 to 0:28:48
6	2:30	0:0:00 to 0:17:00
4	3:48	0:0:00 to 3:10:42
4*	7:48	0:0:18 to 0:29:42
3*	1:42	0:0:00 to 0:06:36

*classes worked on same unit

Table 4: Drawing Program Usage by Class

Grade	Avg. Min/Week	Range in Min./Week
7	6:18	0:00:00 to 0:28:48
6	5:48	0:00:00 to 0:23:18
4	1:12	0:00:00 to 0:15:12
4*	17:42	0:02:06 to 1:58:24
3*	1:07:48	0:31:24 to 2:44:54

*classes worked on same unit

Indeed, the most striking characteristic of the usage data is its variability, both between classes and between individuals, which suggests the ways in which mobile computing appropriated by individual students and student cultures to personalize learning. Notice the significant differences between the two fourth grades and between fourth and third grade students given the exact same assignments. In the sixth grade class, for example, one student used word processing for 6 hours a week while another used it less than 15 minutes. A female student in this class spent 2 hours a week with word processing and another hour using the draw programs, while many students never used the draw programs. Two girls played with the PicChat functions; a few students used the calculator quite a bit while some students never used it; one student spent a good bit of time with Earth and Sun although most students barely looked at this application. The results suggest that at least some students in this study appropriated mobile computing devices for personal use (Roschelle & Pea, 2002).

The usage data findings are supported by the student interviews. More than 75% of the students interviewed reported using their mobile devices outside of their classrooms. Portability seemed a particularly important factor in their use. For example, when asked to compare mobile computing devices to desktop computers, one student told us *"It's kind of like the same thing but it's smaller and easier to do. The computer you can't take with you wherever you go but the* [mobile computing device] *you can just close it up and take it wherever you go."* Students in the middle school classes reported using their mobile computing devices mostly for note-taking, while elementary students reported using them for a variety of writing activities, noting that they preferred using the devices to writing by hand. Many students also reported that they found them to be most useful for various types of organizational activities and that they enjoyed using drawing programs and games.

Teachers also reported that students used the mobile computing devices in their classroom, at home, and on the bus to and from the laboratory classroom for writing assignments, journaling, note-taking, drawing, concept maps, spelling lists, test review, and to do lists. Some also commented that the beaming feature was particularly effective for facilitating the peer editing process. Several teachers noted that when mobile computing homework was assigned, all students completed it on time. One suggested that this was as much because using the mobile computing device helped students organize their work as it was a result of increased motivation. Indeed, one seventh grader stated that when using his device " *I don't lose homework like with papers.*" This possibility deserves further exploration.

Table 5 compares mobile computing usage across classes by gender. These data show a tendency for girls to use mobile computing devices more than boys. As by far the most frequent use of the devices was for word processing, it may be that this occurred because girls tend to write more than boys, but the result clearly deserves further investigation. The gender data also highlight the variability between classroom cultures.. Note, for example, the usage among sixth grade boys.

Table 5: Usage by Gender

Grade	Male	Female	All
7	49:30	87:28	61:48
6	2:39:06	2:03:36	2:12:03
4	1:15:24	1:53:48	1:38:24
4*	3:58:18	5:30:54	4:44:24
3*	3:33:12	4:53:36	4:17:36

*classes worked on same unit

To summarize, our preliminary findings indicate that the use of mobile computing devices extends learning outside the confines of the classroom and suggest unique cultures of use evolved within classes and groups within classes, indicating higher levels of personal appropriation. In addition, the findings indicate that mobile computing devices were used most frequently for writing activities, potentially due to the fact that the device used had a built-in keyboard. These findings clearly invite further investigation and can inform future research.

3.2 Does the use of mobile computing devices affect students' motivation to learn and engagement in learning?

Most teachers interviewed agreed that their students' motivation to learn and engagement in learning activities was improved by their use of mobile computing. For example, the sixth grade teacher reported that "*Taking the* [mobile devices] *home resulted in everyone's homework always being done, and shortened the time frame for getting work done. Having them also improved the writing of all students."* One of the fourth grade teachers noted that mobile computing devices would be highly engaging in a regular classroom, and commented,

"the one benefit I've noticed is that they do write more with the [mobile devices]. *And I believe that as much as it occurs with reading, the more you write, the better a writer you become."*

Interviews with students confirm these findings. Students said that they preferred using the mobile devices over writing by hand and that using them for writing assignments made the work *"easier*" and "*more fun*". One student noted, for example, that, *"my writing is poor and the* [mobile device] *makes it easier to read my writing."* Students also noted that using mobile computing devices helped them keep their work organized. One student commented, "*I don't lose homework like with papers."* Several students commented that they liked being able to share their writing with their friends using the device's beaming capabilities. Although more than a few students noted difficulties and frustrations with the devices, the majority believed the benefits outweighed these difficulties. Students interviewed particularly liked the fact that they could take their devices everywhere. That mobile computing thus enables working on school assignments or exploring personal interests whenever and wherever students are inclined to do so seems to be a critical factor in supporting motivation and engagement in learning. It certainly deserves further study.

