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Personal Digital Assistants (PDAs) in Mathematics Teacher Education

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Rapid increases in knowledge and technology call for the use of such tools as a personal digital assistant (PDA) to increase the quality of education and student performance. PDAs evolved from personal organizers, but today's handhelds can be effective tools that help students organize facts and concepts, develop written documents, understand science and math concepts, and provide tools that help to empower students with special needs. This article gives an overview of the current use of handheld computers or PDAs in teacher education. Specifically, this article explores the potential of these tools in mathematics teacher education within the framework of mathematics education reform. This article shows that with appropriate software, the PDA can support a variety of effective learning activities that support the goals of reform in mathematics. Further, the authors show that preservice teachers who participated in the sessions with PDAs developed positive attitudes towards their use.

Current trends in mathematics education reform require students to be proficient in technology. In the mathematics curricula recommended by the National Council of Teachers of Mathematics (NCTM, 2000), increased attention is now given to mathematical reasoning and problem solving and the use of computational devices in mathematical analysis. With the appropriate and responsible use of technology, students can learn more mathematics more deeply (NCTM). The NCTM recommends that teachers of mathematics be provided with appropriate professional development in the use of instructional technology and the development of mathematics lessons that take advantage of technology-rich environments. The *National Educational Technology Standards for Teachers* (International Society for Technology in Education [ISTE], 2004) also call for schools and colleges of education coursework to consistently model exemplary pedagogy that integrates the use of technology for learning content.

Handheld Computers (Personal Digital Assistants)

One technology tool that is gaining importance in education is the PDA or handheld computer. A PDA is a small handheld computer with applications such as word processing, spreadsheets, personal organizers, and calculators. Other instructional programs allow students to use the handheld as a graphing calculator, test prep tool, and a reference resource. Additional devices such as science probes, digital cameras, digital audio recorders, keyboards, and other modules are expanding the usefulness of these devices. Teachers and administrators can also use handhelds for record keeping, scheduling, and other administrative and teaching applications. PDAs can also allow educators and students to access the internet by modem, infrared, or serial port connections, or by wireless access. There are web services that make it possible to download web sites. Most PDAs come with a collapsible portable keyboard that opens up to about the size of a laptop computer's keyboard. Additionally, the PDA comes with a cradle that attaches to a desktop computer. This way a user can "sync" or *synchronize* data between the computer and the PDA. PDAs are portable, mobile, and versatile in use and at a price of approximately $150- $250 are much less expensive than laptop computers.

REVIEW OF THE LITERATURE

Handheld computers have not been around very long. They represent one of the latest developments in the evolution of computing technology (Williams, 2004). The PDA was designed to help people manage their schedules. The typical features provided by the PDA were an electronic calendar, which allowed the user to manage their appointment book; an electronic phonebook, which allowed the user to manage the phone numbers and addresses of friends and business associates; a calculator; an electronic note pad, which would allow the user to write text; and an electronic To-Do list (Curtis, Williams, Norris, O'Leary, & Soloway, 2003).

Although they evolved from the PDA, today's handheld computers are capable of so much more. Like desktop computers, handheld computers have a screen, allow users to enter and process data, and display the results of processing. Handheld computers are making their way into the realm of education. Handheld computers represent one of many tools that are available for use in teaching and learning. Handheld computers evolved from personal organizers, but today's handhelds can be effective tools that help students organize facts and concepts, develop written documents, understand science and math concepts, and provide tools that help empower students with special needs.

Emerging handheld computer technologies have the potential for "ubiquitous computing" for computer supported collaborative learning (Rochelle & Pea, 2002; van 't Hooft, Diaz, & Swan, 2004), teaching inquiry-based science and assessment (Gado, Ferguson, & van 't Hooft, 2006; Penuel, Tatar & Rochelle, 2004), writing activities and higher level thinking if used appropriately (van 't Hooft, Diaz, & Swan, 2004). The term ubiquitous computing refers to technologies that weave themselves into the fabric of everyday life until they are indistinguishable from it (Weiser, 1991, p. 94). Van 't Hooft and Swan (2004) emphasized the need for systematic research in ubiquitous computing to analyze the impact of everyday classroom integration of less visible and more-human centered learning tools.

Norris and Soloway (2004) advocate "a handheld-centric classroom, where each child not only has his/her own personal, handheld computer, but also has access to networked PCs, probeware, digital cameras, etc." (p.281). Handheld computers, due to their size and portability may increase immediate accessibility and manipulation of data in and out of the classroom. Teacher access to affordable technologies with less total cost of ownership with handheld computers can be a realistic alternative to one-to-one computing to meet the challenges of technology integration and student achievement (van 't Hooft, Diaz, & Swan, 2004; Norris & Soloway, 2004). Rochelle and Pea (2002) highlighted three ways handheld devices have been used to increase learning collaboratively as a classroom response system, participatory simulations, and collaborative data gathering. Teachers reported student collaboration and productivity increased due to the beaming capabilities and mobility of handhelds (van 't Hooft, Diaz, & Swan).

