Palm™ Education
Pioneers Program

Final Evaluation Report

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Palm™ Education Pioneers Program: Final Evaluation Report

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The Palm Education Pioneers program was conducted from February 2001 through August 2002. It is no longer awarding grants. For more information about the PEP program contact:

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Executive Summary

Recent years have seen increased interest in the use of handheld computers for K-12 education. 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. The Palm™ Education Pioneer (PEP) program was created to remedy this situation. The goals of the PEP program were (1) to determine whether classroom teachers find handheld computers a useful educational tool, and (2) to aggregate the knowledge base of a large set of teachers using handheld computers in their classroom. This, the final report on the PEP program, is intended to provide information to those interested in the benefits and drawbacks of handheld computers in the classroom.

This report is based on data collected from the 102 Classroom Teacher Awards during the 2001-2002 academic year. All PEP awards were granted as part of a competitive program. PEP awardees are talented, innovative teachers who collectively have integrated handheld technology into a wide range of instructional activities.

PEP teachers were overwhelmingly positive about the use of handheld computers in their classrooms. Approximately 90% of PEP teachers stated that handhelds are an effective instructional tool; that handhelds have the potential to have a positive impact on students' learning; and that they will continue to use handhelds in the future. Although teachers across all grade levels were positive about the use of handheld computers in their classroom, elementary school teachers were more positive than middle and high school teachers. Teachers who used handhelds for science-based curricula or for writing-based activities found handhelds most effective, although handhelds were found to improve learning activities across many curricular topics and instructional activities.

PEP teachers found that the key benefits to students were increased time using technology, increased student motivation, increased collaboration and communication, and benefits from having a portable and accessible personal learning tool. Key drawbacks included inappropriate use (especially of beaming), technology management issues (particularly synchronization issues), usability issues (particularly using the Graffiti software program for long text input), and equipment damage.

PEP teachers reported that having the appropriate software and peripherals was key to the success of their handheld implementation. The use of probes was considered vital to most science-related curricula, and the use of keyboards was considered vital to extended writing assignments. Nearly all teachers reported that additional software was essential to maximizing the benefits of handhelds for learning.

When assigning handheld computers to students, PEP teachers either used a "shared set" strategy, or a "personal use" strategy. When compared to the more restricted "shared set" strategy, the "personal use" strategy, according to PEP teachers, was more likely to increase students' time spent on schoolwork outside of school time, organization, homework completion, technology proficiency, and opportunity to use technology.

This report concludes with a look forward into the possible future of handheld technology in education. We examine how features of handheld computers, such as mobility, beaming, and personalization of computing at school, create new possibilities for teaching and learning. We also consider how new and anticipated products and technologies, such as wireless connectivity, could amplify key features of handhelds to extend the benefits of handheld technology for teaching and learning.

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Chapter 1: Introduction

The desktop computer has been a part of K-12 education in the United States for approximately 25 years. During this time, research has examined the benefits and limitations of computer technology in schools, as well as conditions that limit and promote its effectiveness. Overcoming some of the limitations of desktop computers in schools has proved neither quick nor easy. Now, handheld computers are emerging as a promising new educational technology, after having been in wide use in business for about seven years. Much of the excitement that greeted the desktop computer has marked the arrival of the handheld computer. Will handheld computers fulfill technology's promise as a learning tool?

The Palm™ Education Pioneers program is the first large-scale, objective, and systematic evaluation of handheld technology for education. The goal of the PEP program was to evaluate the potential of handheld computers for K-12 teaching and learning. To do this, we examined a wide variety of uses of handheld computers, designed by over 100 teachers and implemented in their own classrooms, with diverse students around the country. We evaluated the effective instructional uses of handheld computers, as well as the conditions and implementation strategies that facilitated success. Equally important, we sought to understand the pitfalls and limitations of handheld computers in the classroom.

The primary aim of this report is to provide a research base that can be used by educators, researchers, and others interested in educational uses of handheld computers to make informed decisions about adoption and strategies for implementation. As 25 years of research on desktop computers has demonstrated, under the right conditions, technology can have a beneficial impact on teaching and learning. These conditions include appropriate resources, support, training, and time for teachers to experiment and plan. But in addition, to teach with technology creatively and effectively across the curriculum, teachers need a vision of the possibilities a technology offers. This report also aims to help educators understand the possibilities of handheld technology to transform teaching and learning. We offer a view into some of the PEP classrooms of 2001-2002, as well as a glimpse into the possible future of handheld technology in schools. Finally, this report draws on over 100 PEP teachers' full year of experience using handheld computers in the classroom to offer teachers specific strategies and pragmatic information that can guide adoption and classroom implementation of handheld technology.

About the PEP Program

Through the Palm Education Pioneers (PEP) program, Palm, Inc., awarded sets of handheld computers to over 175 K-12 classrooms throughout the United States. The PEP program was administered and evaluated exclusively by SRI International's Center for Technology in Learning (CTL). SRI International is a leading non-profit, independent research firm. SRI maintains complete objectivity in all research work, and neither Palm, Inc., nor any other vendors had any influence on any aspect of this evaluation study.

The PEP program has granted two types of awards:

Classroom Teacher Awards. There were two rounds of PEP Classroom Teacher Awards. The first round was granted in February 2001, the second round in June 2001. There were a total of 102 Classroom Teacher Awards, and all awardees were classroom teachers or technology coordinators in K-12 schools.

PEP Research Hub Awards. Nine Research Hub Awards were granted in June 2001. Awardees were 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 award recipient received from six to 15 classroom sets of Palm computers.

All PEP Classroom Teacher Awards were granted as part of a competitive program. To qualify for an award, educators submitted proposals to the PEP program, which were rated by an independent panel of external reviewers, according to a set of criteria provided by SRI. No requirements were specified in terms of content areas or grade levels; instead, teachers were encouraged to create innovative projects in areas they felt were most appropriate.

There were a total of 102 Classroom Teacher awards, and all awardees were classroom teachers or technology coordinators in K-12 schools

Figure 1.1: Grade levels of PEP Projects

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

Figure 1.2: Demographics of PEP Projects

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

Figure 1.3: Primary Subject areas of PEP Projects

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

This report summarizes the findings based on evaluation of the PEP Classroom Teacher Awards.

Overview of PEP Classroom Teacher Awards

PEP awardees were 102 talented teachers from around the country. Each award winner agreed to implement his or her proposed PEP project during the 2001-2002 school year. In addition, award recipients agreed to participate in SRI International's evaluation of the PEP program, as well as to conduct their own evaluation of their PEP project. PEP project evaluation plans were included in the proposals for PEP grants. Figures 1.1 through 1.3 present information concerning the distribution of grade levels, demographics, and project topics across PEP projects.

Research Design and Methods

The core of the PEP program is the use of handheld computers by practicing teachers in their own classrooms, with diverse types of students. PEP evaluation findings are based on teacher-designed and teacher-implemented use of handheld technology in classrooms across the United States, from grades 2 through 12.

PEP awardees are talented, innovative teachers who integrated handheld technology into a wide range of instructional activities. The PEP evaluation study relied primarily on teachers' reports on their experiences using handhelds for teaching and learning in their own classrooms. As a relatively technology-savvy group, PEP teachers are not representative of all teachers generally, and therefore their evaluation of handheld computers for teaching and learning cannot necessarily be assumed to generalize to all teachers. However, the PEP teachers are in other ways a highly diverse group, in terms of the grades and subjects they teach, the kind of students they teach, years of experience, and teaching style. The diversity of the PEP teacher group constitutes a strength of the evaluation data. The evaluation study was able to aggregate data from many types of teachers working in many types of classrooms, using handhelds for a wide range of instructional purposes. This gives us a far more rounded view of the performance and usefulness of handheld computers in the classroom than if we had looked at handheld use for only one or two subjects at one grade level.

The core of the PEP evaluation study was the PEP teacher questionnaires, which were administered at the end of each semester of the PEP program. We chose a survey study for several reasons. The main goal of the PEP program was to examine the benefits and limitations of handhelds for education, looking across a wide range uses—a goal that is best met with a survey study. Second, data collection that focused on teachers' reports was well suited to the aim of understanding, from teachers' perspectives, the practicalities of implementing handhelds in the classroom—such as managing the equipment and tracking student work on the handhelds—as well as understanding the difficulties and technical problems that teachers reported. Other approaches, such as quasi-experimental design, would have been less effective at meeting these goals. Finally, educational uses of handheld technologies are still being developed and compelling usage scenarios are only now being identified. We hope that the findings reported here will contribute to the development of quasi-experiment research on the effect of handhelds on teaching and learning.

The PEP evaluation study used a two-level evaluation design that consisted of (1) SRI-created surveys of PEP team members and students, augmented by 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.

This evaluation reports on data from 86 PEP projects in Fall 2001 and 83 PEP projects in Spring 2002 (out of a total of 102 projects). These projects implemented handheld technology for teaching and learning during the 2001-2002 school year, and provided evaluation data to SRI International. In Fall 2001, 147 PEP teachers and their PEP team members completed questionnaires. In Spring 2002, 114 teachers and their teammates completed questionnaires.

Based on the characteristics of the PEP team members, we created two non-exclusive subsets of cases from the questionnaire data: individuals most knowledge-

able about projects and individuals most knowledgeable about students. Thus, we had three datasets in total: the entire dataset of all respondents and the two subsets. Analysis of some questionnaire items included all respondents in the dataset; some analyses included only PEP awardees in the dataset (for analysis of items for which it was important to have only one respondent per project); and some analyses included only PEP teachers and/or other team members most knowledgeable about students' experiences and actual classroom use of the handhelds.

Project Self-Evaluation Reports. Each PEP project was 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. All reports were submitted online and carefully reviewed and coded by SRI researchers.

Student Survey. Students from 25 PEP projects participated in SRI's Fall 2001 and Spring 2002 student survey. A total of 425 students, in grades 1, 3, and 4 through 12, completed questionnaires. PEP projects participating in the student survey were purposefully selected to represent a range of curricular topics and student demographics in the sample.

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

About This Report

This report is the final of three reports on the Palm Education Pioneers program. All reports are available at www.palmgrants.sri.com.

The first two reports, released in October 2001 and March 2002, were designed to address these general concerns about the utility of handhelds in the classroom:

- The effectiveness of handheld computers as an instructional tool
- Benefits of handheld computers for teaching and learning
- Difficulties in using handheld computers in the classroom
- Issues in integrating handheld computers in the classroom

In March 2002 we reported on promising applications of handheld technology such as:

- Using handhelds for inquiry learning
- Using handhelds for student and home-school collaboration
- Using handhelds for extended writing projects

When the PEP program began, the appropriateness of handheld computers in K-12 education was by no means clear. Doubts about handhelds for learning included the following:

- The small number of education-specific applications for handheld computers
- The fear that handhelds required too much motor coordination for young students

- The perception that handhelds were too fragile for the rough-and-tumble world of adolescents
- General doubts that a device designed as a "personal digital assistant" for the business executive could find a niche in the classroom

Finally, the familiar challenge was raised: "Are handheld computers just another flash-in-the-pan technology that will have little to no impact on education? What makes this different from all the other technologies, from film strips to the Internet, that claim to revolutionize education, but in the end have only marginal impact?"

Are handhelds a "flash-in-the-pan"? As the March 2002 PEP report showed, and this report echoes, there is something new and unique about handheld computers in education. For the first time, students can have a truly portable and personal low-cost anytime/anyplace general learning device that can be used in any number of individual or collaborative learning activities such as taking measurements at a stream, learning vocabulary words while waiting to be picked up after soccer practice, or working on a report while on a long car ride.

Are handheld computers just another flash-in-the-pan technology that will have little to no impact on education?

At this writing, it is now evident that a large number of educators believe that there is a useful role for handheld computers in education. This belief is based on the prior results of the PEP program, as well as on reports of successful implementations of handheld computers in schools and school districts around the country.

A large number of educators believe that there is a useful role for handheld computers in education

However, is there a real basis for such a belief? This report will first revisit a subset of the findings from the March report and verify that, after a full year of using handhelds in the classroom, PEP awardees are still enthusiastic about the instructional effectiveness of handheld computers. In addition to examining PEP teachers' general evaluation of handheld technology for teaching and learning, we also examine assignment models for implementing handhelds in the classroom, issues related to equipment management, and how use of handheld technology impacted teachers' technology integration strategies and teaching and learning in their classrooms.

In addition to examining the effectiveness of handhelds across a variety of grade levels and subject areas, we also draw upon the accumulated wisdom of PEP teachers to better understand ways to leverage this exciting new technology, and strategies that have been devised by the pioneering PEP to address some of the drawbacks and pitfalls.

To aid the education practitioner, there are "Strategies for Success" and "PEP Projects: A Closer Look". These sections distill the experience of the PEP teachers into a form that is intended to answer the practical questions that teachers have.

