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Palm Education Pioneers Program
March 2002 Evaluation Report

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Executive Summary

Today it is expected that K-12 students spend increasingly more time using technology in the classroom. Recently, schools have begun purchasing handheld computers in addition to desktop and laptop computers. At this time, however, schools that are adopting handheld computers are doing so without the benefit of systematic research on the effective uses of handheld computers in the classroom.

This report is intended to provide information to those interested in the benefits and drawbacks of handheld computers in the classroom. The report is based on data collected from the 102 Round I and Round II Classroom Teacher Awards in the fall semester of 2001. As of winter 2001-02, the 15 Round I awardees had completed two semesters of use with the Palm computers, and the 87 Round II awardees had one semester of use.

Teachers' evaluation of handheld technology was overwhelmingly positive. Handhelds were seen has having positive effects on student learning, on teaching practices, and on the quality of learning activities. Teachers also stated that handheld technology can make technology more integral to teaching and learning. When asked to indicate their degree of agreement or disagreement with statements about handhelds, teachers' responses were as follows:

- 96.5% indicated that they believed handheld computers were an effective instructional tools for teachers.
- 93% stated that the use of handheld computers contributed positively to the quality of the learning activities their students completed this semester.

The following benefits of handheld technology were cited most often: portability and ease of access, the integration of computing into a wide variety of educational activities, promoting autonomous learning and student organization, promoting student motivation, promoting student collaboration and communication (using infrared beaming), and supporting inquiry-based instructional activities.

Although teachers were very favorable in their evaluation of handheld computers for teaching and learning, they did report some problems, including the following: damage to the handheld devices (especially the screen), problems with synchronization, and some inappropriate use (such as game playing and off-task beaming).

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Introduction

Educational technology is increasingly seen as a fundamental aspect of learning and teaching in K-12 schools, and educators seek to expand students' opportunities to use technology in achieving instructional goals. Although traditionally desktop and laptop computers have been the mainstays of educational technology, recently schools have started adding handheld computers as part of their technology program. At this time, however, schools that adopt handheld computers are doing so without the benefit of systematic research on the effective uses of handheld computer in the classroom.

To understand how handheld computers can be effectively used in the classroom, SRI International and Palm, Inc., created the *Palm Education Pioneers* (PEP) awards. Palm has awarded a handheld computer for every student to more than 175 K-12 classrooms throughout the United States. SRI International's Center for Technology in Learning (CTL) is administering and evaluating the PEP program. CTL's research will help determine the impact that handheld technologies can have on teaching and learning. This is the first major, systematic evaluation research on handheld computers in education.

PEP awardees are talented, innovative teachers who have integrated handheld technology into a wide range of instructional activities. The core of the PEP program is use of handheld computers by real teachers in their own classrooms, with diverse types of students. PEP evaluation findings are grounded in teacher-designed and teacher-implemented use of handheld technology in classrooms across the United States, from grades 2 through 12.

PEP Grant Types

The PEP program has granted three types of awards. All awards were granted as part of a competitive program. To qualify for an award, proposals were submitted to the PEP program. These proposals were read by an independent panel of external reviewers, who rated each proposal according to a set of criteria provided by SRI. No requirements were specified in terms of content areas or grade levels (other than K-12). Instead, teachers were encouraged to create innovative projects in areas they felt were most appropriate.

The award types are the following:

Round I Classroom Teacher Awards. The first set of 15 awards was granted in February 2001. All awardees were classroom teachers in K-12 schools and were required to have research partners to help in the implementation of their projects.

Round II Classroom Teacher Awards. There were 87 Round II awards granted in June 2001. All awardees were classroom teachers or technology coordinators in K-12 schools.

PEP Research Hub Awards. There were nine Research Hub awards granted in June 2001. Awardees were organizations such as research institutions, school districts, and schools of education that committed to training and supporting a set of teachers in the integration of handheld technology. Each awardee received from 6 to 15 classroom sets of Palm computers.

About This Report

This report is based on data collected from Round I and Round II Classroom Teacher Awards in the fall semester of 2001. As of winter 2001-02, the Round I awardees had completed two semesters of use with the Palm computers, and the Round II awardees had one semester of use.

The awards vary across content areas, grade levels, geographic locations, and demographic compositions. PEP awardees tend to be highly motivated technology users, a fact that contributes to their implementation of handheld computers in their classrooms.

This report is the second of three reports on the Palm Education Pioneers program. An initial report, based on Round I evaluation data, was released in October 2001, and is available at the PEP Web site at www.palmgrants.sri.com. A final report on the PEP program will be released in summer 2002, and will also be available on the PEP Web site.

Evaluation Design and Data Sources

The two-level evaluation design consists of (1) a general evaluation, conducted by SRI, involving surveys of teachers and students and a small number of site visits; and (2) project-level evaluations conducted by PEP awardees and their project teams, with guidance provided by SRI researchers. CTL's evaluation of the PEP program has the following goals:

- General evaluation of handhelds for teaching and learning.
- Identifying key benefits of handheld computers for students.
- Identifying drawbacks and pitfalls of handheld computers for students.
- Identifying strategies for the successful integration of handhelds into teaching and learning.

This evaluation report draws on data from 86 PEP projects (out of a total of 102 projects) that implemented handheld technology for teaching and learning during fall 2001 and provided evaluation data to SRI International. The other projects scheduled their implementation to begin in the spring 2002 semester.

The evaluation data sources are the following:

Project Implementation Questionnaire. This online questionnaire included multiple-choice, Likert-type scale, and open-ended items, and was administered at the end of the fall 2001 semester. Questionnaires were completed by 143 PEP team members (including teachers, specialists, researchers, and other PEP team members) from 86 different PEP projects. Only questionnaires from projects reporting an average of at least 1 hour per week of student handheld computer use were included in the analyses of Project Implementation Questionnaire data; 79 projects were represented in this subset.

Two main, non-exclusive subsets of cases were created from the questionnaire data: individuals most knowledgeable about projects ($N = 79$) and individuals most knowledgeable about students ($N = 88$). These data subsets were used for analysis of certain items for which only single data points for each project or each group of students participating in a project were needed.

Project Self-Evaluation Reports. Each PEP project is expected to submit monthly project activity reports and a final Project Evaluation Report at the end of each semester. Approximately 40% of all PEP projects have reported regularly. Project reports are submitted online. All reports are carefully reviewed and coded by SRI researchers.

Student Questionnaire. Students from eight PEP projects participated in SRI's fall 2001 student survey. A total of 171 students, in grades 7, 9, 11, and 12, completed questionnaires. In spring 2002, approximately 500 more student questionnaires will be collected.

Site Visits. SRI researchers visited a handful of classrooms for a day and interviewed teachers and students, as well as observing learning activities that involved handheld technology.

Round II PEP Awards Statistics

Grade levels (some projects span more than one category)

- Primary grades: 23
- Middle grades: 45
- High school: 49

School demographics

- Urban: 39
- Rural: 33
- Suburban: 30
- Public: 91
- Private: 11

Subject areas (main focus)

- Science: 44
  - Environmental science subset: 33
- Cross-curricular: 25
- Language: 13
- Physical education: 5
- Social studies: 5
- Math: 4
- Music: 2
- Special needs: 4

Teachers' Evaluation of Handheld Technology

During fall 2001, PEP teachers and their students used handheld technology for a wide range of projects and purposes. As part of our PEP program evaluation, we asked teachers to evaluate the benefits of handheld computers for teaching and learning, based on their use of handhelds in classroom activities.

Teachers' evaluations of handheld technology were overwhelmingly positive. Handhelds were almost universally seen has having positive effects on student learning, on teaching practices, and on the quality of learning activities. Teachers also said that handheld computers were more easily integrated with the flow of learning activities than desktop computers. This ease of integration is important because it suggests that handheld technology can make powerful computing more integral to teaching and learning.

Evaluation of Handheld Computers as an Instructional Tool

Teachers were extremely positive in their evaluation of handhelds as an instructional tool. From 84 to 86 respondents indicated their degree of agreement or disagreement with statements about the effectiveness of handhelds for teaching and learning. Here's what teachers told us:

- 96.5% indicated that they believed handheld computers were an **effective instructional tool** for teachers.

- 93% stated that the use of Palm computers **contributed positively to the quality of the learning activities** their students completed.

- 95.3% told us that use of Palm computers in learning activities had the potential to have a **positive impact on students' learning**.

- 92.9% stated that having a classroom set of handheld computers would have a **positive effect on their teaching practice**.