Using handheld computers, students may initiate and explore "a more authentic and deeper immersion in technology, not as a separate curriculum, but as an integrated part of [the] curriculum" (van 't Hooft, Diaz, & Swan, 2004, p. 308). Authentic learning and deep learning can be enabled through inquiry-based projects where students collect and analyze data that are connected to their real-life experiences. This tool can motivate students, allow them to collaborate and communicate in different ways, and help them represent their knowledge in different ways (Rochelle & Pea, 2002; van 't Hooft, Diaz, & Swan). According to Soloway (2000), this sharing and commenting on other's work leads to an increase in the quality of finished products, such as lesson plans and artifacts. Soloway (p. 1) also argued that PDAs "support cycles of doing and reflecting" by encouraging teachers to effectively revisit their written work and the accomplishments of their students' tasks at the end of each day.

Today's handhelds are small computers. Although they are not capable of performing all of the functions of a desktop computer, their computing power makes them valuable tools for learning and teaching. As a sample of the capabilities, with handheld computers students and/or teachers can: take notes; track assignments; develop and take quizzes; develop concept maps; access the Web; collaborate with colleagues; utilize graphing calculator functions; create and edit word processed documents; create and edit spreadsheets; capture images (photos); and read electronic books (Williams, 2004).

Teachers can use handheld computers and probeware to build experiences for their students. Probeware described the use of probes and sensors connected to computers (whether handheld or desktop) to collect and display real-time measurements of environmental parameters such as temperature, light, motion, force, sound, and electrical power (Tinker & Krajcik, 2001). Handheld computers and probeware allow students to collect and analyze data that is focused and detailed immediately following their observations (Tinker, Staudt, & Walton, 2002).

In science education, Thornton (1997) demonstrated that high school students' intuitive ideas about motion, velocity, acceleration, and force become more accurate when using probeware than using any other instructional strategy, including lectures, problems, or traditional lab. Integration of handheld technologies in science education can help learners experience abstract concepts in a meaningful manner through manipulating and exploring concrete forms of learning in an inquiry-oriented lesson (Rochelle & Pea, 2002). Fisher (1999) reported high levels of motivation among teachers who considered the palms to be flexible and adaptable. Handhelds are useful in a wide variety of pedagogical and technological applications in a teacher education setting (Franklin, Sexton, Lu, & Ma, 2007).

PURPOSE OF STUDY

While there are existing reports about the use of PDAs to support authentic and deep learning and how this can be enabled through inquiry-based projects, research is lacking about how PDAs can support mathematics teacher education. The project for this article explored the potential of PDAs in mathematics teacher education by bringing technology to the forefront of the mathematics methods course in the context of inquiry-based mathematics teaching and learning. It is recommended that features of technology be introduced and illustrated in the context of meaningful content-based activities rather than on generic teacher learning and development (Garofalo, Drier, Harper, Timmerman, & Shockey, 2000). Teachers who learn to use technology while exploring relevant mathematics topics are more likely to see its potential benefits and use it in their subsequent teaching (Garofalo et al., 2000).

A number of studies have been conducted in content areas such as science and in K-12 settings but there are relatively few studies in preservice mathematics teacher education and the use of PDAs. This project thus focused on introducing teachers to this new technology and to establishing some baseline information about the potential of these devices in mathematics teacher education and is illustrated by several activities that were developed for the Catalyst Ohio Statewide Technology Summit—a showcase for technology innovation in education.

METHOD

The participants in the project for this article were 20 preservice middle school teachers, of average mathematics ability, enrolled in a large midwestern university's mathematics teacher preparation course. The project involved training of middle school teachers on inquiry-based mathematics content integrating PDAs. The content of the training was based on the NCTM (2000) standards and NETS standards (ISTE, 2007). The tasks incorporated the use of PDAs in modeling the teaching of middle school mathematics content that integrated several mathematics concepts including data analysis, ratios and proportions, geometry, and measurement. The tasks which took four one-hour class sessions involved using technology to model the four-step data analysis process, namely, *posing the question*, *collecting data*, *representing and analyzing the data,* and *making inferences* from the data. The data collected was organized in tabular form, graphed, and analyzed using SHEETS-TO-GO software—the PDA version of Microsoft EXCEL software. At the end of the two class sessions incorporating PDAs into mathematics, a brief survey was given to students to assess their perceptions of this new technology.