Environmental Science for High School Students

Project Information:

Grades: High School

Teacher: Patricia Chambers

Other resources used: Vernier probes and the ImagiProbe system; Temperature, pH, and dissolved oxygen probes, and a colorimeter for nitrate and phosphate concentrations. ThoughtManager was used to store collected information in the lab. The handhelds were synched with a central computer and the collected data stored on a server where students could retrieve it for analysis.

Project Description:

Patricia Chambers and Sherry Spurlock of the Pekin Community High School in Illinois used handheld computers and probes to determine the water quality of the Illinois River. Several times during the school year students collected river data in an effort to calculate water quality based on indices developed by Southern Illinois University for the "Rivers Project".

Students used the Palm handheld computers along with the ImagiProbe system and Vernier probes to collect both on-site and laboratory data. The students conducted the following tests: pH, temperature, dissolved oxygen, nitrate and phosphate concentration, turbidity, total solids, fecal coliform count, and biochemical oxygen demand. Students imported this data into spreadsheets for further analysis.

Students also used ThoughtManager to outline their data analysis process, and to sketch their assigned portion of the river system. In addition, students used the memo pad for weekly journal entries outlining their activities related to the project.

Two classes participated in the study. Each class used handhelds with probes for part of the year, and used traditional data collection methods for part of the year. When using the handhelds, students were allowed to take them out of the classroom to become familiar with the technology. Practice sessions with the probe system were scheduled into class time.

The teachers report that the use of handheld technology had a tremendous impact on student involvement. Without the use of handhelds, most teacher effort was focused on the mechanics of conducting tests, and students were often unaware of the purpose behind the test. Using handhelds, students focused on the reason behind the tests, asked more engaging questions, were more on task, and were effective collaborators. Finally, they report that students are now able to investigate remediation alternatives for the area, an instructional goal that has been out of reach using traditional methods.

Using handhelds, students focused on the reason behind the tests, asked more engaging questions, were more on task, and were effective collaborators.

Chapter 2: Teachers' Evaluation of Handheld Technology

PEP teachers' evaluations of handheld computers as tools for teaching and learning are overwhelmingly positive. These evaluations, which were collected throughout each stage of the PEP program, were based on a wide range of projects and purposes, spanning grades 2 through 12. The robustness of this finding, and its persistence over a year and a half of handheld use and PEP data collection, show that handheld computers have a productive role across a wide spectrum of instructional topics and purposes, grades, and student populations.

These teachers report that handhelds have positive effects on student learning, on teaching practices, and on the quality of learning activities. Teachers also indicated 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.

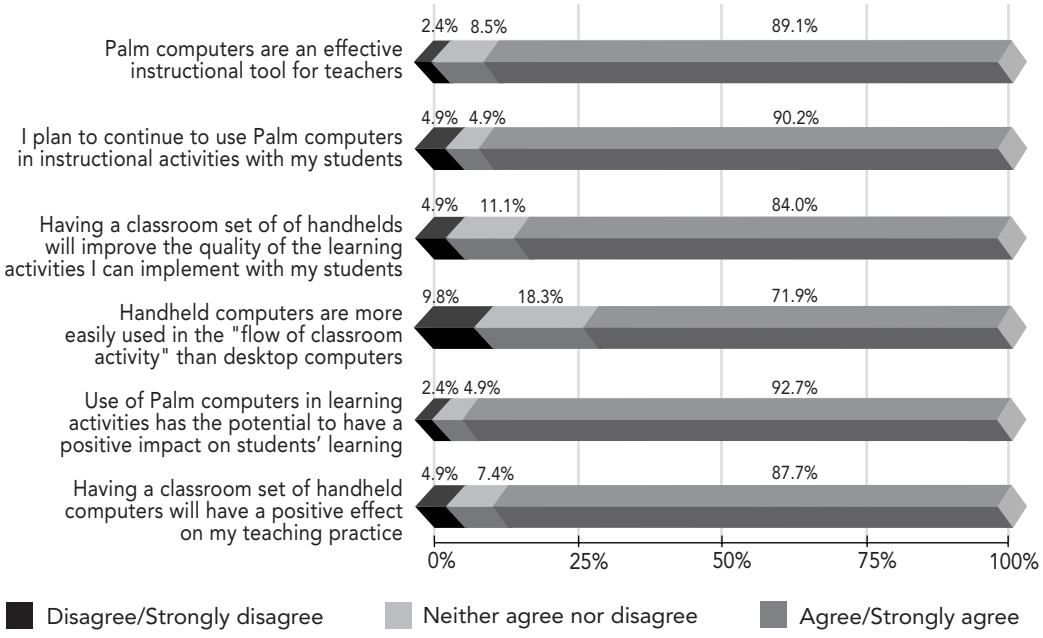
Evaluation of Handheld Computers as an Instructional Tool

In our teacher surveys, we asked about PEP teachers' evaluation of the effectiveness and impact of handheld computers, as well as their satisfaction with the technology's performance. Figure 2.1 shows PEP teachers' evaluation of the use of handheld computers across a range of dimensions. Approximately 90% of PEP teachers stated that handhelds are an effective instructional tool, that handhelds have the potential to have a positive impact on students' learning, and that they will continue to use handhelds in the future. Approximately 85% of PEP teachers stated that handhelds can improve the quality of learning activities and can have a positive effect on their teaching practices.

Approximately 90% of PEP teachers stated that handhelds are an effective instructional tool

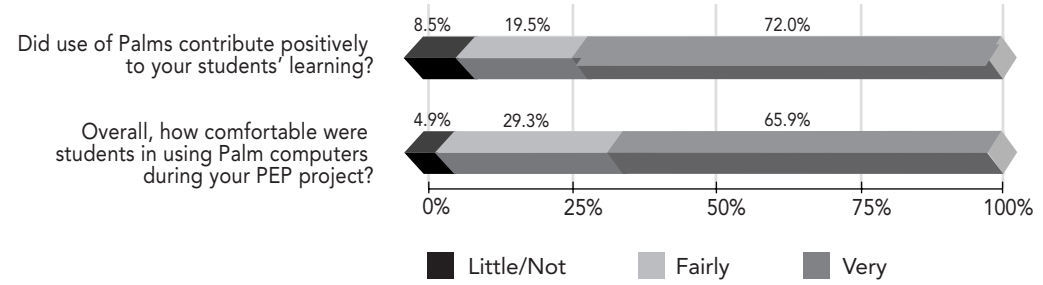
Although very enthusiastic, teacher evaluations of the use of handhelds across a number of dimensions showed a slight decrease from the numbers reported in our March 2002 Report on the PEP evaluation. We believe this is because PEP teachers' use of handhelds was still new at earlier phases data collection, and there may have been some "novelty effect" operating. The data in Figure 2.1 were gathered after the teachers had had handheld computers for a full academic year, and had experienced the benefits and drawbacks in one year of the "real world" in their classrooms. As time goes on, we may expect these numbers to stabilize or increase, as teachers gain more experience at exploiting the unique advantages of handheld computers in learning activities, and in designing strategies for their smooth integration.

Figure 2.1: Teachers' Evaluation of General Benefits of Handheld Computers



Over 90% of PEP teachers stated that handhelds contributed positively to student learning.

Figure 2.2: Evaluation of the Impact of Handhelds on Student Learning



Evaluation of Handheld Computers on Student Learning

PEP teachers indicated that using handhelds as a learning tool had a positive effect on students' learning. Over 90% of PEP teachers stated that handhelds contributed positively to student learning (See Figure 2.2).

While PEP teachers may not be representative of all teachers generally (perhaps being more technologically savvy on average), nevertheless, they do represent a broad sample of teachers, with a wide range of technology proficiency levels, training, experience, and student populations. In addition, most PEP teachers had no experience, prior to the PEP program, in using handhelds for teaching and learning. We believe these characteristics (among other considerations) make the PEP program findings largely applicable to students and teachers in general.

Evaluation of Handheld Computers Based on Grade Level

Teachers' evaluation of handhelds showed a fairly strong (though not statistically significant) trend, with elementary school teachers being the most enthusiastic about the use of handheld computers, followed by middle school teachers, then high school teachers. (Figure 2.3 shows an analysis of teachers' evaluation of handheld computers by grade level.)

It may be surprising that elementary school teachers are more enthusiastic about the use of handheld computers than their upper-grade peers, because it is sometimes said that young students may not have the technical savvy to effectively use handheld computers, or the fine motor coordination required to use the touch-screen input. However, it is clear from these findings that young students *are* able to use handheld computers as a productive learning tool.

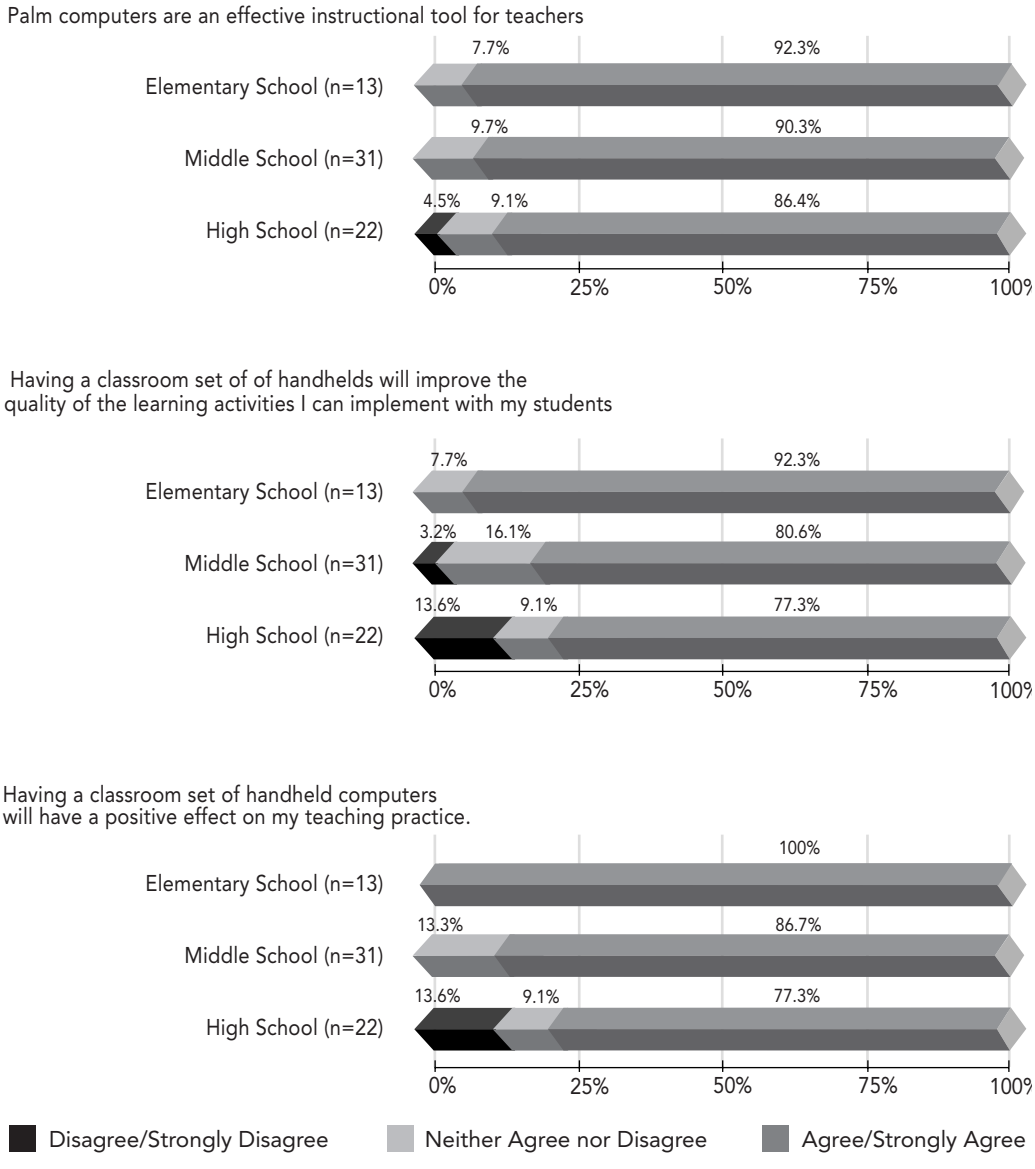
We examined whether access to desktop computers, as an alternative to handhelds, might underlie the small differences among teacher grade-level groups in the strength of positive evaluation of handhelds. If high school students and teachers have convenient access to desktop computers and a 1-to-1 ratio, we reasoned, this may result in relatively less enthusiastic about handhelds, because an alternative is available. To check this, we examined whether teachers at different grade levels differed systematically in reported frequency of use of desktop computers. They did not. We also examined whether type of handheld computer use (e.g., in core curricular areas versus as a cross-cutting learning tool) or teaching style might vary systematically by grade level and thus affecting teachers' ratings. This was not the case.