- 73.3% indicated that handheld computers were **more easily used in the "flow of classroom activity"** than desktop computers.

- 97.6% indicated they **planned to continue to use handheld computers** in instructional activities with students.

We also asked teachers how satisfied they were with the performance of handheld computers in the teaching and learning activities they designed and implemented. Teachers were very positive in their responses:

- In general, how effective were Palms for the specific needs or purposes of your PEP project?

  [Over 95% said "fairly" or "very" effective]

Little/Not	3.60%
Fairly	35.70%
Very	60.70%
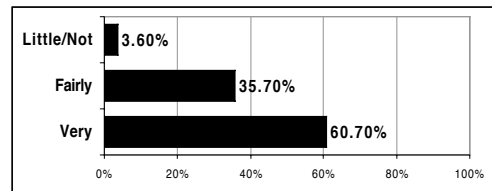
- Overall, how satisfied were you with the performance of Palm computers in your project?

  [Over 95% said "fairly" or "very" satisfied]

Little/Not	4.70%
Fairly	29.80%
Very	65.50%
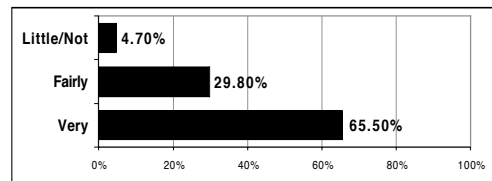
- How likely would you be to use handhelds for instruction again?

  [Over 97% said "fairly" or "very" likely]

Little/Not	2.40%
Fairly	11.90%
Very	85.70%
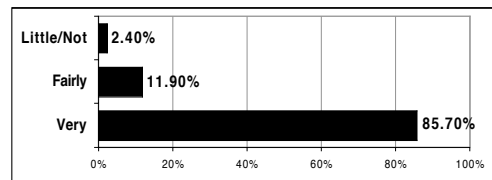
- Overall, how comfortable were students in using Palm computers during your PEP project?

  [Over 98% said "fairly" or "very" comfortable]

Little/Not	1.20%
Fairly	26.50%
Very	72.30%
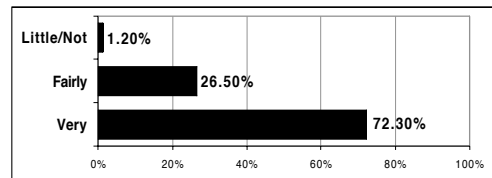
Does Use of Handheld Technology Contribute to Student Learning? Teachers Say "Yes"

PEP teachers strongly stated that integration of handheld technology into instruction had a positive effect on students' learning. Because teachers' responses are based on their own actual classroom use of technology, in a wide range of applications, with a large sample of students, this finding makes a strong statement about the role of handhelds in benefiting learning.

Teachers also reported that use of handheld computers increases the amount of time students spend using technology.

- Did use of Palm computers contribute positively to your students' learning?

  [Over 96% said "fairly" or "very"]

Little/Not	3.60%
Fairly	26.20%
Very	70.20%
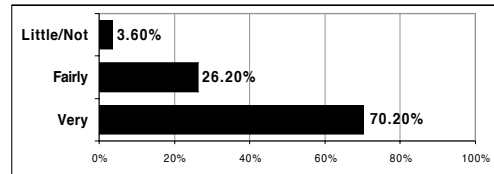
- Did use of Palm computers increase the amount of time students spent using computing technology?

  [Over 95% said "fairly" or "very"]

Little/Not	4.70%
Fairly	17.90%
Very	77.40%
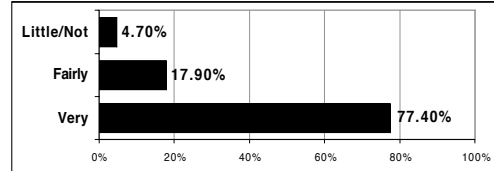
Palmtop, Laptop, and Desktop: How Handhelds Compare

Technology_savvy PEP teachers were asked to compare handheld computers with desktop and laptop computers along several dimensions. A large majority of teachers (72% to 85%) indicated that handheld computers had the advantage over desktop and laptop computers in the following dimensions:

- Easy to integrate into class
- Usable in many places
- Easy to share
- Convenient to access.

Desktop computers were evaluated more favorably than handhelds on the dimensions of durability and power. In terms of ease of use, handheld computers were seen as having the advantage over desktops, but only by a small margin. Laptop computers were not evaluated more favorably than desktops or handhelds on any dimension.

While teachers see handhelds has having key benefits over desktops in integrating technology into learning activities, 33.7% of teachers agreed or strongly agreed with the statement that handheld computers needed to be "re-tooled" specifically for education users. This result indicates that although teachers are highly positive about the benefits of handhelds for education, they see opportunities for improving this technology to maximize its contribution to teaching and learning.

Handhelds in the Classroom

Handheld computers were used in a wide variety of ways across the PEP projects: for inquiry-based environmental science activities, chemistry laboratory projects, physics, art, cross-curriculum integration, promoting student organization skills, and many other activities and purposes. In some projects handhelds were integrated into a variety of classroom activities; in other projects handhelds were used episodically for specific curricular units or projects. This section provides a general overview of how the handheld computers were used by students across this range of projects.

Assigning Handheld Computers to Students

Because of the small size, portability, and personal nature of handheld computers, teachers have a variety of options for assigning handheld computers to students. PEP teachers assigned their handhelds to students in the following ways:

Each student assigned a handheld computer and could take it home (46%)

Students were assigned a handheld that they could use throughout the school day and could take home with them.

Each student assigned a handheld, which was used episodically in class (24%)

Each student was assigned a handheld, but students could not take the handhelds home. Instead, each time the handhelds were used for instruction, students used the handheld they were initially assigned.

Classroom set of handheld computers was used by all (22%)

The students used one classroom set, and students selected a handheld each time they were used for instruction. Handhelds were not assigned to individual students, and students could not take the handhelds home.

Each student assigned a handheld for use throughout the school day (5%)

Each student was assigned a handheld. Students used the handhelds throughout the school day but could not take them home.

Other (3%)

A method other than those above was used to assign handhelds to students.

The assignment method has significant implications for the uses of the handhelds by students. Although a set of core applications was used by students no matter what the assignment model, other applications were used only by students who could take the handhelds home.

The following applications were used frequently by students across all the assignment models (over 60% of respondents cited "frequent use" or "occasional use"):

- Memo Pad
- Calculator
- HotSync
- Beaming

The following applications were used frequently *only by students who could take handhelds home* (over 60% of respondents whose students could take home handhelds cited "frequent use" or "occasional use"; fewer cited this in other categories):

- Date Book
- To-Do List
- Address Book
- Downloading applications

The applications used by students' who could take the handheld computers home with them were those that support personalization of the handheld – addresses, to-do lists, and downloading desired applications.

In addition to affecting students' use of handheld applications, the assignment model also largely determined the intensity and frequency of students' handheld computer use:

- 92% of teachers who did not allow students to take the handhelds home said their students used handheld computers only for specific, limited-duration learning activities.
- 77% of teachers who allowed students to take handhelds home reported that their students spontaneously used handheld computers for learning tasks or activities without teacher direction. Only 34% of teachers whose students did not take the handhelds home reported that students spontaneously used handhelds for learning tasks.

It appears that students who can take the handhelds home find more integral use than those who leave the handhelds at school. When students are allowed to take the handhelds home with them, and handhelds are not limited to specific classroom-based activities activities, students find more spontaneous uses of handhelds, and students more fully take advantage of organizational applications, such as the To Do List and Date Book.

A significant factor in determining the method used to assign handhelds is the grade level of the students. Students in higher grades were more likely to be allowed to take the handhelds home than students in lower grades: 61% of students in grades 9-12, compared with 48% of students in grades 7-8 and 22% in grades 3-6. Future studies will investigate the interplay between assignment of handhelds, grade levels, and student uses of handhelds.

Benefits of Handheld Technology for Teaching and Learning

We asked teachers to describe, in their own words, the main benefits of handhelds for instruction and received a wide variety of comments. Teachers' responses fell primarily into the following categories:

- Handheld computers are **portable, ready-at-hand instructional tools** that allow the integration of computing into a wide variety of instructional activities and contexts. (39%; n = 45)

- Handhelds are **personal learning tools that promote students' autonomous learning**. (20%; n = 23)

- Handhelds support students' **organization**. (16%; n = 18)

- Use of handheld computers is highly **motivating** to students. (16%; n = 18)

- Use of infrared beaming **enhances collaboration and communication**. (14%; n = 16)

- Use of handheld technology increases students' **technology use**. (11%; n = 13)

- Handheld computers provide **support for inquiry-based activities**. (10%; n = 11)

  N = 114; multiple categories were counted within responses.