Videotaped observations of students in the laboratory classroom also provide confirmatory evidence of student engagement in learning when working with mobile computing. Of particular note is their high engagement when using them for recording data from a variety of experiments. Perhaps this is because, as one student noted, the use of mobile computing makes such activities seem more like what "*real scientists do*." It may also be that the ability to easily carry the devices anywhere and their capacity to collect and store a variety of information and directly input it into desktop computer applications alleviates much of the drudgery of working with data. The finding clearly deserves further investigation

In addition, B.O.S.S. data from observations of selected special needs science students indicate that they students were significantly more engaged in classes in which mobile computing devices were employed. The data indicate that for all of the students the percentage of off-task behaviors were markedly reduced when the mobile devices were used, with off-task behaviors occurring less than 5% of the time observed. Interestingly, the findings indicate that students displayed more actively engaged behaviors during the classes in which they were instructed to use their mobile devices, regardless of whether they were actually using them during the entire class period. In other words, if the devices were just on the student's desk with a possibility of use, the students were more actively engaged with class lecture and activities. This phenomenon should surely be investigated further

In summary, findings show that the use of mobile computing devices can increase student motivation and engagement in learning, especially their motivation to complete written assignments. Findings also indicate that special needs students' engagement in learning may be particularly affected by the use of mobile computing. Continuing research to further explore these findings is indicated.

3.3 Does students' use of mobile computing devices support learning processes?

Teacher interviews indicate that mobile computing has the potential to enhance learning processes, especially with respect to writing. One teacher commented that the use of mobile devices resulted in noticeable improvements in both peer editing and the quality of student writing. She stated,

> *"The biggest change has been in their weekly journals. We have been journaling all year and they have always written them but in using the* [mobile devices]*, peer editing takes on so much more meaning when they can beam to someone rather than trading papers. With the* [mobile computing] *they are editing their own writing more and it keeps getting better."*

Teachers also reported improvements in spelling and mechanics as a result of more time spent on writing and editing. Perhaps most importantly, many teachers also noted improvements in the written work of special needs students. One teacher stated, "*Having the* [mobile devices] *improved the writing of all students but special education students in particular.*" Another noted that "*the special education students were empowered to write*."

Table 6: Comparison of Conceptual Understanding Levels as Evidenced in the Work of Selected Students

	Avg. rating for laboratory school students	Avg. rating for 7th grade science students
High ability	10.0	7.2
Medium ability	9.4	5.5
Low Ability	8.5	4.0
Special Needs	9.3	4.7

Indeed, many teachers commented on ways the use of the mobile devices seemed to lessen the gap in academic achievement between regular and special needs students. This observation is supported by work samples obtained from targeted students analyzed for evidence of conceptual understanding. Results of these analyses averaged across classes are given in Table 6 (ratings rage from 3 to 12 possible points). The results indicate that special needs students in the laboratory classroom tended to perform on a level similar to medium ability students, while the 7th grade special needs students fell somewhere between low and medium ability peers. (Analysis of lessons indicates that the overall lower ratings for the seventh grade science students may reflect assignments that did not elicit higher order thinking). The results provide evidence for positive impacts of mobile computing on the learning of special needs students.

Interviews with students support these findings. For example, fifteen of the eighteen 7th grade science students interviewed stated that they believed their use of mobile computing helped them in their school work. These students particularly noted their usefulness for taking notes, test review, and doing calculations, and that keeping their work on the devices helped them stay more organized. One student mentioned that she got "*two letter grades higher in science.*" As previously noted, students in the laboratory classes reported that they preferred using mobile computers over writing things by hand and that using mobile computing for writing assignments made the work "easier" and "more fun". The majority of students in these classes also stated that they thought their written work in particular improved as a result of their use of the devices.. Indeed, all students interviewed seemed to view mobile computing devices as a tool that could help them with their school work. This aspect of their use surely deserves further investigation.

In summary, findings from this preliminary study provide some indication that the use of mobile computing devices can enhance student learning processes, especially when it comes to writing, an activity for which the devices used in this study are particularly designed. Interviews with teachers suggest that the use of mobile computing resulted in greater productivity and improved writing skills among their students. Findings also suggest that mobile computing devices may provide increased support for schoolwork and levels of conceptual understanding, but only when assignments elicit it. Perhaps more importantly, the results suggest a lessening of the gap in conceptual understanding levels between regular and special needs students using mobile computing devices. These findings surely deserve further investigation and should inform future research.

4. Conclusions

This preliminary investigation of the use of mobile computing devices shows that elementary and middle school students use them in a variety of ways, principal among these writing, in and outside of class. The findings suggest both the personalization of learning supported by such devices and their usefulness in both supporting collaboration and extending learning beyond the classroom. They also suggest that students easily adapt the use of mobile computing devices to their own needs and hint at the influence of classroom cultures on this appropriation. The findings also indicate that use of mobile computing devices may increase student motivation to learn and increase their engagement in learning activities, which in turn, leads to an increase in time spent on learning activities and higher quality work. This result seems to particularly apply to special needs students and suggests an important way mobile computing might be employed to help close the achievement gap between these students and their peers. It clearly deserves further investigation.

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