More research is required to determine whether elementary school teachers are indeed more enthusiastic about handheld computers in the classroom than other teachers, and if so, why. Hypotheses that might explain our finding include the following:

- Elementary school teachers are more optimistic than teachers in higher grade levels
- The simpler content of elementary school classes is more suitable for the small handheld screen than the content in higher grade levels
- Elementary school teachers are less constrained by standardized testing, and so have more latitude to take advantage of the benefits of handheld computers.

Figure 2.3: Evaluation of Handheld Computers by Grade Level

(n = number of projects reporting for that grade level)

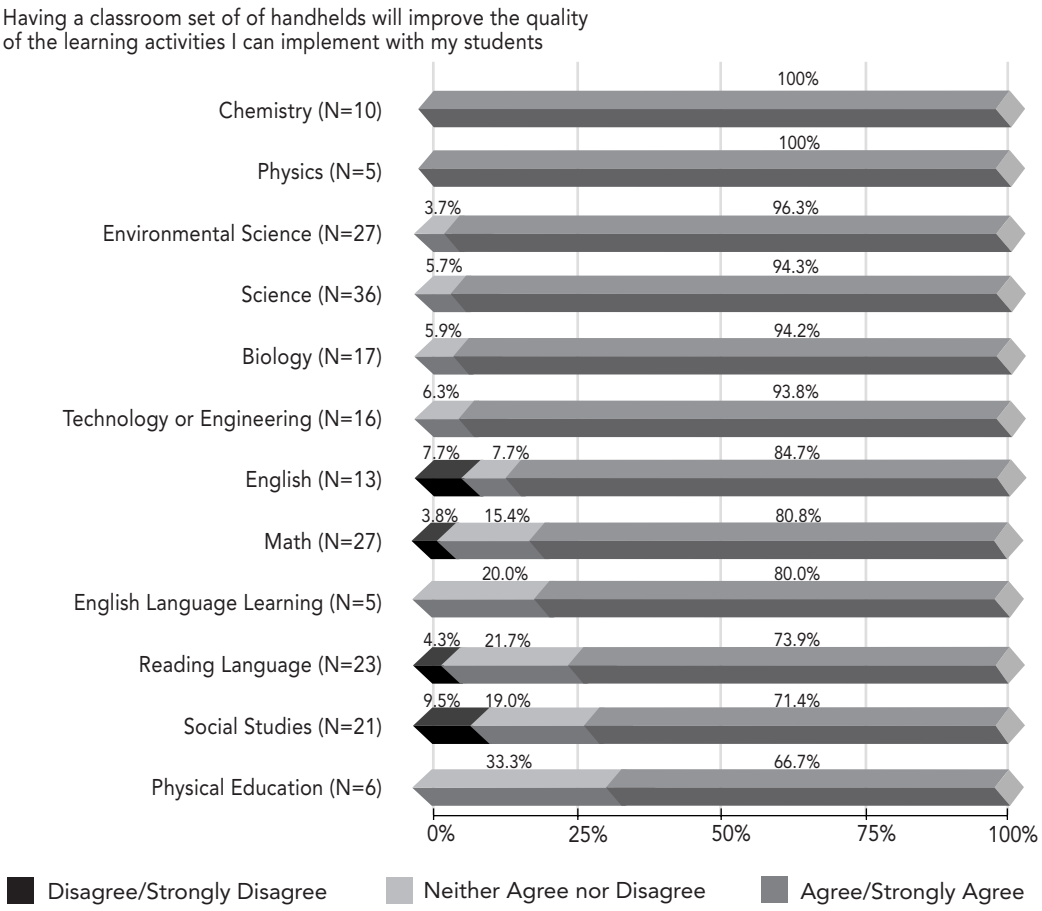


Evaluation of Handheld Computers Based on Curricular Area

We examined how PEP teachers' evaluation of handheld computers differed according to how they used handheld technology. Although a large majority of teachers across all curricular areas find that handheld computers can improve the quality of learning activities, teachers who use handhelds for science are most enthusiastic about the use of handheld computers in the classroom. Figure 2.4 shows teachers' evaluation of handheld computers by curricular area. Well over 90% of teachers who engaged in science-based curricular areas reported that handheld computers can improve the quality of learning activities. This enthusiasm is likely due to a number of factors, including the mobility of handheld computers, the availability of calculators and spreadsheets for data analysis, and the availability of handheld computer peripherals, such as probes and sensors.

Over 90% of teachers in science-based curricular areas believe that handheld computers can improve the quality of learning activities.

Figure 2.4: Evaluation of handheld computers by curricular topic



Teachers involved in the few PEP projects that had a physical education component were least enthusiastic about the use of handheld computers. This is somewhat surprising, because the mobility of handheld computers, combined with the use of probes for health monitoring (heart rate, for instance) point to a new and exciting direction for physical education activities: Students can more easily investigate how physical activity directly results in changes to critical health indicators. We posit two potential explanations for this lack of enthusiasm. The first is simply the small number of projects employing physical education components (one teacher makes the difference between a 66.7% agreement rating and an 80% agreement rating). The second is the lack of materials for physical education, combined with the historical lack of an inquiry approach to physical education classes. We expect that, if inquiry becomes a

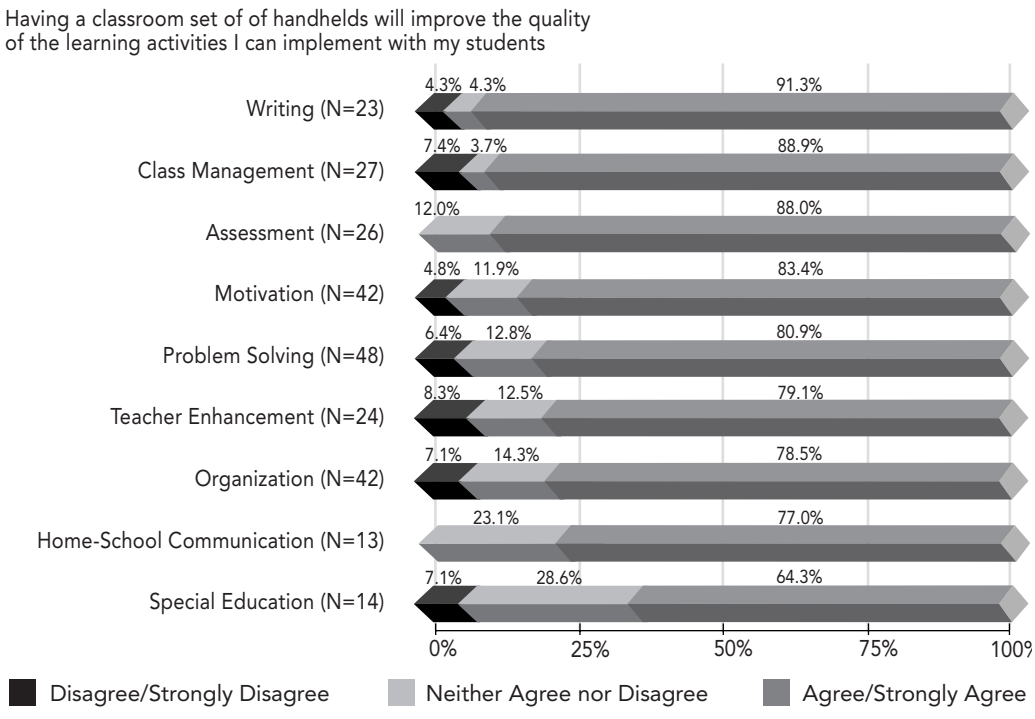
more significant aspect of physical education, handheld computers will become more valued in these classes.

A range of 70% to 75% of teachers involved in reading and social studies projects agreed that handheld computers can improve the quality of learning activities. While this clearly indicates that handheld computers can be used effectively in these subject areas, this is the low end of the rating scale for PEP teachers. This is most likely due to a number of factors, including the lack of materials created specifically for these topics, and a smaller benefit to having a small mobile computer for these subject areas.

Eighty percent of teachers involved with English language learners (ELL) projects, and almost 85% of teachers of PEP projects implemented in English classes found that handhelds improve the quality of learning experiences. At first glance it may be surprising that teachers of these topics were more enthusiastic about the use of handheld computers than teachers in social studies: after all, we expect the same drawbacks for English projects as for social studies projects. However, English and ELL projects rely mainly on eBooks, dictionaries, thesauri, and writing tools (such as the Memo Pad or word processor). By providing handheld computers to every student in the class, all students can use these computer-based tools to improve their writing and language skills. And, as evidenced below, PEP teachers found handheld computers to be particularly useful for writing activities.

Figure 2.5 shows teachers' responses broken out by the types of instructional activities they employed. It shows, for example, that 91.3% of teachers who had their students use handhelds for writing assignments reported that they thought the use of handhelds will improve the quality of learning activities. This finding, while consistent with prior PEP reports, may be surprising: since most classrooms already have computers, and most schools have a computer lab, why would teachers use a handheld computer for writing assignments?

Figure 2.5: Evaluation of handheld computers by activity



The answer can be found by considering key features of handheld technology: small size, the ability to have a handheld for every student, and the availability of keyboards and word processors for handheld computers. To engage

in writing activities in most of today's classrooms, students must either 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 or her own assignment, then beam it to other students for editing, beam to an IR-enabled printer, or synchronize to a computer to hand the work in.

We found that while a majority of teachers who used handhelds with special education students reported an improvement in the quality of learning activities, this was one of the weakest instructional areas for handhelds. This is surprising, as earlier PEP evaluation data indicated that special needs teachers are particularly enthusiastic about the use of handheld computers. Additionally, some special needs teachers are among the most enthusiastic of the PEP teachers. Further research is required in this area to understand the discrepancy and determine what types of handheld-enabled scaffolds are particularly well suited for special needs students, and what aspects of handheld computer use are less productive for special needs students.

Evaluation of Handheld Computers and Teaching Style

In the PEP evaluation study, we examined the connection between teachers' instructional style and their use and evaluation of handheld computers. Becker and Riel's (1998) Teaching, Learning, and Computing Study found that teachers who are more comfortable with a constructivist learning style are more likely to use Internet-connected computers for teaching and learning. In Fall 2001, we administered a measure of constructivist teaching style, adapted from the measure used in the Becker and Riel study. Using this data and our Spring 2002 Teacher Survey data, we investigated the relationship between constructivist teaching style and evaluation of handheld computers.

Based on their scores on the constructivist teaching style measure, teachers were divided into three categories: high, medium, and low constructivist teaching style. Figure 2.6 shows that the teachers who completed the measure divided nearly equally across the three groups.

Figure 2.6: Constructivist Teaching Style Categories

CONSTRUCTIVIST TEACHING STYLE	NUMBER	PERCENT
Low	27	28.7
Medium	23	24.5
High	27	28.7

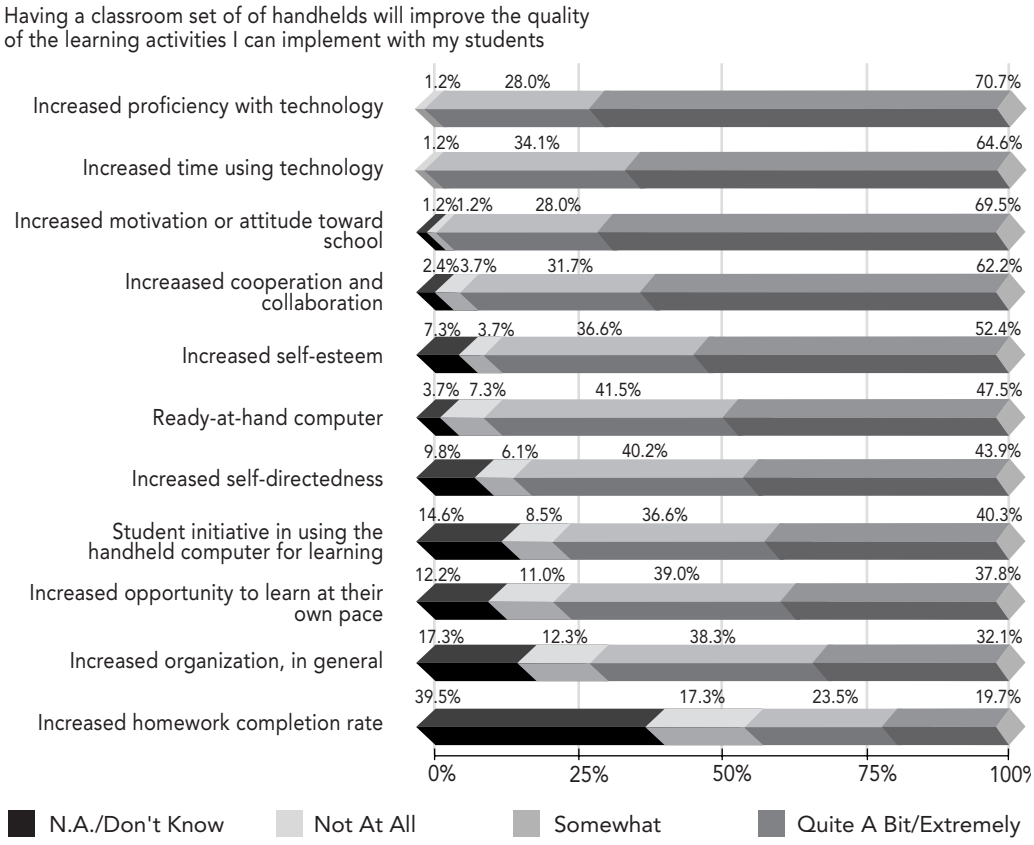
There was a trend, although not statistically significant, for high-constructivism teachers to evaluate handheld computers more positively than their medium- and low-constructivism peers. However, medium-constructivism teachers did not consistently, across all dimensions, evaluate handhelds more positively than low-constructivism teachers. This may be because low-constructivism teachers were more likely to be elementary school teachers, and elementary school teachers were the most favorable of all grade level groups. The PEP findings point to an important research area: Is the use of handheld computers consistent with the Becker and Riel (1998) findings related to desktop computers, and do high-constructivism teachers more readily integrate handheld technology? The PEP study findings show that inquiry-based science and open-ended writing tasks are particularly effective for handheld computers use, and both of these are generally considered constructivist uses of technology. However, some PEP teachers reported suc-

cess in using handheld computers for flash cards and multiple choice quizzes, which are less constructivist uses of technology.