An interesting aspect of these findings is that handhelds are seen as supporting aspects of group learning—collaboration and communication—as well as autonomous learning—two dimensions of classroom learning that are often seen as in tension with each other. The combination of portability and infrared

beaming underlies this versatility. Portability allows handhelds to be personal tools that students can use at their own discretion to support their shifting learning-support needs. The beaming function allows quick and easy sharing of information as students work in groups, compare information, and share results.

Portable, Ready-at-Hand Instructional Tool

A large proportion of teachers stated that the primary benefit of handheld computers is that they are portable, giving students access to digital information and computing power in a wide variety of contexts and activities. In this vein, some teachers also mentioned the portability of a range of applications and peripheral tools—such as the calculator, word processing software, probes and sensors for data collection, organizational tools, and digital cameras—that can be used anytime and anywhere.

Sample comments

- *Opportunity for students to have their own work station, to have technology immediately available to them without waiting to go to a computer lab or to the one computer they have available in their classroom. They can do most of the things they need a computer for with a Palm, and can go to a desktop to extend and complete a project, or produce multimedia.*
- *A truly personal computing device that is useful anywhere. The students can use the Palm anywhere, but with a Palm keyboard they have an instant powerful tool that they can get some serious work done in a wide variety of places and not really have to carry very much.*
- *The main benefit is to allow teachers and students to utilize computers in situations where desktops and laptops are not practical or available. For example, I have 5 desktop computers in my classroom and they are a hassle in terms of how much space they occupy and dealing with wires etc. The school computer lab is not always available, we have very few laptops. I love being able to pass out the Palms and add computing to whatever we are doing.*

Personal Learning Tool That Supports Autonomous Learning

Another main benefit mentioned by teachers is that handheld computers allowed students to continue learning activities outside the classroom on their own. For example, some students used quizzing software to continue self-assessment at home; others continued word processing documents at home or during class free time. Similarly, some teachers also reported that students devised, on their own, additional ways of using handhelds as learning tools. For example, students downloaded additional software applications to use for learning, such as

dictionaries and other reference tools; some students reviewed notes or facts to memorize; other students spontaneously began to use the organization tools to keep track of homework or schedules.

Sample comments

- *Our students can begin work at school and take it home to finish or sync it to a computer at home and continue working. We only have eight computers in our classrooms, so not all students can use the computer at the same time.*
- *The kids are not limited by conventional classroom assignments. Palms give students an opportunity to gain leadership in their projects. They become more focused and aspire to work really well with each other.*
- *They use the equipment and are constantly finding ways to facilitate their learning experience through the handhelds.*

Organizational Tool

Some projects used the handheld computer primarily as an organizational tool; in other projects, this was a use of handhelds that was added to other, planned project activities. Some teachers mentioned support for organization and productivity as the main benefit of handheld computers. Teachers mentioned not only that students were better organized, but that teachers and the class as a whole were better organized. For example, a few teachers mentioned that use of handhelds to record schedules and assignments made it very easy for substitute teachers to manage classroom activities in the regular teachers' absence, and made it easy to communicate with parents about homework and schedules. Teachers of students with special needs also commented on the benefits of handheld computers for coordinating teachers' and aides' work with students, as well as for keeping these students organized.

Sample comments

- *The Palm has great organizational features and that helps everyone including students. It builds habits that are good—organization, keeping records, etc.*
- *Organization and ability to maintain and build upon previous work, which with notebook paper and folders often get lost.*
- *When they can be used by one individual over a long term period, they are great compact devices for keeping track of events, tracking homework assignments and keeping simple notes.*

Motivational Effects

Some teachers saw the motivational effects of handheld computers as their key benefit. Students find handheld computers motivating, according to teachers. Students themselves also reported enjoying the use of handhelds; 88% of students surveyed (see Students' Evaluation of Handhelds for Learning, below) agreed or strongly agreed that "I liked using a Palm computer at school." Some teachers reported that students brought greater enthusiasm to the handheld-supported version of tasks than to the paper-and-pencil version of the same tasks, such as writing, collecting data, and memorizing facts.

It will be important to track the motivating effects of handheld computers when their novelty for students decreases. A few projects have reported, in monthly project reports, that the motivational effects of computers began to decline as students became more accustomed to using them.

Sample comments

- *Technology can motivate students to do things that they have difficulty completing by giving them immediate feedback and independence.*
- *It has been extremely motivational and the students look forward to using them.*
- *Enthusiasm and motivation abound with Palm use. All learners are able to work with the Palms and really get the kids engaged.*

Enhancing Collaboration and Communication

A main benefit seen by some teachers was facilitation of collaboration and communication. Teachers found the beaming function an effective tool for sharing and comparing information in learning activities and for coordinating classroom work. Some teachers mentioned the convenience of quickly passing out documents to students, and collecting student work, through beaming. Handhelds were seen as supporting student collaboration in small-group work, as well as supporting students' spontaneous collaboration, mutual aid, and information sharing.

While teachers see the infrared beaming function as one of the main benefits of handheld computers, some teachers mentioned that the lack of broadcast beaming is a limitation. In monthly activity reports and the project implementation questionnaire, teachers indicated that the ability would enhance the usefulness of handheld technology for classroom tasks such distributing homework assignments and handouts.

Sample comments

- *The beaming capability promotes the sharing of ideas.*
- *The ability to communicate easily and quickly, which is a function of Palm's portability and beaming.*
- *Ability to share info with others with relative ease. With the right software, it can give instant feedback to solve/check learning.*

Other Benefits: Support for Inquiry-based Instruction and Technology Use

Support for inquiry-based learning was another one of the main benefits of handheld technology. (See also "A Closer Look at Handheld Technology in Inquiry-based Instruction," below.) In addition, students' use of new technology, or extended use of technology, was also cited as a main benefit of handhelds. Sample comments are listed below.

Support for Inquiry-based Activities: Sample comments

- *My kids are amazed at the fact that we can analyze, collect, share, and document information and data while we're on the move and then we can hot sync back to our PCs and print out our findings...pretty darn slick!*
- *Accurate data collection, descriptive notes and digital pictures can be done every time our class uses the Palms.*
- *Teach "real world" science and data collection with probes*

Technology Use: Sample comments

- *The major benefit was the introduction of new technology to third graders. I believe making Palms user-friendly and accessible took the "mystery of technology" away from the kids.*
- *Palms help students relate to using technology in their everyday lives. It helps them manage their time, and it is exciting and different to them.*
- *Students being able to work with cutting edge technology. Being exposed to learning in a nontraditional form.*

Unexpected Uses of Handhelds

Many PEP awardees reported that handheld computers were incorporated into learning activities and classroom tasks in ways that were unplanned. In many cases, teachers reported that additional uses were innovated by students, who found ways of integrating handhelds into instructional activities and organizational tasks. Most of these unplanned uses were seen as beneficial uses of the handhelds for learning, although a small number of teachers pointed out inappropriate uses (such as games and cheating). Unexpected uses fell primarily into the following categories:

- Students independently adopted or explored uses of handhelds
- Students sought out and used additional software
- Students spontaneously collaborated on tasks, as well as supporting each other's exploration of handheld computer functions and software

Students' Independent Adoption/Exploration of Handhelds

Over 30% of the respondents stated that students independently explored various uses of handheld computers to enhance their learning, and this exploration was associated with a high level of engagement in school tasks and activities. Students' independent use or exploration of handhelds included:

- Finding specific software or online information (even suggesting additional software programs to purchase)
- Doing deeper analyses of data they gathered with handheld computers
- Organizing data and information for presentations

In general, PEP teachers' comments regarding unplanned uses of handhelds in the classroom responses suggest that students were developing a sense of ownership of their learning and mastery of the technology. Teachers were surprised by this unexpected outcome.

Sample comments

- *Kids seemed inspired to take notes. They want to take notes on everything. As I said they also surf the Web looking for freeware for their Palms.*
- *I had not expected it to be used as a notebook to the degree that it was. … And it turned out to be a great tool for organizing presentations by small groups of students.*
- *The unexpected results were some days I did not plan on using the Palm per se, and students would ask for it to do their work. This is a very positive sign.*
- *Some of my advanced students went on-line and downloaded a scientific calculator to use in their math and science classes.*
- *Students who were quite facile on the Palms organized their schedules and their parents' busy schedules.*

Use of Previously Unknown Software

Approximately 20% of the respondents reported that additional software programs unexpectedly promoted more and various uses of the handheld computers in various contexts. For example, students made concept maps using Pico Map, collected data using Handy Sheets, took pictures with digital camera and practiced spelling with self-made games, all of which were beyond teachers' expectations.