Theoretical Framework

This article uses a socio-constructivist framework to analyze the potential of PDAs in mathematics teacher education. Although there are many versions of constructivism, they all seem to share one basic tenet: that knowledge is not passively received by learners from their teachers, but rather, it is constructed actively by learners through their own experiences (Cobb, 1994). From a socio-constructivist perspective, a technology-based learning environment can be created where students construct their mathematical knowledge through interactive inquiry-based activities with a technology tool such as the PDA. Such a learning environment can also provide students with opportunities for social interaction where they share and discuss ideas with their peers as well as their teachers thus supporting communication and collaboration as advocated by the NCTM. The social context constructed in the course of their interaction helps to enhance the students' thinking and learning in the classroom.

The framework involves four key components that are fundamental processes of mathematical thinking. These are exploring (problem solving), conjecturing, generalizing, and communication. Since the mathematics education reform movement advocates these processes, it is considered to be important for developing technology-based mathematics lessons. The exploring process can promote students inquiry and investigation of the task while the conjecturing and generalizing processes provide a means for students to construct their own mathematical knowledge. The generalizing process is crucial, especially in the development of formulas, because it involves students' construction of mathematical knowledge as they articulate what they have obtained from a specific case, to a general situation. The communication process helps build meaning and permanence for ideas.

The framework is best illustrated by an example. Therefore, following is a description of the mathematical activities that represents the previously mentioned framework.

Activity I: Scavenger hunt—Familiarization

The introductory activity was designed to help the teachers explore and familiarize themselves with the PDA's basic functions and operating system while at the same time exploring mathematics in their everyday environment. The students were asked to use the camera function to document mathematics in their immediate environment and share these, using the beam capability, with their group members. Using the PDA's collapsible portable keyboard, students wrote descriptions of the pictures they took in the scavenger hunt activity.

The students then used the built-in infrared communications capability to beam their completed assignments to the instructors PDA. This "learning how to use PDA" session was important for participants as it addressed the technical aspects of the tool such as using the stylus, writing with Graffiti, taking pictures with the built-in camera, creating memos and using the keyboard while at the same time helping the students develop relevant mathematical concepts.

Activity II: Determining the formula for the circumference of a circle

The poor performance of students in geometry and measurement may be attributed to the fact that the teaching of measurement concepts in the middle school such as perimeter, area and volume focus exclusively on formulas to be memorized and applied in routine problems with little attention focused on the development of meaning for the formulas (Martin & Stutchens, 2000). Many middle school teachers have little experience in teaching these topics in any way other than the one that focuses on rote memorization and application of formulas. This activity used an inquiry-based approach to help teachers focus on helping students develop an understanding of formulas that is not limited to memorizing and applying standard formulas.

This activity was designed to help students determine the relationships among the diameter; circumference, and pi ($\prod$) of circular objects and to understand that the ratio of the circumference of a circle to its diameter is an approximation of $\prod$. The two questions posed to the teachers were;

1.What is the relationship between the circumference and the diameter?
2.What is the relationship between the ratio of the dimensions of the actual and image of the object?

The goal was to develop the formula for circumference as the product of *pi* (∏) and the diameter, or mathematically C= ∏ D, by doing the following: Students identified several 3-dimensional (3-D) circular objects and for each, measured the circumference and diameter. Using SHEETS-TO-GO software, the data was organized using a table and then graphed on the PDA. The ratio of circumference to the diameter was then computed for each object and the results placed in another column (Table 1). The table was then examined for patterns and the graph for trends. The slope of the graph was determined. Table 1 shows the circumference and diameter of circular objects.

Table 1
Circumference and Diameter of Circular Objects

Item	Diameter (D)	Circumference (C)	Ratio of C/D
Oatmeal Jar	4.00	12.57	3.142
Bowl	4.20	13.25	3.154
Bucket	8.06	25.25	3.135

Activity III: Determining scale factor

To connect with ratio and proportion concepts, pictures of the same circular objects from Activity II were taken using the PDA's camera function. To facilitate ease of measuring the image, students printed these and took measurements of the circumference and diameters of the images on paper. Next, they formed ratios between the actual and pictorial measures of the diameter and circumference of the circular objects. Then they determined how many times more the measure of the actual object was compared to its image and stated the scale factor. A discussion followed on the usage of scale factors in real-life. This extended to a lesson on proportional thinking.

RESULTS

From the table, students were able to see that the ratio of circumference to the diameter was a constant, approximately equal to 3.14, better known as $\prod$. Further, they were able to determine that the graph of circumference versus diameter on their PDA had a constant slope, also 3.14, which was interpreted as $\prod$. Based on these results they were able to determine the relationship among circumference, $\prod$, and the diameter, and develop the well known formula $C= \prod D$.