Specific Benefits of Handheld Technology for Teaching and Learning

PEP teachers report that use of handheld technology in their classrooms confers a range of benefits to students, including increased access to and proficiency with technology as well as more complex and subtle impacts, such as increased self-directedness in learning and increased collaboration and cooperation. Figure 2.7 shows how teachers rated specific benefits of handheld computers. Teachers also provided more complete explanations of what they considered to be the most beneficial aspect of handheld computers.

Figure 2.7: Teachers' Rating of Specific Benefits of Handheld Computers



Increased Time Using Technology, and Increased Technology Proficiency: PEP teachers reported that handheld computers allow students to use technology more often and more intensively than was otherwise possible. Additionally, PEP teachers stated that it is important for their students to become proficient with technology. By providing a one-to-one computing ratio with new technology, PEP teachers indicated that they are giving their students valuable technology experience. The following comments from two teachers exemplify how teachers see handheld technology as increasing students' proficiency with technology:

- I believe that handheld computers can be used in my classrooms (with keyboards) for a wide variety of applications, from notes, to an on-going lab manual to data collection during site field trips. Learning to use these units as a tool gives students a tremendous advantage in school, and I believe, in future business enterprises.
- Students who were using handhelds were given an opportunity to use current technology in association with their normal classroom activities. This allows students to be familiar with other forms of technology beyond their X-Box and desktop computer. It also shows them how technology can be used in the "real-world" through data collection and analysis applications.

Increased Motivation: Use of handheld computers in the classroom has a motivating effect on students, and when comparing results from the March 2002 evaluation results to the current results, the importance of motivation seemed to *increase* over time.

This is surprising because one would expect, that as the novelty of handheld technology wanes, the motivational effects of using the technology would similarly decline. As we wrote in the March 2002 PEP Evaluation Report:

> *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*[i].

An analysis of teachers' comments on this topic suggests that there may be four distinct sources of motivational effects of handhelds for students:

- Motivational effects stemming from the novelty of doing something new in the classroom
- Motivational effects attributable to the perceived status associated with use of the device, which is usually used by business people and new in school
- Motivational effects due to the use of more leading-edge technology, which is exciting to technology-savvy students, who are therefore more likely to be engaged in learning activities when relevant technology is used in a meaningful way
- Motivational effects due to the perception that the use of handhelds is better than other ways of working in school.

Data collection becomes interesting and fun.

It may be that motivation due to novelty did in fact decrease over time, but that motivation due to other factors remained stable or even increased over time. Certainly, PEP teachers' comments indicate that motivational effects of handheld use remained robust through the second semester of students' use:

- For students the biggest factor I see is motivation. They are motivated by the "coolness" factor of it, and after that wears off they are motivated by the fact that there are no papers to lose or get messed up. And if they do "lose it" another student can beam it to them instantly.
- Students are engaged and interested in activities they might normally avoid when you put a Palm in their hand. Data collection becomes interesting and fun with Palms.
- [Handhelds] engage the students, especially since students are technologically savvy.

Increased Collaboration and Communication: Teachers found the beaming function to be an effective tool for student's sharing and comparing of information in learning activities and for coordinating classroom work. Handhelds were seen as supporting student collaboration in small-group work, as well as supporting students' spontaneous collaboration, mutual aid, and information sharing. As a PEP teacher stated, "Information can be shared easily with peers and the teacher, [handhelds] facilitate small-group work."

Some teachers mentioned the convenience of quickly passing out documents to students and collecting student work, through beaming. While teachers see the infrared beaming function as a source of some of the benefits of handheld computers, some teachers mentioned that the lack of broadcast beaming is a limitation.

Portable and Accessible Instructional Tool: The portability of handheld computers gives students access to digital information and makes computing technology "ready-at-hand" at the time and place that it's needed. This gives students truly "anytime and anywhere" access to the full range of handheld applications and peripheral tools—such as the calculator, word processing software, probes and sensors, data analysis tools, organizational tools, and digital cameras. The following comments from teachers exemplify how teachers see handheld technology as providing technology access when and where it is needed:

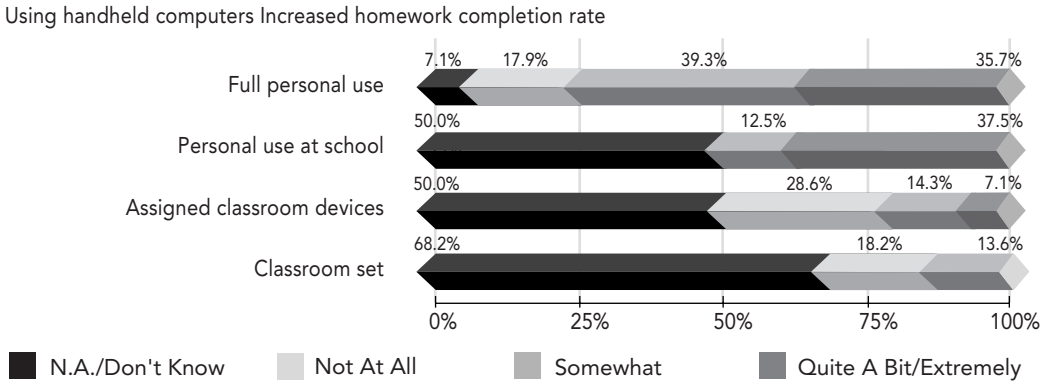
- [You have] all information in one place, portable and manageable . . . not too big to be a burden, not too small to be lost . . . easily organized to keep different kinds of information separate yet still able to access quickly and easily.
- Handhelds can go anywhere and will soon be able to be connected to anything, unlike desktops or laptops which are bulky and difficult to operate

Personal Learning Tool: Handheld computers can empower students to take responsibility for their own learning, according to PEP teachers. When using handheld computers, students are more engaged in learning, and often find their own ways to use handheld computers to support their learning, both in and out of class. Teachers indicate these benefits in several of the questionnaire item responses presented in Figure 2.8: Students have increased self-esteem, self-directedness, take initiative in using the handheld computer for learning, and have an increased opportunity to learn at their own pace.

The area that teachers were least enthusiastic about was the impact of handheld computers on increasing the homework completion rate. Although approximately 40% indicated an increase in homework completion rates, approximately 40% of respondents said that this was not applicable, or they didn't know. Given the reports of increased motivation and increased student self-directedness, we would expect there to be a

On projects where students were able to take the handhelds home, 75% of teachers reported an increase in homework completion.

Figure 2.8: Teacher evaluation of "increased homework completion rate" by handheld assignment model



stronger relationship between handheld use and homework completion. However, there is a simple explanation for this apparent discrepancy: On projects where students were able to take the handhelds home ("full personal use"), 75% of teachers reported an increase in homework completion. As Figure 2.8 shows, the more "ownership" of a handheld by the student, the greater the influence on the homework completion rate. (See Chapter 4, Assigning handhelds to students, for more on how the handheld assignment model influenced PEP projects.)

Organizational Tool: Handheld computers allow students to be more organized and keep track of homework assignments, calendars, notes, and data. Teachers reported this to be especially useful for low-performing students and students with special needs. As stated by PEP teachers who used handheld to help their students stay organized:

- [Handhelds] may be a significant personal management tool for students with disabilities.
- This is an organized student portfolio that tracks the growth of the student!

Drawbacks of Handheld Technology for Teaching and Learning

After using handheld technology in the classroom for one school year, PEP teachers have gained solid, first-hand 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. The most significant drawbacks found by PEP teachers were:

- Inappropriate use of handhelds
- General classroom equipment—management issues
- Usability issues
- Equipment damage
- Potential for loss or theft

Inappropriate Use and Its Prevention

As teachers and student learned through the introduction of the Internet into classrooms, not every technology use is appropriate for the classroom. To discover how 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?" A total of 44% said that there were no inappropriate uses, while 56% indicated the occurrence of some inappropriate uses.

Descriptions of inappropriate uses of handhelds centered on games played during class time, downloading inappropriate materials, and inappropriate use of beaming. The wide availability of games and other inappropriate materials was mentioned as a problem by some teachers. Students used beaming in several ways that teachers felt were inappropriate. These included passing notes, cheating on tests, and "copying" by handing in assignments beamed from other students. Several teachers mentioned that this was simply a new wrinkle on behaviors that have been around since the beginning of education, and could be handled by standard classroom management procedures. Others felt that new procedures were required to prevent these activities.

A discussion of "appropriate use" policies is found in Chapter 5, Managing Classroom Handheld Technology. And in the Strategies for Success in Chapter 5, we present teachers' strategies for preventing inappropriate use.

General Classroom Equipment Management Issues

Teachers found several problems in integrating handhelds into the classroom. These include the use of HotSync, collecting and reviewing student work, finding and using appropriate software and peripherals, and issues with battery life.

The use of HotSync was particularly problematic, and mentioned by a majority of PEP teachers. Current synchronization models are based on each user synchronizing with their personal computer, a situation that does not exist in the classroom. Teachers had to administer the synchronization process to make sure that students were synchronizing with the correct computer, and troubleshoot problems that arose when having many students synchronize their handhelds with a small number of computers. In addition, teachers had technical problems with HotSync, and had to spend significant time debugging HotSync to get students' handhelds to synchronize properly.

As discussed in Chapter 3, Integrating Handheld Technology in Instruction, having appropriate software and peripherals is an important part of successfully integrating handheld technology into the classroom, and this can take a significant effort. Some teachers expressed frustration at the difficulties in finding, purchasing, and learning the different software and peripheral packages that exist.

Many teachers also reported problems with battery life. It can be difficult to integrate charging the handheld computer with all the other activities that take place in school. Some teachers who allow students to take the handhelds home also give the students the charging cradles, and have students charge the handhelds overnight.

Usability Issues

Although handhelds were found very easy to use, there were still some usability issues that hindered PEP projects. Approximately 40% of respondents stated that their students had some difficulty using Graffiti. Respondents noted that, without keyboards, Graffiti input was "too difficult" and "too time consuming," especially for extended writing. PEP teachers note that keyboards are vital for any project that requires students to do a significant amount of writing.

Approximately 30% of respondents stated that they had some difficulty with the screen. Some stated that the screen was too small, and many PEP teachers found that it was difficult to read the screen outdoors. Although the issue of outdoors readability rarely arises with other technologies, the portability of handhelds encourages teachers to take their classes beyond the traditional classroom walls.

Equipment Damage and Other Technical Issues

As reported above, PEP teachers were highly positive in their overall evaluation of handheld computers as a teaching and learning tool. In fact, over half of all respondents reported that they were "very satisfied" with of the performance of handheld computers; nearly all of the remaining teachers reported they were "fairly satisfied" with handheld computer performance. (See Figure 2.9, below.) This was in spite of the fact that many teachers experienced technical problems with handhelds.