Sample comments

- *I did not originally assign phases of the moon for my project, but then the students discovered the Moon Phase application I had loaded on it. They became so engaged that we ended up charting the phases of the moon on a daily basis. The PDAs and their applications serve as springboards for all kinds of learning experiences for the students.*
- *Spelling – some [students] use Palms to learn word patterns and to make up their own games.*
- *We discovered that Handy Sheets is a cool way to collect data. We created our own survey to collect data for our Science Fair projects.*
- *Students used the Palm for making concept maps (using Pico Map). They took pictures and created a slide show of their classmates. They played the virus simulation game (Cooties).*
- *We didn't think the mini piano was a useful piece of software, but the children really put it to good use writing and practicing their music.*

Collaboration

Most PEP teachers expected beaming and collaboration to be part of their projects. However, some were surprised to discover the value of handhelds in facilitating collaboration. Over 15% of the respondents were surprised at how the beaming function of the handheld computer promoted interaction and collaborations among students. For example, handheld computers were used in "jigsaw" classroom activities, so that students contributed to the group work by adding new information through beaming. Students also shared notes and exchanged questions to prepare for tests. Moreover, students enjoyed beaming and became more on task in the classroom. These comments indicate that students were becoming "collaborators" to help each other learn more, which was beyond teachers' expectations.

Sample comments

- *One of the best uses was by a group of students who were at the stream site and I asked them to draw a map of the area and take notes. One group had a student who was artistically challenged. Another student offered to beam a basic outline so that he could add trees, grass, and brush. It developed into each student adding something to the drawing. I adopted this for the other classes and it worked well. The students typed notes while they waited to add their part of the drawing. More detail came from these than when the students worked alone.*
- *[Students used beaming] to quiz each other in preparation for memorization tests to study for tests.*

A Closer Look at Handheld Technology in Inquiry-Based Instruction

Handheld computers appear to hold tremendous benefits in the area of inquiry-based science learning activities. These benefits are most likely due to the availability of probes and sensors for handheld computers, as well as software that allows data visualization and analysis, combined with the portability and broad functionality of handheld computers. Because many state and national science achievement standards call for an inquiry-based approach to science instruction, there may be an important niche for handheld technology in science instruction.

Teachers' Evaluation of Handhelds for Inquiry-based Instruction

PEP awardees clearly stated that handheld technology improved the quality of inquiry-based instruction and made a positive contribution to student learning outcomes. Teachers who used handhelds in field investigations with their students were especially positive in their evaluation of the benefits of handhelds. Benefits for laboratory-based science activities were also described by PEP teachers.

PEP awardees whose students used handheld computers for inquiry-based instructional activities were even more positive about the benefits of handheld computers than PEP awardees as a whole (inquiry-based projects included any of the following inquiry activities: collecting data in the field, collecting data in a lab activity, or analyzing data, comprising 66 projects). These teachers were overwhelmingly highly favorable about the beneficial effects for student learning outcomes. In addition, these teachers found handheld computers highly effective as instructional tools. Figure 1 presents the results of the evaluation of handheld computers by teachers who used handhelds for inquiry-based activities.

Figure 1. Teachers' Evaluation of Handhelds for Inquiry-based Instruction

Did use of Palms contribute positively to your students' learning?	77.3 / 19.7 / 3
Overall, how satisfied were you with the performance of Palm computers in your project?	69.7 / 28.8 / 1.5
In general, how effective were Palms for the specific needs or purposes of your PEP project?	68.2 / 30.3 / 1.5

□ Not at all or A little ☒ Fairly ■ Very
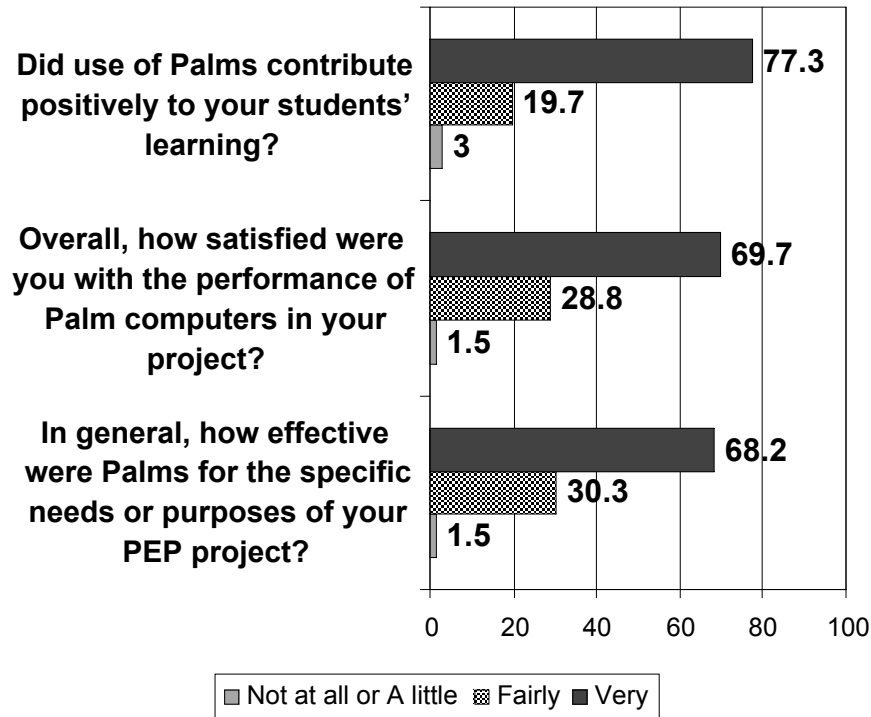
N = 66; graphed values are percentages.

We asked teachers to tell us, in their own words, about the most successful aspects of the PEP projects. Many PEP awardees mentioned the benefits for inquiry conferred by handheld computers as one of the most successful aspects of their PEP projects. Among the benefits of handheld technology for science activities frequently mentioned by teachers are the following:

- Greater coherence across phases of inquiry: formulating hypotheses, data collection, data analysis.
- Easier transitions across inquiry activities and contexts (data collection, analysis, reporting; in the field, in the classroom) with digital data and data transfer.
- Data collection in the field.
- Organization of data collected (no lost papers, information ready-at-hand).
- Greater accuracy in data collection.

Teachers provided detailed information regarding how they used handhelds in inquiry activities, and what they saw as the key benefits. Below are a few sample teacher comments.

- *Palms, interfaces and sensors allowed for accurate and easy data collection in our study of school microclimates. Students could take data readings, see these readings in both chart and graph form immediately and begin the process of looking for patterns and comparisons while still at the test sites. Palms and Imagiprobes provided accurate data. Students did not have to struggle with partners not willing to take their turns at instrument readings or partners inability to correctly use or manually read an instrument. Everyone wanted to participate and could easily do so!*

- *My students have not succeeded in traditional high schools and have come to our school as a last resort. Many of my students have poor attendance records, ADD/ADHD, substance abuse history, and little parental support. Successes in my project might seem minor when compared to a "regular" high school science class. Aspects most successful: 1. My students loved doing the field studies at our local rivers, the Yakima and the Columbia River. We tried to go once a week to collect data and to assess each site for possible restoration work. Portability of the Palms and probes really made our data collecting easy and convenient. 2. The environmental topic, water quality studies, has been of high interest to my students all semester—their attention has stayed focused and keen on learning more material. Field trips, testing the water quality (use of the Palms), and the wide range of topics have all contributed to this success. 3. Good attendance and participation from 75% of my students. Topic was highly motivating for them to be in class and to be able to go out to do river studies.*

- *The use of the Palms to collect and record data has been the most successful. It has totally engaged the students in inquiry science. They can hypothesize, record observations, and collect data all on one device. The key factors here were having the class set of Palms, as we so often have to have kids share expensive equipment. The other key factor was writing another grant to purchase some probes.*

- *Sharing of data within lab groups by beaming is a key success. Turning in data and reports by beaming is also a major success. The IR capability of the Palm allows the beaming—much easier than a physical connection.*

- *Students created great driving questions for their studies. They also created well-defined studies that incorporated the use of the Palm handheld computers. They were very clever to not only use the Palm as a writing tool, but a tool that can carry data into the field. They use the Palm to carry images of animals and plants to locate and information about elements that needed to be present in an amphibian's habitat Students use the Palm and the GPS to create maps. Students also were successful at writing presentations on the Palm handheld, then transferring the data to the PC to create presentations in PowerPoint and Microsoft Publisher. Finally students*

were successful in using Probes attached to the Palm. Not only did they work with several types of water quality studies, but they also incorporated the probe use in a study of light during art class.