From the perceptions survey, it was found that 80% of the preservice teachers (12/15) agreed that the PDA is a valuable educational technology tool. Ninety-three percent (93%; 14/15) of the preservice teachers believed that if given the opportunity, they would like to learn more on how to use handheld computers for instructional activities. Fifty-three percent (53%; 8/15) of the preservice teachers found that working with the PDA was enjoyable and stimulating. This was confirmed further from the instructor's field notes where students noted a lot of enthusiasm about the PDA, expressed by such comments as "this is the best thing I have learned since I came to this school", and "why did we not have more of these kinds of classes."

Several students noted that sufficient time should have been allocated for learning to use this particular technology beyond the two-hour sessions, especially since the learning curve for the software was rather steep. About 90% (13/15) indicated that given more time, they were confident that they would learn handheld skills. The camera function of the PDA was especially a hit and really made math come alive with the scavenger hunt.

DISCUSSION

The following observations were made regarding the potential of PDAs in mathematics teacher education.

Supporting problem/inquiry-based learning. Inquiry-based learning is a student-centered, active learning approach focusing on, exploring and investigating, conjecturing, generalizing, questioning, and problem solving. PDAs have the potential for inquiry-based learning in mathematics especially when used to collect and analyze data immediately following their observations. In this study, the PDA allowed students to encounter mathematical ideas in more realistic settings. Students were able to easily and efficiently represent their data in graphical or tabular form and draw inferences from them. This is in line with NCTM's technology principle that advocates for the need to use technology to enhance students' learning opportunities "by selecting or creating mathematical tasks that take advantage of what technology can do efficiently and well—graphing, visualizing, and computing" (NCTM, 2000, p. 25).

Communication and collaboration. With a shift from teacher-centered to student-centered classroom environments, PDAs can play an important role in enhancing the teaching and learning process. One advantage of PDAs is their portability and size, which makes them useful as field journals and can promote writing in mathematics. Writing in mathematics can help students consolidate their thinking because it requires them to reflect on their work and clarify their thoughts about the ideas" (NCTM, 2000, p. 61). Writing can provide students the opportunities to construct their own knowledge of mathematics. To support writing in mathematics, the preservice teachers in this project were required to use the PDA's collapsible portable keyboard to write descriptions of the pictures they took in the scavenger hunt activity. The students then used the built-in infrared communications capability to beam their completed assignments to the instructor's PDA. The instructors docked their PDA to a desktop computer and uploaded all the assignments at once. This allowed using the PDA for communication, management of assignments, and teacher-student interaction as well as student-student interaction. This is in line with NCTM's call for instructional programs at all levels to enable students to communicate their mathematical thinking coherently and clearly to peers, teachers, and others and to be able be able to use the language of mathematics to express mathematical ideas precisely.

Equity and accessibility. A PDA has the potential to provide a one-to-one ratio in terms of availability and access to technology thus addressing the issue of equity and accessibility of technology. A PDA can also provide the needed mobility of the classroom without boundaries, thus allowing every student in the classroom to have access to the information formerly restricted by the number of personal computers found in the classroom. In this project, each preservice teacher was provided with a PDA to take home. Because of their low cost, PDAs may provide a reasonable and affordable means of assisting schools to meet the goal of access to technology for all students.

Challenges. A big concern was the amount of time spent learning to use the PDA. There was a general feeling that the time it took would drag down any gains that might be offered by its use. For instance, students took more time to type using the keyboard or take notes using the stylus than they would have normally when using pencil and paper or on a desktop computer. The use of spreadsheets also still appeared much easier with the desktop or laptop versions than that for the PDA. This was, however, expected to get easier with more use as students became more comfortable inputting information on the handheld.

Based on evidence from this study, the biggest drawback to a widespread educational use of a PDA is the lack of appropriate software. Most of the software developed for PDAs is primarily for business, though some applications such as spreadsheets are applicable to the classroom. Good educational software is expensive and most freeware is not appropriate as it supports calculations more than inquiry-based learning. In addition, peripheral devices or data collection tools are expensive.

CONCLUSION

Emerging technologies such as the a PDA can provide opportunities for teachers to experience ubiquitous computing and learning. A PDA technology has the potential to meet the goals of inquiry-based mathematics learning. The PDA technology such as the one used in this project has the potential to change teaching in two ways: (a) it allows the learner to do the same thing in a more motivating way and (b) provides for convenient, accurate, and dynamic drawing and graphing, thus removing the constraints of routine computation and manual graphing. This allows the teachers to spend more time developing deeper conceptual understanding and reasoning skills and offers opportunity to develop broad range and quality of students' mathematical investigations.

Evidence from this project suggests that the introduction of new technology tools into instruction can make a difference as evidenced by the enthusiasm some of the students showed while performing class activities. These results, however, suggest that teachers need much more training on the use of these tools. Consequently, there is need for colleges of education to be proactive in implementing teacher education programs that integrate technology throughout the entire program by providing opportunities for preservice teachers to observe model inquiry-based lessons that appropriately integrate technology.

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