Figure 2.9: Teachers' Reports of Teacher and Student Satisfaction with Performance of Handheld Computers

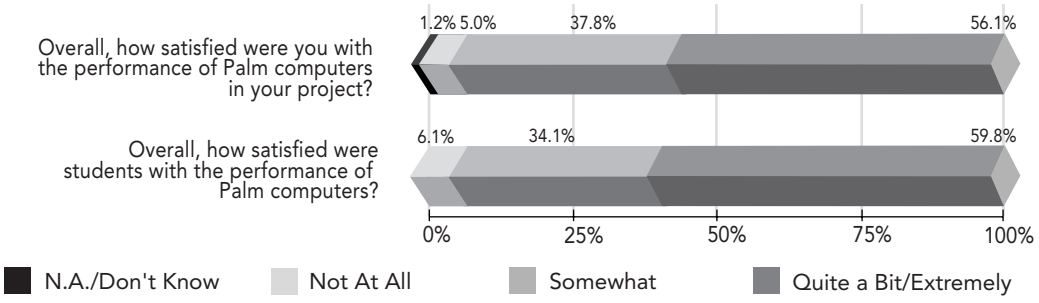


Figure 2.10: Teachers' Reports of Technical Problems with Handheld Computers

	YES (N)	%
Broken Palm computer (non-functioning)	44	55.0
Cracked or broken Palm computer screen	35	42.7
Batteries running out	26	32.1
Palm computer was otherwise damaged (but not broken)	22	26.8
Problems with HotSync	22	26.8
Non-functioning upon delivery	18	22.0
Running out of memory	13	15.9
Difficulty with interface to peripheral	8	9.8

The main technical problem teachers encountered was breakage: 55% of teachers reported having at least one broken handheld. About 43% reported at least one occurrence of a cracked screen (note that the handhelds used in the PEP program have a glass screen, and many newer models have plastic screens that should be less fragile), and about 27% reported at least one incident of damage to a handheld that remained functioning. Given that handheld computers were often taken home, taken outdoors, used at fields and streams, and otherwise used at locations that are uncommon for other technologies, it is perhaps not surprising that some breakage occurred.

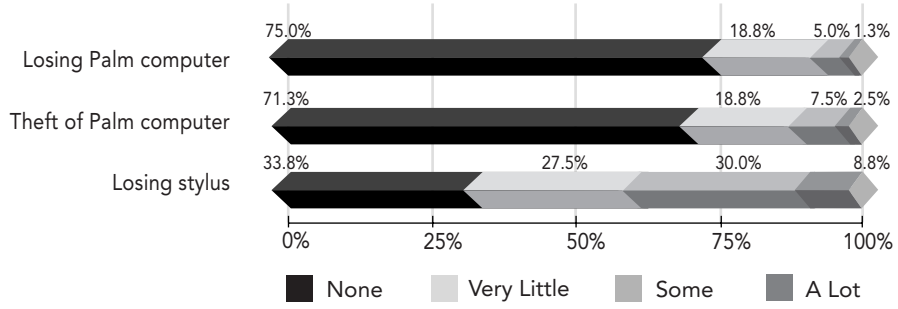
Other problems that we inquired about included batteries running out (32% of respondents reported that this occurred); problems with hot-synching (about 27%); non-functioning of devices upon delivery (22%); running out of memory (16%); and difficulty with interface to a peripheral device (about 10%). (See Figure 2.11).

Potential for Loss or Theft

Whenever technology is introduced into a new environment there will be some concern about loss and theft, especially when the technology is portable. After a full year of using handheld computers in a variety of settings, PEP teachers give us reason to be optimistic about the amount of loss and theft that can be expected when introducing handhelds into the classroom. PEP teachers were very concerned about the potential for loss and theft at the beginning of the program, and so implemented policies to guard against loss and theft. These policies include:

- Tagging the handheld computers with a form of identification, and taking inventory of the handhelds on a regular basis
- Having parents sign forms taking responsibility for replacement of the students' handheld, if necessary
- Not allowing students to take handhelds out of the classroom

Figure 2.11: Loss and Theft of Handheld Computers



It is perhaps because of the caution taken by PEP teachers that loss and theft was minimal. Figure 2.11 shows the amount of loss and theft reported by PEP teachers over the school year. Although there was a significant loss of styli (the inexpensive "pen" used for input), there was not much loss and theft of the handheld computers themselves. In fact, only one PEP project reported "a lot" of loss, and only two reported "a lot" of theft.

[i] Crawford, V. M. & Vahey, P. (2002, March). Palm Education Pioneers Program: March 2002 Evaluation Report, page 14. Available at http://www.palmgrants.sri.com

Fostering Writing Expertise for Special Needs Students

Project Information:

Grades: Middle School

Teacher: Michael Ryan

Other resources used: Portable keyboard

Project Description:

For special needs students, a seemingly simple writing assignment can be grueling. Due to learning disabilities, dyslexia, or grapho-motor problems, students may struggle to get a few sentences legibly on paper. This challenge is exacerbated when education standards increase the amount of writing required across the curriculum. Michael Ryan of Blauvelt, New York, has been investigating how students diagnosed as having grapho-motor problems or severe difficulty with written expression can be helped by the use of handhelds and keyboards.

Students were introduced to the handhelds through short activities such as typing contests, summarizing stories, and vocabulary lists, all of which the students would then download to the small number of personal computers that the students had to share.

Students used the handhelds in their English and resource-room classes as a substitute for pen and paper. Students started out by writing short paragraphs on the handheld, but were soon drafting complete essays. They used the Memo Pad to keep track of individual problem areas, such as frequently misspelled words, frequently broken grammar rules, and difficult vocabulary words. While other students were drafting on paper, they were using their handheld device. The handhelds allowed students to build upon the ideas that they had already typed, without the pain and frustration of rewriting the piece over, using pen and paper

Michael Ryan reports that during this project there was a significant decrease in student frustration with writing, and students became significantly more efficient at their daily work. Using pen and paper, writing was a torturous subject, but with handheld computers these students now enjoy and even look forward to their writing tasks.

Additionally, students took advantage of the vocabulary lists that they kept, and word usage on the whole went up for the group. Michael reports that use of handheld computers had a positive effect on students and their writing, and he has found that the incredible boost in the students' self-esteem was an additional bonus that he hopes will carry over into future grades.

Michael Ryan reports that during this project there was a significant decrease in student frustration with writing, and students became significantly more efficient at their daily work. Using pen and paper, writing was a torturous subject, but with handheld computers these students now enjoy and even look forward to their writing tasks

Chapter 3: Integrating Handheld Technology in Instruction

The PEP evaluation study investigated the impact of using handheld computers on teachers' thinking and practice related to technology integration strategies, as well as its impact on teaching and learning activities. We also sought to understand what factors, such as resources, training, and integration strategies, PEP teachers see as important in successfully integrating handheld technology.

While some of the findings we report in this section are based on a relatively small number of teacher responses, themes emerged robustly across many open-ended response items. Given the PEP evaluation study goal of understanding the impact of this new and little-studied technology, these findings are important, since emerging themes are useful in guiding future research.

Changes in Technology Integration

Teachers see handheld computers as having a significant impact on how technology is integrated into instruction. Teachers reported that use of handhelds changed their instructional planning and their thinking about instructional needs. Interestingly, many teachers said that the use of handhelds had little or no effect on their students' use of desktop or laptop computers although some reported a reduced use of desktop computers as a consequence of handheld computer availability. Figure 3.1 presents an overview of these findings.

When we asked teachers, "Has your experience using handhelds changed your thinking about the way, or extent to which, technology can be integrated into learning activities?" about 37% of teachers reported "a lot" of change and about 35% said "a little."

Similarly, teachers report that use of handhelds changed or will change their instructional planning. Fully 45% of respondents indicated their instructional planning had or would change "a lot," about 33% replied "a little," and 22% stated their instructional planning would not change.

In addition, teachers reported that using handheld technology had a significant effect on their thinking about technology needs at the classroom and school level. Over 52% of teachers indicated their thinking about technology needs had changed "a lot," while about 26% indicated their thinking had changed "a little," and 22% indicated their thinking had not changed. (See Figure 3.1.)

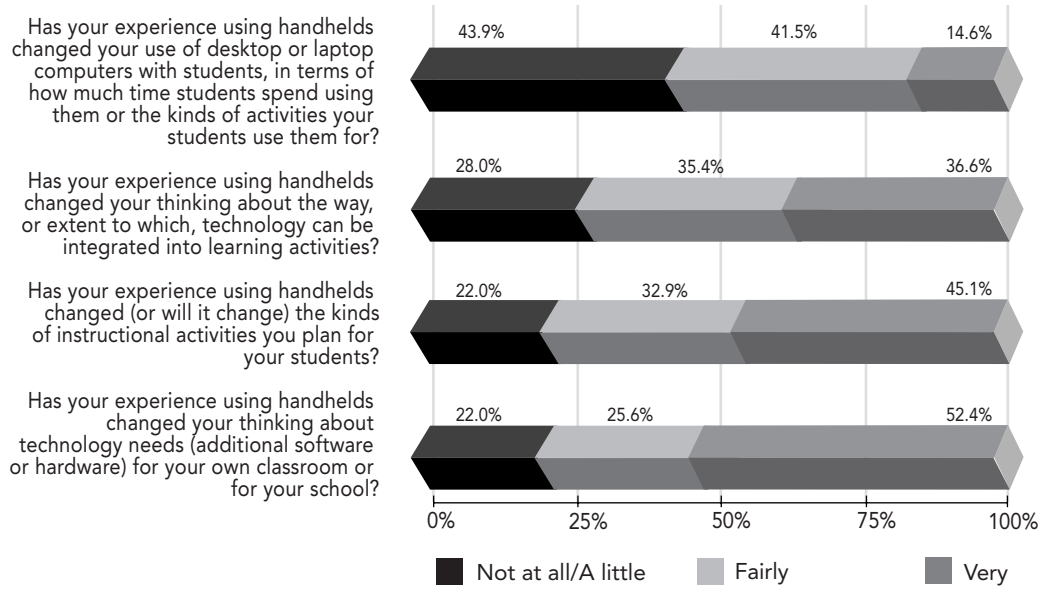
To further interpret these findings, we analyzed teacher responses to open-ended items in which teachers described specific impacts of handhelds on technology integration in their classrooms. Teachers reported a fairly wide range of effects that using handheld technology had on their thinking and practices related to technology integration. The most common effects were the following:

- Greater use of technology
- Technology integration is seen as easier with handhelds

- Technology can be used in context and in more places
- Improvement in instructional activities
- Frequency and type of use of desktop computers does not necessarily change when handhelds are used as well

These impacts are described further below.

Figure 3.1: Teachers' Reports of the Impact of Handheld Technology on Instructional and Technology Integration Practices.



Increased Technology Use, Easier Integration, and Use in Context

The most common impact that teachers reported was an increased use of technology. In addition, teachers stated that with handheld computers, they see technology as appropriately and easily integrated into a wide range of instructional activities, and more easily used in various settings, as compared to desktop computers,. This probably contributed to the increased technology use reported by many PEP teachers.

Teachers' views on the ease with which handheld technology can be integrated into learning are exemplified in these comments:

- Technology can be properly integrated into almost every lesson- if you take the time to do it.
- Handhelds have made it easier for the classroom teacher to bring the use of technology to all of their students and more often.
- The accessibility of the Palms makes them more apt to be integrated to a greater extent throughout the curriculum.
- They can be used for just about anything the curriculum asks for.
- We don't have nearly as many limitations on classroom use [as with desktop computers

The portability and flexibility of handhelds, as compared to desktop computers, are probably the key factors that allow handhelds to be used more frequently and in a wider range of activities. Several teachers indicated the importance of portability in their explanations of how handheld technology affected their thinking about technology integration:

- Technology doesn't have to be like a field trip, where you go to the computers or the lab, complete the requirements, and then return to the normal world. Instead, technology can be part of your whole life as a young adult.
- Handhelds are so portable. They make learning a more on-the-go activity.
- They are very effective as a tool used at the student's desk or workstation. They are extremely effective as data collection devices.
- Students can use technology in more ways and more places. They are no longer tied down to a desk.
- Everywhere there is learning, the handheld computers will make that learning easier for some students.

Impact on Use of Desktop and Laptop Computers

While many PEP teachers report that many instructional activities are improved by the integration of mobile computing, and that handheld computers are easier to integrate than desktop computers, most PEP teachers also report that their use of desktop computers was relatively unchanged by the integration of handheld computers. This finding supports our initial belief that handheld computers would not displace or replace desktop computers, but rather would become an additional tool in teachers' educational technology toolkit. Only a small percentage of teachers (about 15%) indicated that use of handheld technology changed the frequency or type of desktop or laptop computer use "a lot." (See Figure 3.1.)

Use of handhelds is most successful when they are used in conjunction with desktop or laptop computers, for several purposes and reasons, including the following:

- The need to back up data
- Using the larger display of a desktop computer
- The network connectivity, memory, and power of desktop computers surpass that of handheld technology currently available

Moreover, a host of applications specific to desktop computers are available that can enhance learning and presentation of work instructional activities begun on the handheld. For this reason alone, it is highly unlikely that use of handhelds would eliminate the need for desktop computers. At the same time, some teachers did report that they began to use handheld computers for activities with which they had previously used desktop computers. Other teachers indicated that handheld computers might replace desktops for some specific tasks, as teachers determine that handhelds are more appropriate than desktop computers. One teacher, for example, reported, "Handouts were delivered through the Palm [computer] rather than on the desktop [computer]. Communication with students worked better on the Palms than with the Web site we were using."