How Handheld Technology Supports Environmental Science Inquiry: Some Illustrations

The portability and versatility of handheld computers, along with the range of sensors and other peripherals available for them, create many possibilities for integrating digital tools into inquiry instruction. The following description of how handhelds are used in an inquiry-based unit, taken from a PEP questionnaire, illustrates many uses of handheld technology in the context of an environmental science project.

> *Students designed research projects for the Prairie Oak Preserve, a nature preserve located next to the school. They were told that they could do species location and identification, GPS mapping, Habitat Assessment, or Water Quality Assessment. Each student designed a study that would utilize the Internet, the Palm handheld computer, a digital camera, and when required, probes, or a GPS connected to the Palm. Students had to create driving questions to define their study. The group's overall question was "Why are there no amphibians on the Prairie Oak Preserve?" … In species location and identification students began learning how to photograph species located, identify them using the Internet, and then loading pictures of species located and species to locate onto the Palm using Album to Go. … In mapping students are using the GPS unit to create an accurate map of the habitat and the trails that we are building. In Water Quality Studies students are using [handheld computer-based] probeware to assess pH, Temperature, Salinity, Total Dissolved Solids, Biochemical Oxygen Demand, and Nitrate levels. Students are researching acceptable levels in these areas and will publish a study of the pond located on the preserve. In the area of habitat assessment, the Palm is used to keep notes of plants and animals located along with the identification of any other factors that could affect the animals of the habitat (factors such as pollution and vandalism). The goal is to assemble a large amount of data about the habitat and determine what factors would contribute to amphibians living in the habitat and what factors are deterring the existence of amphibians in the habitat. As a teacher it is my goal to see how handheld computers can enhance the learning environment in my classroom.*

PEP awardees used handheld technology for a wide range of science inquiry activities (as well as social science investigations), including marine science, biology, environmental science, and earth science. Handhelds were also used in laboratory activities. Below, we provide sample descriptions of the uses of handhelds in inquiry-based instruction.

Respondents' descriptions of handhelds in field investigations

- *Students use Palm handheld computers to monitor their coastal embayments, paying close attention to location, temperature and anecdotal observations. The peripheral technologies ... allow students to integrate quantitative and qualitative data into Vital Signs records that are uploaded to a central database housed on the Gulf of Maine Aquarium's server.*

- *Students used the Palm as a versatile learning tool. We used it in gathering and collecting data, writing, math facts, graphing, previewing/predicting, comparing/contrasting, mapping, and sketching.*

- *1. Collecting water quality data in the field (or rivers as it may be). 2. Research pH levels of substances in the class. 3. Monitor water in our "salmon in the classroom" project. 4. Take notes out in the field (very preliminary application at this point).*

- *The head teacher is working on a Columbia River project—monitoring and planning some restoration of habitat, culminating in the release of salmon smolts this spring. Palms are used for present statistics and evaluation of improvements.*

- *Students have used Palms to produce products related to water quality studies of a local stream, and to the raising of salmon in the classroom. They have recorded temperature, pH; they have made concept maps, used PicoChat to quiz each other on specific issues, and used the Memo Pad to keep track of things for themselves. They have used Sketchy to produce flip books on various issues. They access their data on the computer and use Excel to manipulate and analyze their data. All of these uses have also been shared (or will be by the end of January) with their third grade buddies.*

- *Using earth and sun software to determine sunrise, sunset and day light length for a period of 2 months. Recording the data on the calendar. Taking temperature measurements of soil temperatures 2 a week during this time. Measuring differences in light intensity and heat intensity when the light/heat source is changed from indirect to direct angles.*

Respondents' descriptions of handhelds in laboratory activities

- *Record, share and analyze experimental data. Distribute assignment sheets. Draw diagrams of apparatus store research notes and beam to instructor Write some journal entries.*

- *Record, share and analyze experimental data. Distribute assignment sheets. Write lab reports Write some journal entries.*

> ▪ *The Palm was used as a collaborative device in a differentiated chemistry class. They used the device and software to enhance the learning of stoichiometry and the mole concept, as well as, balancing equations. They also used it as an electronic lab book.*

Extended Writing with Handhelds

Most of the PEP projects used handhelds for extended writing activities, but with varying frequency. Informal interviews have indicated that teachers view writing with handhelds to have benefits over current alternatives. To engage in writing activities in most of today's classrooms, students must write by hand, share the small number of desktop computers found in the classroom, or take a trip to the computer lab. Using handhelds, each student can work on his/her own assignment, and then beam it to other students for editing or synch it to a computer to hand in.

The main drawback to extended writing on handhelds is text entry. Entering text in Graffiti is cumbersome and not amenable to extended writing. However, there are keyboard-based solutions to this issue. Of students who used handheld computers for extended writing 34% used keyboards and 66% did not use keyboards.

Eighty-five respondents offered comments on handheld computers for writing. Among the teachers whose students used handheld computers for extended writing *without* keyboards, evaluation of handhelds for extended writing was largely negative. Results are presented in Figure 2.

Among teachers whose students used keyboards for extended writing, evaluations of handheld computers for writing were overwhelmingly positive (over 90%).

Figure 2. Teachers' Evaluation of Handhelds for Extended Writing, With and Without Peripheral Keyboards

With Keyboards n = 29; Without Keyboards n = 56

■ **Positive Evaluation for Writing** ▨ **Negative Evaluation for Writing**
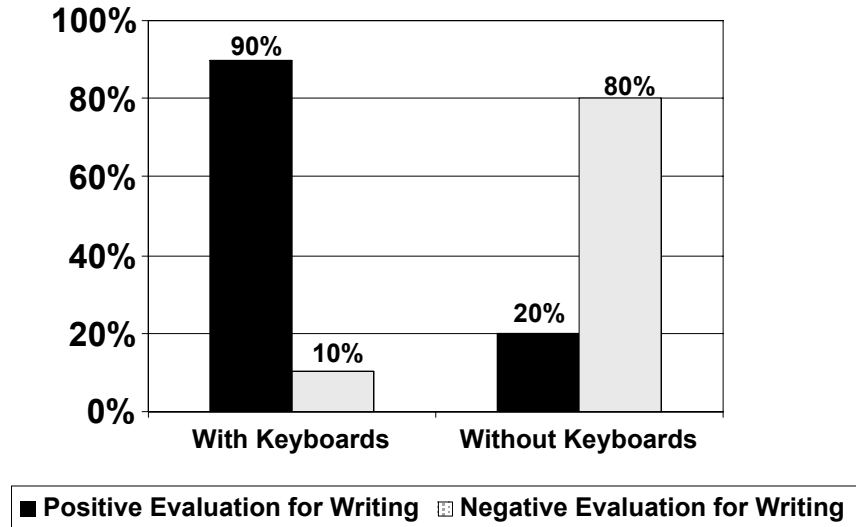
Learning Graffiti

Teachers were asked whether their students had any difficulties learning to write in Graffiti, the special alphabet of characters for text input with the Palm computer.

Teachers were asked to rate the difficulty their students had in learning Graffiti: "none," "very little," "some," or "a lot." Although the majority of teachers reported "none" or "very little," slightly over 40% reported "some" or "a lot" of difficulty. Interestingly, we found virtually no differences in reported difficulty learning Graffiti across grade levels, as shown in Figure 3.

What might account for the differences in reports of students' difficulty learning Graffiti? From our review of PEP awardees' monthly activity reports, as well as student questionnaires, there is some evidence to suggest that explicit instruction in Graffiti writing and practice time were factors in students' success in learning and using Graffiti. Some teachers facilitated students' learning of Graffiti, using a variety of strategies such as games that teach Graffiti, posting posters of the Graffiti alphabet, giving students practice time, and quizzes on Graffiti.

Figure 3. Teachers' Report of Degree of Student Difficulty Learning Graffiti, by Grade Level.

Grades 3-5 n = 18; grades 6-8 n= 27; grades 9-12 n = 29.
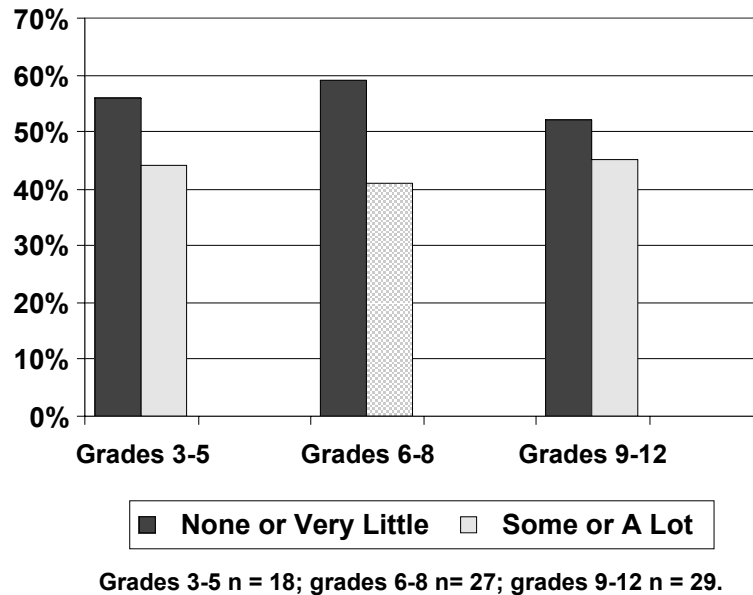
Handhelds for Home-School Communication

Handhelds were used for communication between school and home in 13 projects, which includes more projects than originally planned to use handhelds for this purpose. One teacher for whom home-school communication as an additional use wrote:

> *The use of the Palms to communicate with parents [was the most successful aspect of the PEP project]. I had no idea when I started what a valuable tool that would be for me, the students, and the parents.*

Evaluation of Handhelds in Home-School Communication

Evaluation of the use of handhelds for this purpose was overwhelmingly positive. The main benefits cited were increased parental involvement (by about 70% of respondents) and increased homework completion (by nearly 15% of respondents). Two respondents, however, indicated that parents did not use the handheld computers as much as expected.

Many comments indicated that using handhelds made communication with parents easier and more reliable and contributed to increases in parental involvement. Other comments indicated that as a result of handheld use for home-school communication, students became more responsible for their homework.

Comments about parental involvement

- *Communication was absolutely facilitated by the Palms. This has been a great year for keeping in touch with the parents.*
- *Definitely a plus for parents of special education students who do not always get the exact message across.*
- *This is great for documenting contacts so that the administration is aware of what interactions there are between the teacher and parent.*

Comments about greater homework completion

- *Students who take their computers home have a 90% homework completion rate vs. 72% completion rate for non-users.*
- *This child's parents seemed to enjoy using this tool and it seemed to keep the student interested in keeping track of his homework.*

Uses of Handhelds for Home-School Communication

Teachers who used handhelds in home-school communication used them to communicate with parents about students' homework assignments and completion, school calendar and events, and student behavior.

Use of handhelds as a home-school communication channel requires that students be allowed to take handheld computers home. When handheld computers were used to inform parents regarding homework or behavior, students gave their handheld computers to parents to review. In some cases, teachers asked parents to write comments or provide information in response.

Respondents' descriptions of handhelds for home-school communication

- *Parents know where to look to check homework assignments—this has been SO helpful—salso students used Go and Tell to take pictures and write about our water testing trips. The parents enjoyed seeing the pictures!*

- *They were used to communicate homework assignments and notes back and forth to and from teachers and parents.*

- *Twice a month the students would take their Palm home and show parents what they were learning in school. Then they would help their parents send me a note on their Palms.*

- *Student calendar and events were on the memo pad, as well as a phone list.*

- *The Palm computers go home on a daily basis with 12 out of 20 students. Homework is listed in the "To Do" list for student and parent review. Parents are sent a color-coded behavior notice. Parent sign the note daily, and the classroom teacher checks it.*

A Closer Look at Beaming

We asked PEP teachers and other team members to tell us about the use of infrared beaming and to evaluate the function. About 100 respondents offered comments. Evaluation of the beaming function as a classroom tool was highly positive. Some respondents emphasized that beaming is "the most powerful" and "valuable" part of the device for their classrooms. Only 5% of respondents reported concerns and limitations.

Evaluation of the beaming function echoed the themes that emerged in teachers' general evaluation of the benefits of handhelds for teaching and learning. Three themes in particular emerged from comments regarding the usefulness of beaming:

- Efficiency and convenience afforded by beaming
- Collaboration and social interaction are facilitated
- Beaming is fun and motivational

Nearly half of the respondents claimed that the beaming function was efficient and made some classroom tasks and activities more convenient. It made information dissemination and collection easy and accurate. Not only did it save

teachers' and students' time, but it also saved paper, according to some respondents.

Approximately 25% of the respondents claimed that the beaming function promoted and facilitated student interaction and collaboration. The motivational effect of beaming was mentioned by about 15% of respondents. They described how students became "motivated," "empowered," and "serious" about their work through use of this "futuristic" function.

A few negative comments (made by fewer than 5% of respondents), mentioned misuse of the beaming function, especially during tests and lectures. Two limitations were pointed out by the respondents:

- Not being able to write comments or corrections on student work on the Palm computer.
- Not being able to beam to the entire class at once.

Comments regarding efficiency and convenience

- *Beaming is very useful. It allows students to catch up quickly. This allowed for more time for actual instruction or interaction.*
- *The best part was the ability to read and respond to each student without having a ton of papers to carry or lose.*
- *Very useful, saved time and answered many questions that the students had. They could simply check what was beamed to them. It also saved me time when I was checking in with their work.*

Comments about facilitation of collaboration and interaction

- *Students could each be responsible for a small part of a lab problem and then share that info with their classmates. Students could collaborate to solve a problem.*
- *Students were able to share information with each other which is important in mathematics and science. By giving them a interesting way to communicate, the level of interaction was increased.*
- *This was not only a fun way to have students interact with each other, but when students worked in their teams of 4 and 5, they realized the value of everyone doing their jobs in their groups so that everyone had all the pieces of their project on their Palms. What a time saver!*

Comments about the fun and motivational aspects of handhelds

- *It is probably the most enticing feature to my students. They will do anything to beam. Beaming activities increase the level of participation to the maximum.*
- *Students feel empowered, "futuristic", and have something to show each other as a newly learned capability.*

- ▪ *When they beamed information to each other they were more careful in preparing the information and they were interested in seeing what the other person wrote… It was a very motivational tool and it really held their attention. They were more serious in their purpose and this alone makes it a worthwhile classroom tool.*

Negative comments

- ▪ *This function [beaming] is useful when it is appropriately used. It can be a very serious issue if used to cheat at test time.*
- ▪ *It [the beaming function] was actually a disruption because students would do that instead of paying attention to the lecture.*
- ▪ *Corrections on paper itself——proved impossible to replicate.*
- ▪ *I wish it could be done with more than one at a time, though, in the interest of time.*

<u>Drawbacks and Pitfalls of Handheld Technology: Challenges and Possibilities</u>

For any educational technology to be useful, there must be a strategy for integration into the classroom. This includes developing appropriate learning activities, as well as maintaining and managing the technology. As many educators have learned when introducing Internet connections into the classroom, proactively organizing and guiding students' productive use of the technology can prevent problems.

Having used handheld technology in the classroom for a semester, PEP teachers have gained knowledge about the benefits and limitations of handhelds for teaching and learning. Although PEP teachers are enthusiastic about the benefits of handheld technology for student learning and for quality of instructional activities, they also have important insights about the challenges of integrating handheld technology into the classroom, as well as strategies for avoiding pitfalls. These are critically important topics in instructional integration, classroom management, professional development, and technology design and development.

To tap teachers' insights about drawbacks, we asked PEP teachers a range of questions regarding problems, challenges, and difficulties they encountered integrating handhelds into the classroom. Information from PEP teachers' monthly reports and online discussion also provided information about problems and challenges. Additionally, some PEP teachers felt they had avoided potential problems and difficulties through their introduction of classroom policies and equipment management strategies, and we collected data on these policies and strategies.

Technical Difficulties with Handheld Computers

Technical problems and limited access to technical support can be a barrier in teachers' efforts to integrate technology into instructional activities. We asked PEP teachers to evaluate the performance and reliability of handhelds through a variety of questions, in multiple choice, Likert-type scales, and open-ended formats.