In addition, handhelds tend to be more accessible than desktops, either because the student-to-device ratio is higher, or because handhelds are used right in the classroom. As one teacher commented: "[With handheld computers], technology is brought to the classroom. We no longer need to go to the lab." Another stated, "Because we were able to do whole-class activities, we used computers more than if I had been

dependent on my eight desktops." The following comments exemplify the range of teachers' views about the impact of handhelds on their use of desktop computers:

- Palms have not replaced the time kids spend in the computer lab—they have added to their technology experiences.
- Previously, all data collection was done through the desktop computers. Now, a portion of that work is being done on the handhelds.
- We can spend more time drafting writing in the classroom at desks or outside and don't need to always be in the computer lab.
- Data from the stream study is now recorded and analyzed in the Palms rather than being typed on word processors.

Integrating Handheld Technology: Peripherals and Software are Key

One of the changes in thinking about technology integration strategies and needs that many teachers reported is that they now see handheld technology as an important teaching and learning tool in the classroom. As one teacher stated, "I think that handhelds have a definite place in education."

Handheld technology seemed quickly to gain an important place in the technology toolkit because it can be used in many different ways and places, and it is easy to integrate handhelds into learning activities.

Teachers readily find value in handhelds' flexibility, a feature achieved, in part, through the use of peripheral devices that greatly extend the functionality of handhelds. Software applications, which can be used for a wide variety of purposes and activities, also add to the technology's flexibility. Exploring these hardware and software products and determining how they can be used to meet instructional goals is a critically important aspect of integrating handheld technology. Many teachers indicated the importance of peripherals and software:

- I would like to have keyboards and probes, which would make the Palms more useful.
- Handhelds have their own requirements-software and hardware—to be effective, and that requires planning.
- I need more software and hardware to get the most out of the handhelds and vary the activities more.
- I want more peripherals! I love them, my students love them, the parents love them, and my teachers love them. They make the Palms more useful than can be imagined.

Most Teachers Used Additional Software and Peripherals

PEP teachers were asked to list the three most important software applications used in their PEP project and to briefly describe the purpose for using them. Sixty-three projects reported their most important software, resulting in 162 entries. Figure 3.2 shows the applications that were ranked the top five most important across all PEP projects. Figures 3.3 to 3.5 show the top three ranked applications in high school, middle school, and elementary school, respectively.

Figure 3.6 shows the peripherals that PEP teachers found most valuable. Overwhelmingly teachers chose keyboards, digital cameras, and probes as most valuable to their projects.

The most popular applications and peripherals fall into the categories of: inquiry science, productivity applications, Internet access, and education-specific applications.

Inquiry Science

The popularity of probes among PEP teachers points to the usefulness of handheld computers for scientific inquiry. The ImagiProbe system by ImagiWorks was the most noted software package, and probes were found to be essential peripherals. ImagiProbe was deemed crucial by almost 25% of responding projects across all grade levels, and was ranked number 1 at both the high school and middle school levels and number 3 at the elementary school level. In addition, several projects used digital cameras to support their inquiry activities. For instance, some projects had students take pictures of their lab setups to aid in their lab write-up, and others had students take pictures of the location (such as a stream) where their samples were taken from.

Figure 3.2: Five Top-Ranked Software Packages Across all PEP Projects

RANK	PROGRAM
1	ImagiProbe
2	Documents To Go
3	PicoMap
4	PalmPix MemoPad WordSmith
5	AvantGo

Figure 3.3: Three Top-Ranked Software Packages for High School

RANK	PROGRAM	GENERAL RANK
1	ImagiProbe	1
2	Documents To Go	2
3	AvantGo	5

Figure 3.4: Three Top-Ranked Software Packages for Middle School

RANK	PROGRAM	GENERAL RANK
1	ImagiProbe	1
2	Documents To Go	2
3	PalmPix QuickSheet FlingIt PalmPix4	4

Figure 3.5: Three Top-Ranked Software Packages for Elementary School

RANK	PROGRAM	GENERAL RANK
1	MemoPad	4
2	Quizzler	
3	PicoMap	3
	ImagiProbe	1

Figure 3.6: Three Top-Ranked Peripherals

RANK	PROGRAM
1	Keyboards
2	Digital Cameras (notably the PalmPix by Kodak)
3	Probes

Productivity Applications

Next to inquiry science, high school and middle school uses of handhelds were predominantly based on traditional office productivity tools. For both high school and middle school, the second most crucial software package was Documents To Go (by

DataVis) and Middle School teachers also considered WordSmith and QuickSheet vital. Documents To Go allows editing of Microsoft Office applications on handheld computers. Some PEP projects used Documents To Go to synchronize with the desktop versions of the MS office software, whereas others used the Documents To Go applications as stand-alone applications. Many PEP teachers used WordSmith, a word processing application for handhelds, and PEP teachers also reported using QuickSheet, a spreadsheet application, for handhelds.

This contrasts with handheld use in the elementary grades. The only productivity application in wide use by elementary teachers was the built-in Memo Pad application, which can be considered a very simple word processor. The one elementary school project that used Documents To Go used it to synchronize with AppleWorks, a simplified integrated productivity suite.

Across all grades, teachers found external keyboards key to successful project implementation. Keyboards were vital to projects with extended writing, and the predominant use of handhelds for productivity applications underscores the importance of keyboards.

Internet Access

Perhaps surprisingly, middle school projects used handhelds as a way to leverage the Internet more than either high school or elementary school projects. Most of this Internet access was using Hi-Ce's FlingIt software, which allows students to mark a page in a Web browser and download it to their handheld. This enabled students to conduct quick Web searches using desktop computers, and then download potentially interesting pages to their handhelds. Thus, multiple students could share the desktop computer for Internet research: after one student downloads pages, she can then peruse the pages on her handheld while the next student uses the desktop computer to conduct Internet searches.

AvantGo is commonly used as a conduit to Web-based content. AvantGo allows users to specify Web pages to be downloaded to a handheld each time the user synchronizes to a desktop computer. A small number of PEP projects used AvantGo this way, notably to download current news stories to be read on the handheld. However, the most common use of AvantGo was as a conduit for HandySheets, a Hi-Ce application that allows the creation of custom worksheets that then are loaded onto the handheld computer.

Education-Specific Applications

Quizzler, the second most commonly used application for elementary school PEP projects, is used to create quizzes on a desktop computer, and then download them to students' handhelds.

PicoMap, the third most commonly used application for elementary school, also had limited usage in high school and middle school. PicoMap is a Hi-CE application that allows students to create, share, and explore concept maps on their handheld computers.

Digital Camera/PalmPix, is a digital camera attachment for handhelds. While not strictly an educational application, the digital camera attachment was used for a variety of educational purposes. These included taking pictures of classroom activities, documenting field trips, and providing photos for reports and presentations.

Changes in Teaching and Learning

Handheld technology can benefit teaching and learning in the classroom in ways that teachers had not expected. In describing how use of handheld technology changed their instructional planning and technology integration strategies, some teachers reported that handhelds facilitate or promote the following in their classrooms:

- Cooperation among students
- Self-paced activities and independent work
- Partnership between teachers and students
- Improvement in teaching style

Cooperation among students: Teachers reported that the beaming function allowed students to share information more easily. In some cases, teachers reported that use of handhelds inspired students to help each other more. Other teachers reported that they would plan more cooperative activities because handheld technology made this easy.

- I loved seeing the students work cooperatively in teams and groups. They helped each other and shared information readily. This just wouldn't have happened if they were using pencil and paper or if they were seated in a permanent position in front of a PC.
- I have always been a technology advocate. This [beaming] has especially added the aspect of collaboration
- I would definitely add more activities that require collaboration.
- [Handhelds make possible] More emphasis on a collaborative environment.
- [Handhelds facilitate] more exchange of information, more documentation of tasks by students, more teaming projects.

Self-paced learning activities and independent work: Some teachers reported that when each student has access to a handheld computer, it is easier for teachers to incorporate self-paced activities, and easier for students to work on tasks and assignments at their own pace, rather than as dictated by the computer lab schedule or the class period. One PEP teacher stated that handheld technology will eventually enable self-paced learning to become the norm: "Eventually, when handheld systems 'work', all of education will have to transform accordingly. The lecture/field trip model will break down and students will learn at their own pace in their own way."
Here's what other teachers had to say:

- [Handhelds make possible] more time for independent activities, knowing that I can track progress with hot synching.
- Greater student autonomy and accountability toward assignments and a greater sense of partnership in learning together (teacher and student).
- I am more likely to let students work on things more independently.
- I see the students being able to take their thinking and work with [the hand-

held] right then. I see that handhelds as being essential to helping that thought process along and in the place that the student is at.

- [Using handhelds] allowed the students to work more independently.
- Students were able to take computer assignments home with them instead of having to come in before or after school to finish up assignments.

Greater partnership between teacher and students: PEP teachers reported that students were very comfortable using handheld technology and that in many cases, students took the lead in developing ways to use handhelds for learning. In our Spring 2002 survey, some teachers reported that allowing students to participate in developing the integration of handhelds enhanced the learning partnership between teachers and students. Some teachers reported that this partnership was promoted by specific capabilities of handheld computers, such as the beaming function, which teachers said enhanced communication between teacher and students. Other teachers indicated that giving students a role in the integration of handheld technology gave teachers and students a greater sense of shared mission.

- [Use of handhelds facilitates] greater student autonomy and accountability toward assignments and a greater sense of partnership in learning together (teacher and student).
- Learning the possibilities of the Palms with my students leveled the playing field between us and brought us so close together.
- I have learned to think out of the box. The students assist in determining their needs for learning...I spend time listening to them.
- I am … more connected with the students' parents and can expect more follow through with them.
- Increased communication with students about behaviors and projects [resulted from my PEP project].

Improved teaching: Some teachers reported that use of handheld technology improved their teaching. In some cases, teachers reported that their experimentation with integrating handhelds into instructional activities facilitated their becoming more comfortable with new methods of teaching. In other cases, teachers reported that the technology itself allowed them to improve their teaching of specific concepts or allowed them to decrease the amount of 'wasted time' in the classroom.

- I have had to teach in an impromptu, improvisational way. I felt we were on the cutting edge. There were no text books or lesson plans. I also relied heavily on the PEP team teachers for their levels of expertise. Each teacher needed to carry his/her weight.
- Science is becoming more student-centered, [with] more true inquiry from the student, [and] less teacher-driven curriculum.
- In class we now spend more time working with technology and integrating new technologies. I expect more of my students in the areas of organization

and follow through. I find I can expect students to take more notes and organize them in the graphic organizers (and keep track of them for a longer period of time). New technology has led to higher expectations from the students and myself.

- I think that using less real paper gets you covering material (content) in better, faster fashion. For example, you don't need to duplicate and hand out, or have the student copy from the board, a list of vocabulary terms. Just beam them. Then those terms can be integrated into other things like Quizzler for review. Saving "wasted" time in the classroom for more content instruction.
- I have designed and implemented more lessons that integrate technology. Also, I have taken a more project-oriented approach that ever before.
- I think it has made me be more creative and therefore more motivating to my students.