Although teachers were very favorable in their evaluation of handheld performance for teaching and learning, they did report a range of technical problems with handhelds. The primary technical problems indicated were damage to the devices (especially the screen) and problems with synchronization. Both of these problems were reported by approximately 30% of respondents.

Inappropriate Use and Its Prevention

As is made particularly evident by the introduction of the Internet into classrooms, all technology has the possibility of inappropriate use. To discover how beaming, game play, and other inappropriate uses of handheld computers were manifested in PEP classrooms, PEP teachers were asked: "Were there any problems regarding inappropriate use of Palm computers, such as use of inappropriate games, privacy issues, disruptive uses, cheating, or distraction during class time?" The majority (59%) said that there were no inappropriate uses, while 41% indicated some inappropriate uses.

Descriptions of inappropriate uses of handhelds that occurred centered on three types of uses: games played during class time; inappropriate use of beaming, and handheld use distracting other tasks.

Teachers were also asked to describe the strategies and policies they used to prevent inappropriate use of handhelds. Approximately 70% of the respondents indicated that establishing clear policies and classroom management practices prevented the occurrence of inappropriate uses. Some teachers had written appropriate-use policies and communicated them not only to students but also to parents and teachers.

> ### *Sample descriptions of appropriate-use strategies*
> - *We told the students what they could and couldn't do, early and often; we carefully went over these expectations, sent them home to parents for signing (in translation!), and communicated them to all other teachers at the school.*
> - *With the younger children, we monitored them, and they were so happy to be using the computers that distraction was not a problem.*

- *I didn't see any of the above and all the teachers in the school were aware that if the students were seen using them inappropriately in class, they could take them from the students and the students would be on Palm restriction for a certain amount of time. I think because the Palms were so special and that threat was over the students' heads, they behaved very well.*

Teachers' Perceptions about Drawbacks

In addition to the specific questions above, PEP teachers were asked a more general question: "What do you see as the major drawbacks or pitfalls of using Palm computers, for students?"

Teachers mentioned classroom integration, equipment damage, and inappropriate use as concerns. Additionally, teachers mentioned usability issues and the potential for loss and theft as drawbacks

General classroom integration issues

Just over 25% of the remarks were about classroom integration of the handheld computers. These issues included the time required for logistics, such as synching and charging handheld computers, as well as for learning the handheld computer and software; difficulty in finding and purchasing the right software; and inconvenience resulting from not having a handheld for every student.

Usability issues

About 25% of the remarks addressed usability issues. The most frequently mentioned issue was writing/input difficulty. Respondents noted that without keyboards, writing was "too difficult" and "too time consuming," especially for extended writing. Other usability issues included the small size of the screen, difficulty reading the screen outside, and memory running out quickly.

Potential for equipment damage

Approximately 20% of the remarks addressed the potential of the handheld computers to be damaged. In particular, some respondents found the handheld screen fragile (note that the models used in the PEP program have a glass screen, and many newer models have plastic screens). Others expressed concerns for possible breakage when students drop it or carry it outside. These concerns about damage were tied to concerns about responsibility for replacement of the equipment. Respondents indicated that some parents would be unable to pay for replacement equipment,

making it difficult to make parents responsible for the costs. There was also concern about the logistics and cost of having the school replace the units.

Behavioral problems

Behavioral problems associated with handheld computers were noted as a major drawback by approximately 15% of the remarks. These problems included the inappropriate use of games, cheating and copying homework from others, and the use of beaming for off-task "side talk". Some respondents also mentioned students' overuse of handheld computers and games on them as a drawback.

Potential for loss or theft

About 10% of remarks were about equipment loss or theft. Although the actual reports of loss or theft were very few, respondents were concerned about the potential. Respondents mentioned that the handheld computers are "small"; therefore, they can be "easily stolen."

While there is significant concern about loss and theft, reports of actual loss and theft were quite low across all PEP projects.

- 80% of PEP teachers reported having no equipment loss.
- 74% of teachers reported having no theft of handheld computers; 18% reported "very little" theft. Only one PEP project reported "a lot" of theft.
- Loss of styli was more common. About 10% of PEP teachers reported "some" loss of styli, and 27% reported "very little" loss. "None" was reported by 57% of teachers.

Sample Responses

General classroom integration issues

- *The learning curve. Teaching how to use the handhelds can be time consuming and take away from district mandated instructional objectives expected to be met.*
- *Inability to HotSync with limited number of desktop computers in a classroom and thus inability to share information on a large screen or printout.*
- *Time constraints. Working with the equipment takes a lot of planning and time for students to work towards collecting information. If one plans to complete an activity in one hour it seems to take an hour and a half.*

Usability

- *Some of the kids don't want to take the time to learn the [Graffiti] alphabet and they become frustrated with their results.*
- *There are limitations to the functionality of Palms used for extended writing assignments. Palm handheld computers are not a replacement for laptop or desktop computers.*
- *Hard for more than one person to see at the same time in bright sunlight light.*

Damage/Fragility

- *The Palms are fragile!!!! Teenage boys are less than graceful. Accidents happen, not because of carelessness, but because of klutziness! I would love to see Palm develop a "kid-proof" Palm that was rubberized, as many handheld video games are.*
- *Too fragile! One drop should not break the screen.*
- *Dropping the Palms ... they need to come with built in bumpers for kids.*

Behavioral problems

- *The biggest disadvantage to using the Palms seems to be the distraction factor… [I] have found that management of the class becomes much more draining when Palms are involved. Many times when new software was introduced to the students they would choose to play games on the Palms rather than listen. This compounded the problem of my students' lack of perseverance when it comes to learning to do new things.*
- *It is easy to cheat by beaming homework back and forth.*
- *Students will want to use the Palm even when it is not the best tool for the job.*

Loss and theft

- *Easily stolen—Classroom Palms should have a homing device that can be tracked by teacher. I haven't had one stolen, but I have had to keep track of every Palm every time they are used.*
- *We are concerned about allowing the students to take responsibility for such an expensive piece of equipment—afraid of loss or damage. I believe they would be better off to have the Palms with them at all times, but the cost concern prohibits use.*
- *Working with many adjudicated young people, the Palms are prime targets for theft.*

Students' Evaluation of Handhelds for Learning

To better understand student perceptions on the use of handheld computers in teaching and learning, a subset of students were asked to participate in a survey. This data represents a small subset of students, and is used primarily to shed further light on the general questionnaire findings.

Student Survey Methodology

Eleven classrooms were selected to participate in the student survey. Questionnaires were returned from eight classrooms. Classrooms were selected purposefully to represent a range of PEP project types and school demographic profiles. Only one classroom per PEP project was included. Where more than one teacher was involved in a PEP project, the participating classroom was randomly selected. A total of 170 students completed the survey, with the following grade breakdown:

Grade 7: n = 19
Grade 8: n = 15
Grade 9: n = 48
Grade 11: n = 26
Grade 12: n = 62
Total: N = 170

Approximately 78% of students reported not having used handheld computers prior to their participation in a PEP project.

Students' Evaluation of Handhelds for Learning

The students were quite positive in their assessment of handheld computers for education (although possibly not as positive as the teachers):

- 88% agreed or strongly agreed that "I liked using a Palm computer at school."
- 83% agreed or strongly agreed that "Using a Palm made learning more fun."
- 75% agreed or strongly agreed that "Every student should have a Palm computer."
- 57% agreed or strongly agreed that "Using a Palm computer makes me a better student."

Students' Favorite Handheld Activities

In an open-ended question, students were asked what they most liked to do on the handheld computer. Game playing was overwhelmingly the favorite activity. Other activities mentioned were organizing, taking notes, and beaming.

Playing games (64%)

Overwhelmingly, playing games was the favorite activity that students listed in their responses. In general, as student age increased, the number of students who cited playing games decreased:

- 80% of 8th -graders and 9th-graders cited game playing.
- 60% of 11th-graders cited game playing.
- 29% of 12th-graders cited game playing.

One anomaly was in the 7th-grade data: only 21% of the 7th-graders cited playing games, but because only one classroom of 7th-graders is represented this result may be due to specific classroom policies instituted by the teacher.

Organizing, planning, and scheduling (20%)

At the high school senior level, 37% of students cited organizational activities as a favorite, compared with 22% or fewer at the other grade levels.

As we saw in the section on handheld use in the classroom, older students are more likely to take handhelds home, and thus are more likely to use handhelds for scheduling and organizing tasks. Future reports will investigate the relationship between students' age and their use of handhelds for different activities, such as organizing.

Taking notes (18%)

Writing for class work (taking notes, writing memos, writing in journals, etc.) was listed as a favorite activity by 18% of students, overall.