Facilitating Integration of Handheld Technology

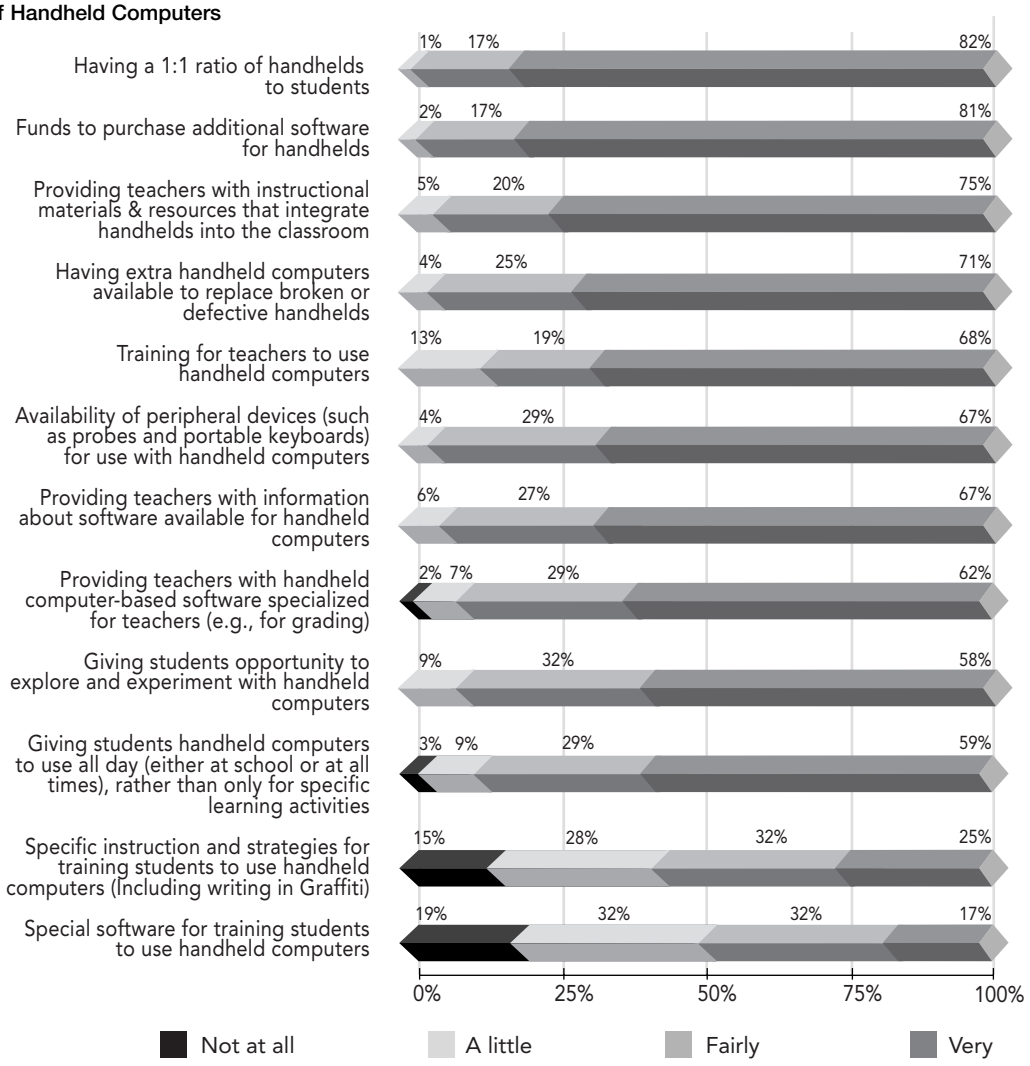
We asked teachers to rate the importance of each of 12 factors for the successful integration of handheld computers. Their ratings are displayed in Figure 3.7, below. Ten of the 12 factors listed were rated as "very important" by over half of all respondents (100 teachers responded to each item).

The factor rated very important by the highest percentage of teachers (82%) was having a one-to-one student-to-handheld computer ratio. A one-to-one ratio facilitates whole-class activities as well as self-paced learning. Having a one-to-one ratio allows the teacher to conduct whole class activities in which every student is engaged in the activity and using the technology. The term "conduct" is apt, because with each student using a handheld, it is possible for the teacher to lead students through an activity, or to allow students to work on their own simultaneously, with all students engaged and on task. In addition, a one-to-one ratio means that each student can work on activities at their own pace and, especially when handhelds can be taken home, on their own schedule. When a one-to-one ratio is absent, teachers must coordinate students' sharing of the technology and carefully manage the activity so that all students can complete the activity. In this case, the teachers' role becomes more complicated and the students have less opportunity to use technology and be on task.

In keeping with teachers' comments about the importance of peripherals and software in maximizing the potential of handheld technology, additional software was the second most important factor, and availability of peripheral devices was the sixth most important factor in successful integration of handheld technology. Availability of instructional resources and materials to support integration of handheld technology was the third-most important factor.

Student training on handhelds is not very important to successful technology integration, according to PEP teachers. Special software for training students on technology and instruction of handhelds were the lowest-rated factors. This is consistent with many teachers' reports that students find use of handheld computers easy and largely intuitive.

Figure 3.7: Teachers' Ratings of the Importance of Key Factors in Successful Integration of Handheld Computers



✓ *Strategies for Success*

Integrating Handhelds into Learning Activities

PEP teachers' evaluations make a compelling case for the thoughtful integration of handhelds into the classroom. PEP teachers found that handheld computers can increase the quality of instructional activities, can have a positive effect on teaching practices, and can positively contribute to students' learning. As discussed in Chapter 2, teachers identified the following specific benefits of handheld computers:

- Increased technology proficiency for students
- Increased student motivation
- Increased collaboration and communication
- Portable and available instructional tool
- Personal learning tool
- Organizational tool

When considering the use of handheld computers in instructional activities, it is important to think about these benefits along three dimensions:

- How can handhelds enhance my existing uses of computers?
- How can handhelds enhance activities that I'm currently doing?
- How can handhelds enable new activities that I haven't done before?

It is also important to think about logistical issues, such as assignment of handhelds, as well as potential drawbacks of using handhelds in the classroom.

Enhance Current Computer Use

One example of how PEP teachers used handheld computers to enhance the their current use of computers is extended writing assignments. As shown in Figure 2.5, PEP teachers found handheld computers very effective for projects that include writing assignments. The portability of handhelds, combined with the use of external keyboards, allows every student to have their own word processor right at their own desk. This means that students don't have to share computers at the back of the room, nor do they need to use the computer lab for a writing assignment. With an IR-enabled printer, students don't even have to synchronize with a desktop computer to get a printout of their work- they can just beam right to the printer. In addition, the ease of beaming allows students to easily share and edit each other's work, and the organization features of the handheld can be used to support the entire writing process.

Another example of enhancing existing computer use is in an unexpected area: Internet research. After students connect to the Internet with a desktop, there are currently two different software applications, FlingIt and AvantGo, that allow them to download information to their handheld for future use. (As discussed in this chapter, it is important to learn about available software applications.) When used in this way, handheld computers can actually increase the usefulness of the small number of desktop computers found in most classrooms. And, as with writing, the organization and collaboration features of handhelds can further increase the benefits to students.

Enhance Existing Instructional Activities

The most common area in which handhelds were used to enhance existing activities was inquiry-based science activities. Handheld computers make environmental science investigations more sophisticated, yet more accessible. For instance, instead of going to a stream, collecting water in bottles, labeling the bottles, and then running tests on the water back in the classroom, students are able to record

and visualize the water quality data right at the stream location. This allows students more time to do their investigations, compare results with other students, and create inferences about water quality than was otherwise possible.

Other teachers found that the motivational aspects of handheld computers, and the fact that students consider handhelds to be personal learning tools, resulted in students using handhelds in ways not expected by the teacher. For example, some students used quizzing software to continue self-assessment at home; some students downloaded additional software applications to use for learning, such as dictionaries and other reference tools; some students reviewed notes or facts to memorize; and other students spontaneously began to use the organization tools to keep track of homework or schedules. In each of these cases, the use of a personal, portable, powerful learning device allowed students to enhance activities that were already ongoing in the classroom.

Enabling New Activities

Some PEP teachers reported that the beaming capacity of handhelds allowed new forms of collaboration that had not been successfully achieved in the past. Jigsaw-type collaboration activities were now more feasible, as students could easily distribute, aggregate, and edit information. Teachers who used handhelds for digital portfolios commented that their students were able to keep detailed project portfolios, as all their work was stored on the handheld. These teachers stated that they now had a tool that could support portfolio assessment in their classes.

Some PEP teachers used a program called "Cooties" for an activity that dramatically shows the propagation of a disease throughout a population. Cooties is a virus-transfer simulation program that allows students to be active participants in the simulation. Students "meet" by beaming their handheld. The teacher can determine characteristics such as the incubation time of the virus, immunity levels, etc. By participating in these simulations, students gain an understanding of disease propagation in a way that PEP teachers state is more engaging and more understandable to students than traditional teaching methods.

Logistics and Drawbacks

PEP teachers reported several drawbacks to using handhelds in the classroom, and had helpful insights into ways to counter these drawbacks. Figure 2.10 discusses the main drawbacks of integrating handhelds into instruction:

- Inappropriate use and its prevention
- General classroom integration issues
- Usability issues
- Equipment damage
- Potential for loss or theft

PEP teachers found that initial precautions could counter many of these drawbacks. Some of these strategies are described in Strategies for Success in Chapter 5, Managing Classroom Handheld Technology. For instance, many PEP teachers created "acceptable use policies." These policies often extended beyond the PEP teacher's classroom, so all teachers knew the policies, and were empowered to take appropriate corrective action when they saw the handhelds being used for inappropriate purposes. Perhaps as a result of such policies, PEP projects experienced little loss or theft (see Figure 2.10).

To ensure that handhelds are used as effectively as possible, it is important that teachers find time to research available software and peripherals, have the budget to purchase appropriate software and peripherals, and take the time to learn how to use them, as well as understand how to integrate the handheld, software, and peripherals into their learning activities. A lack of appropriate software and peripherals, and a lack of time for learning them was frustrating for a number of PEP teachers.

PEP teachers reported some technical problems, primarily in the use of synchronization hardware and software. PEP teachers reported that having available technical personnel who were familiar with handheld technology was important in overcoming these problems.

Software and Peripherals

The right applications and peripherals can make the difference between success and frustration when integrating handheld computers into the classroom. PEP teachers have valuable experience in determining essential software and peripherals, and the types of uses that are most effective in the classroom.

PEP teachers found that the ImagiProbe system, which combines a sensor interface and corresponding software for real-time data collection and analysis, was a valuable addition to their science curriculum. PEP teachers found that the ability to take real-time readings using different probes and sensors resulted in greater student engagement, and allowed students to concentrate on the science rather than logistics, such as using pH strips, for example.

PEP teachers also found keyboards invaluable, especially for projects that used handhelds for extended writing. Keyboards, combined with word processing or general productivity applications, allow students to use their handheld instead of a desktop computer for many activities. Furthermore, some PEP projects also used applications such as PrintBoy, which allows handheld computers to print to any IR-enabled printer. PEP teachers felt that this gave students a truly portable personal computer.

There are too many available applications and peripherals to describe each adequately here. Appendix A provides a list of the applications and peripherals identified by PEP teachers as important to their projects.

The following is a list of websites and resources that may be useful for anyone wanting to integrate handheld computers into the classroom.

http://www.handango.com
http://www.handheldeducation.com
http://www.palm.com/education/
http://www.pdaed.com
http://pie.concord.org/
http://www.handheld.hice-dev.org/
http://palmgrants.sri.com/ideabank.html

Electronic Journalism Using Handheld Computers

Project Information:

Grades: High School.

Teachers: Ann Reed, Jamie Alexander

Other resources used: None.

Project Description:

The Klickitat, Washington, School District Newspaper has been the responsibility of the high school journalism class since September 2000. Using paper-based notebooks, students must struggle to have their facts available when needed, their interview questions orderly and legible, and their interview notes accurate and legible. The Klickitat journalism class investigated how handheld computers could aid students with these tasks.

The handhelds were introduced at the beginning of the year, and the teachers reported that students were highly engaged in formulating interview questions and inputting them into the handhelds. As handheld computer use increased during the year, students were able to easily retrieve the factual information that they had stored as notes on their handhelds.

Additionally, by the end of the year, key staff began using the handhelds as a device for communicating with the journalism students. Students began communicating with these key staff members, and information that was outlined by the staff was beamed to the students for use in the school newsletter. Students then learned how to expand such summary information into an article. This further increased the reliability of information to the point where the May and June issues contained no factual errors. The English department head evaluated the newspaper and reported an improvement in imaginative language or interesting sentence structures, although there was no significant decrease in grammatical errors.

The use of handheld computers has created a learning environment that improved student writing, communication skills, and production of the school district newsletter. Students acquired and used interviewing skills at a faster rate than through conventional lessons taught last year to older students. When students used Palm handhelds in the spring semester to communicate with the key staff members, positive relationships developed between staff and students.

However, not all students used the handhelds equally effectively. Students who joined the journalism team during the spring term preferred using paper and pencil. Those students did not receive the same thorough, structured training as the fall students received. The lesson learned: ensure that all students have adequate training in using their handheld computers.

The use of handheld computers has created a learning environment that improved student writing, communication skills, and production of the school district newsletter. Students acquired and used interviewing skills at a faster rate than through conventional lessons taught last year to older students.

Chapter 4: Assigning Handhelds to Students

Handheld computers can be assigned and used in a variety of ways. The two main assignment strategies used by PEP teachers are the "shared set" strategy and the "personal use" strategy. Each strategy has two versions (see Figure 4.1).

Shared Set Strategy. There are two versions of the shared set strategy. In the "classroom set" version, a pool of handhelds is available for use by all students in a classroom. Individual handhelds are not assigned to specific groups or individuals. In the second versions, the "assigned classroom handhelds" version, individual students or groups are assigned specific handheld devices. In both versions, students use the devices episodically for specific periods of time or activities, and both allow the teacher to use the same set of handhelds for multiple classes. PEP teachers generally used the "shared set" strategy when handhelds were used for specific learning activities and shared by groups of students, such as in a chemistry lab or for environmental science activities.