Beaming (15%)

Overall 15% of students mentioned beaming as a favorite activity. Most of these students mentioned beaming in a social manner, such as "beaming notes to friends."

The Best Thing about Handhelds

We also asked students to tell us the "best thing about a Palm computer." Thirty percent of students liked the portability and convenience of being able to have their information at hand anywhere they went. Twenty-three percent of students mentioned games as the best thing about their handhelds.

> ***Sample comments***
> - *It's like a little computer that you can take everywhere with you!*
> - *The best part is you can take it everywhere.*
> - *It like having a extra brain just for memory.*

Technical Problems

Students were asked to describe any problems they had with handheld computers. In general, students did not report significant problems; 28% mentioned problems with Graffiti, and only a few mentioned problems with batteries or synching.

Other Student Comments

> - *Everyone should experience a Palm.*
> - *They would be great instead of textbooks.*
> - *What could make the Palm better, would be if they could record things, so that if you were absent from school you could just have someone record what the teacher said in class that day.*
> - *I don't think they are that great for learning, they are too much fun.*

Integrating Handhelds: What's Involved

As with all educational technology, successful integration of handheld computers into the classroom requires planning and preparation. From teachers' monthly project reports, and other data sources, we compiled an overview of some of the key issues involved in integration of handheld technology.

Dimensions of Handheld Technology Integration

Teacher Technology Training

Teachers' mastery of handheld technology includes the following dimensions:

- Learning to use the handheld computer

- Learning about available software and peripherals
- Learning to integrate handheld technology into the curriculum

Teachers need an opportunity to master basic use of the handheld computer and any peripherals being used. Beyond this, teachers need to learn about additional software applications to be used in instruction. Teachers' innovation in integration handheld technology is enhanced by knowledge of available software and peripherals. Finally, teachers told us it is helpful to have models of handheld technology-supported learning activities, as well as strategies for integrating technology into regular classroom practices.

Teacher professional development for handheld technology integration seems to be entirely consistent with the major frameworks for teacher technology competency, such as that set forth in Milken's Professional Competency Continuum.[1]

Student Technology Training

Some teachers indicated that students needed explicit training on the handheld computer, although other teachers indicated that students very quickly mastered operation of the handheld computer with little instruction. At one school we visited, teachers told us that fifth-graders "were beaming to each other within five minutes of being given the Palms."

Teachers used a variety of approaches in training students on handheld computers. For example, some teachers trained a few students as technology mentors, who in turn trained their fellow students – and sometimes trained other teachers as well. Some teachers used handheld screen projectors (such as an Elmo), or handheld emulators used on desktop computers with projected displays, to create a public display, which they used to review the functions of the handheld computer.

Learning to write in Graffiti, the special alphabet for text input on the Palm computer, requires some time for students to master. Some teachers reported giving students aids for learning Graffiti, such as games that enable students to practice, as well as giving students time to practice Graffiti and offering incentives for mastery, such as quizzes or prizes.

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[1] *Coughlin, E., & Lemke, C. [1999]. Professional competency continuum: Professional skills for the digital age classroom [Online document]. Santa Monica, CA: Author. Available at: http://www.mff.org/edtech/projects.taf?_function=detail&Content_uid1=104.*

Handheld Computer Assignment Model

Because of their portability, handheld computers can be assigned to students and used in different ways in the classrooms. Two basic assignment models are the classroom set of handheld computers and the personal tool model. The assignment model has important implications for the nature, frequency and intensity of handheld computer use by students. Furthermore, the PEP evaluation findings indicate that students develop greater ownership of handheld computers as a learning tool, and integrate the device more into organizational and learning tasks, when they are allowed to take handhelds home. The assignment model also has implications for the kinds of equipment use policies that teachers may wish to develop, as well as for equipment management issues, such as HotSyncing and recharging.

Initial Equipment Setup

Initial setup of handheld computers may involve the following tasks:

- Register software and hardware.
- Assign an ID to each handheld computer and other related devices.
- Assign the ID, handheld computers, and other devices to students (for class meeting, class use, or personal use).
- Initial setup for handheld computers, which includes the following:
- Put batteries and charge the handhelds.
- Enter user information and install all the basic programs onto the   handheld computers for young students.
- Set up desktop computers for HotSyncing handhelds. This may involve the following:
- Assign desktop computers in the classroom and/or in the computer lab for HotSyncing.
- Install Palm Desktop software and set up accounts on desktop computers under the Palm ID numbers or student names for HotSyncing
- Assign desktop computers to students.

Equipment Management and Use Policies

Routine equipment management may involve the following tasks and needs:

- Arrangements for HotSyncing and recharging batteries.
- Storage of handheld computers in classroom (for classroom set model).
- Handheld computer checkout system (for classroom set model).
- Protection of handhelds computers when transporting outside of classroom.
- Software installation on handhelds computers (for personal tool model).

- Collecting work from or clearing data off handhelds between classes (for classroom set model).

A school may wish to develop policies related to equipment use, accountability, and replacement.

- Establish rules and practices regarding equipment management to avoid loss and damage.
- Policies and plans for replacing lost or broken equipment (e.g., reserve "extra" handhelds computers for replacement).

Instructional Planning for Curricular Integration of Handhelds

A critical aspect of technology integration is instructional planning. Two primary tasks are the following:

- Designing learning applications for handhelds.
- Identifying opportunities in regular classroom processes and/or instructional activities where handhelds can confer benefits.

Knowledge of educational or educationally relevant software and peripherals for handhelds, as well as of instructional resources, is very helpful in planning curricular integration of handheld technology.

Once teachers have explored hardware and software and planned curricular activities for handhelds, purchasing plans may need to be made and funding identified.

Integrating Handhelds with Other Technologies

Handheld computers are probably best not viewed as a replacement for desktop computers but as a supplement to them. A key factor in making effective use of handheld technology, therefore, is in planning integration of handhelds with other technologies. Thinking through the integration of handhelds and desktop computers involves addressing some of the equipment management issues discussed above, such as setting up procedures for HotSyncing handhelds, as well as analyzing instructional activities to evaluate learning tasks, and activities may need to be divided between handheld computers and desktop computers. For example, with writing, students may write on handhelds, then beam papers to an infrared port on a printer, or they made need to transfer their documents to a desktop computer for printing. In another example, students may collect data outside using handhelds and sensors, and then synch their data to a desktop computer for data analysis. In sum, integrating handhelds with other technologies may involve, among other things, the following aspects:

- Backing up handheld computer data onto desktop computers
- Analyzing instructional activities to evaluate such needs as:
- The "work flow" and appropriate or needed technologies for each stage (e.g., writing and printing; data collection and data analysis)
- How student work will be collected and returned.

Conclusions

Handheld technology is emerging as an effective instructional technology in K-12 classrooms. PEP awardees' implementation and evaluation of handheld technology clearly establishes that this technology can be used effectively in grades 2-12.

Overwhelmingly, PEP teachers stated that handheld computers are an effective instructional tool. The portability and versatility of handheld computers allows computing to be integrated into a wide range of instructional activities, both in and out of the classroom. These teachers indicated that handheld technology confers a range of benefits on instruction, including improving the quality of instructional activities, promoting students' autonomous learning, enhancing students' communication and collaboration, improving students organizational skills, and enhancing students' motivation.

Although teachers were overwhelmingly positive about the benefits of handheld computers for teaching and learning, they also experienced various technical difficulties and drawbacks in using handhelds in the classroom. About 30% of reporting teachers mentioned problems with synchronization and equipment damage among the problems they experienced. Other drawbacks of handheld computers in the classroom that teachers cited included inappropriate use by some students (primarily playing games and off-task use of handhelds) and logistical challenges associated with integration of handhelds.

As with all educational technology, planning and preparation are important aspects of successful integration of handheld technology into the curriculum. PEP teachers have provided a wealth of information regarding the key issues in equipment management and technology integration for handhelds. Assigning handhelds to students, IDing them, and developing appropriate—use policies and responsibility agreements were cited as important tasks. It is also important for educators to create routines for synchronization and charging, and methods for storage and protection of handhelds. Many teachers also reported the need for

resources and references related to handheld software and peripherals in order to better leverage handheld technology in instructional activities and tasks.

While planning and preparation are important, many PEP teachers also reported a range of unplanned uses of handhelds that emerged in their classrooms, in many cases introduced by students. These uses were driven by the discovery of additional software that could be used in instructional activities, as well as students' desire to use handhelds as an integral part of their educational experience.