Personal Use Strategy. The PEP teachers used the "personal use" strategy when it was important for students to have access to a handheld computer all day. In the "personal use at school" version, students keep the handhelds with them to use for tasks and activities throughout the school day. In the "full personal use" version of this strategy, students have the handhelds all day at school and are allowed to take them home, too.

Figure 4.1 shows the proportions of PEP teachers using each of these four handheld computer assignment strategies.

Figure 4.1: Frequency of Handheld Computer Assignment Strategies

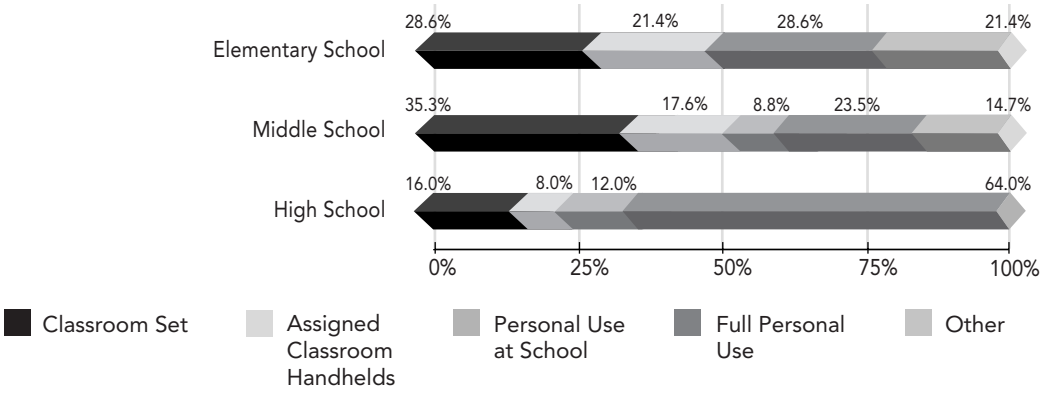
ASSIGNMENT STRATEGY	NUMBER	%
SHARED SET		
1. Classroom set: A set of handhelds was used episodically by students (in groups or individually) for specific periods or activities	23	24.7
2. Assigned classroom handhelds: Each student or group was assigned a Palm computer, which were used episodically, for specific periods or activities only.	18	19.4
PERSONAL USE		
3. Personal use at school: Each student was assigned her or his own handheld to use throughout the day; handhelds were not taken outside the classroom.	9	9.7
4. Full personal use: Each student was assigned her or his own handheld; students could take handhelds home	33	35.5
5. Other strategy	10	10.8

Most teachers (87%) used the same assignment strategy both semesters of the 2001-02 academic year.

Use of assignment strategies varied somewhat across grade levels. Most elementary school teachers used a version of the shared set strategy (50%), and about 28% used the full personal use strategy. Most high school teachers implemented the full personal use strategy (64%); 24% opted for a version of the shared set strategy. The distribution of assignment strategy across middle school classrooms was very similar to that of elementary school classrooms. See Figure 4.2 for breakdown of assignment strategy by grade level.

Among PEP teachers, there was not a robust relationship between the projects' curricular topic and the equipment assignment strategy used. However, projects with topics that involved use of the handheld for specific learning activities-such as environ-

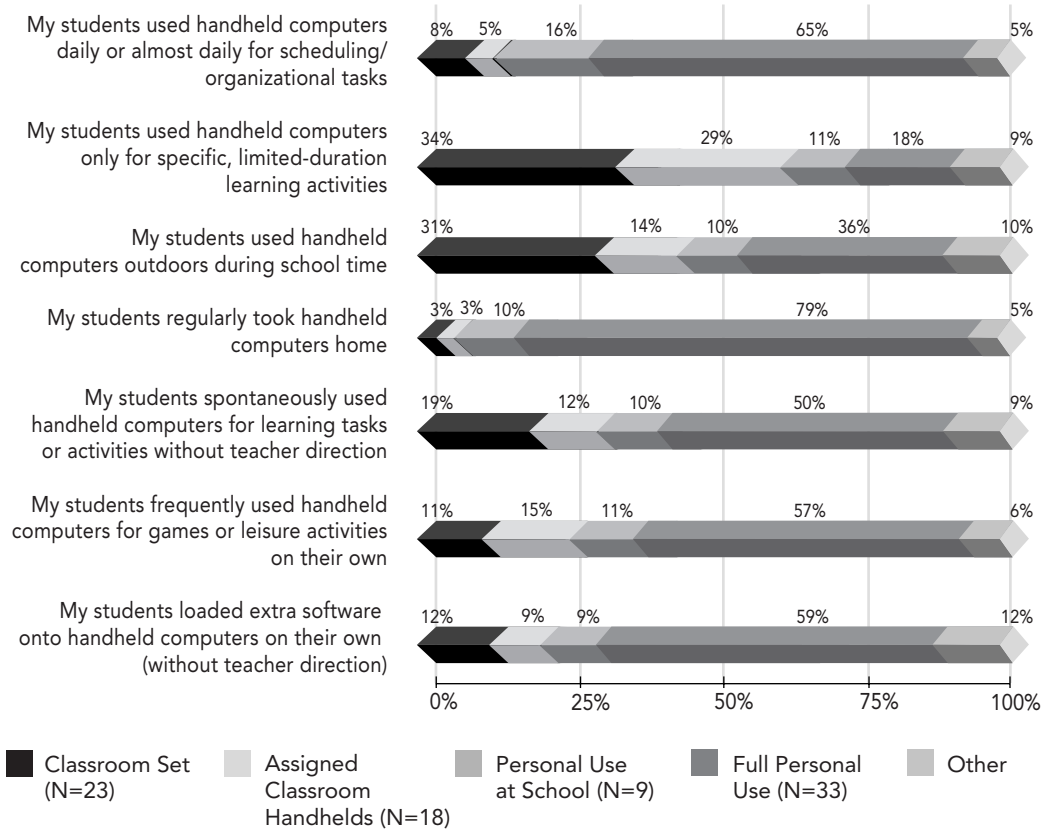
Figure 4.2: Assignment Strategy by Grade Level



mental science, social studies, reading, and science-were somewhat more likely to use the classroom set assignment strategy. The "personal use" strategy was more commonly used for projects with instructional goals that cut across the curriculum, such as organizational skills, enhancing student motivation, supporting problem solving, writing with the PDA, and home school communication, Such applications usually involve students using handhelds for several activities, for purposes that span classes (such as scheduling), or across settings, such as for home/school communication.

Some PEP teachers who used a version of the personal use strategy reported that they had originally planned episodic use of handhelds for specific learning activities. However, once students were allowed to use the handhelds all day and to take them home, students discovered additional instructional uses for the handhelds. In some cases, the new use became part of the classroom activity for all students.

Figure 4.3: Teachers' Reports of Student Uses of Handhelds, by Assignment Strategy



Students' uses of the handheld computers (according to teachers' reports) varied by assignment model in predictable ways. With the personal use model, students were far more likely to use handhelds for scheduling and organizational tasks. In addition, students who were assigned handhelds as personal devices were far more likely to spontaneously use them for learning activities without teacher direction.

With the classroom set assignment strategy, students were far more likely to use the devices for only for specific learning activities. However, students were nearly equally likely to use handheld computers out-

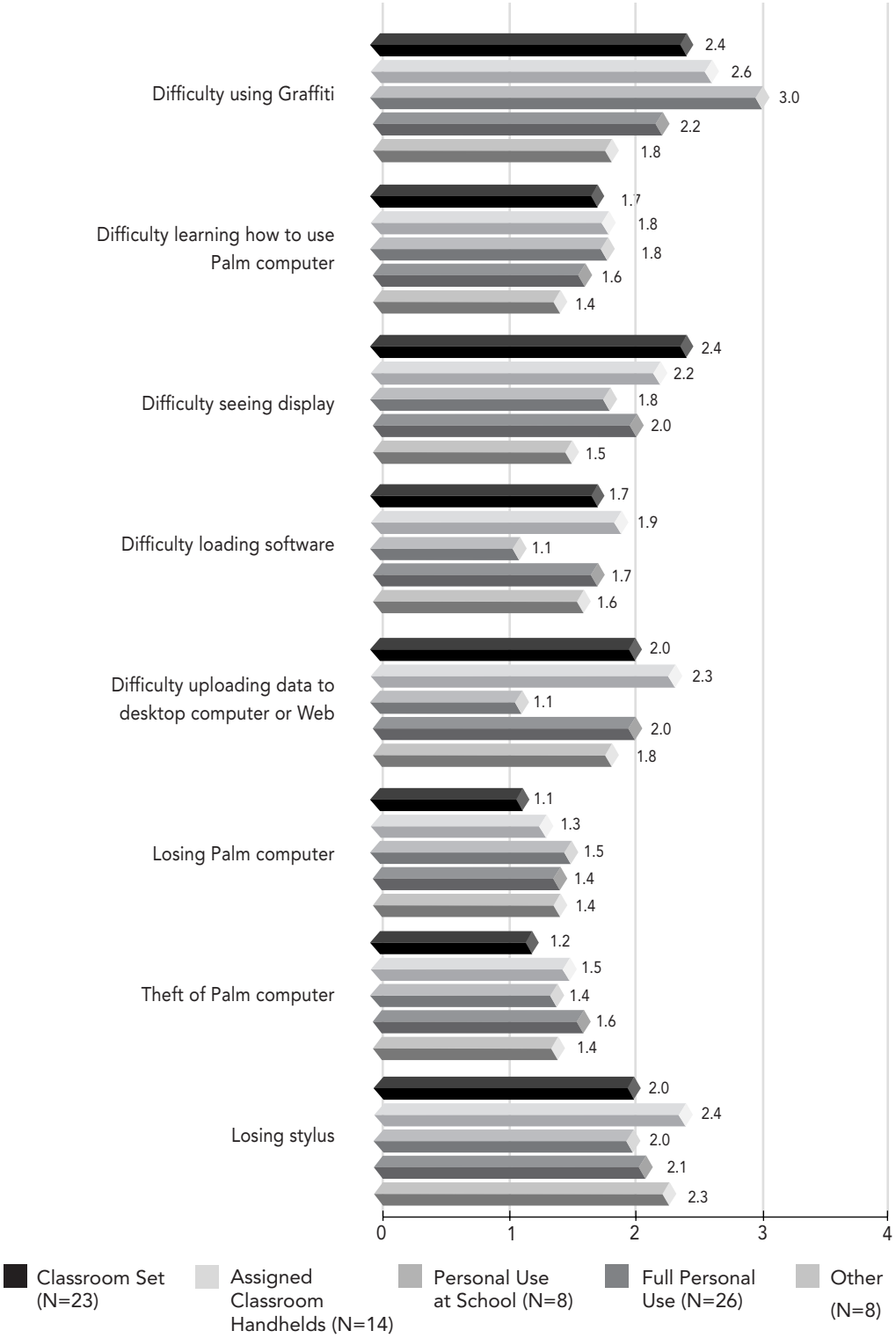
doors (for instance, collecting data at a local stream or in the school yard) under both the personal use strategy and the classroom set model. Figure 4.3 presents key uses of handhelds by assignment strategy.

Interestingly, teachers' reports of students' difficulties or problems with the handhelds did not vary by assignment model. Most notably, teachers who used the shared set strategy were about as likely to report loss or theft of handhelds as teachers using the personal use strategy. Figure 4.4 presents teachers' reports of difficulties by assignment model. In general, loss and theft were rare (see Chapter 2, Teachers' Evaluation of Handheld Technology).

We examined how teachers implementing the two main assignment strategies (personal use and the shared set) evaluated the benefits of handheld technology to students. Specifically, we examined whether teachers' perceptions of the benefits to students differed by assignment model. We combined teachers in both versions of the shared set assignment strategy and both versions of the personal use strategy to create the two comparison groups.

Compared to teachers implementing the shared

Figure 4.4: Teachers' Reports of Student Uses of Handhelds, by Assignment Strategy



*** Teachers reported the frequencies of each problem on the following scale: 1 = None, 2 = Very little, 3 = Some, 4 = A lot.**

set strategy, teachers who used the personal use strategy saw handheld technology as conferring relatively greater benefits to students in the following areas:

- Increased time spent on schoolwork outside of school time
- Increased organization, in general
- Increased initiative in finding ways to use the handheld computer for school or learning-related tasks or activities
- Increased time spent on voluntary (not assigned for school) learning activities
- Increased homework completion rate
- Increased opportunity to use technology

In all other benefit categories, teachers using either of the two assignment models were generally very similar in their evaluation of handheld computers' benefits to students. Figure 4.5 summarizes how these two groups evaluated the benefits of using handhelds.

Figure 4.5: Teachers' Ratings of the Benefits of Using Handheld Computers, by Assignment Strategy

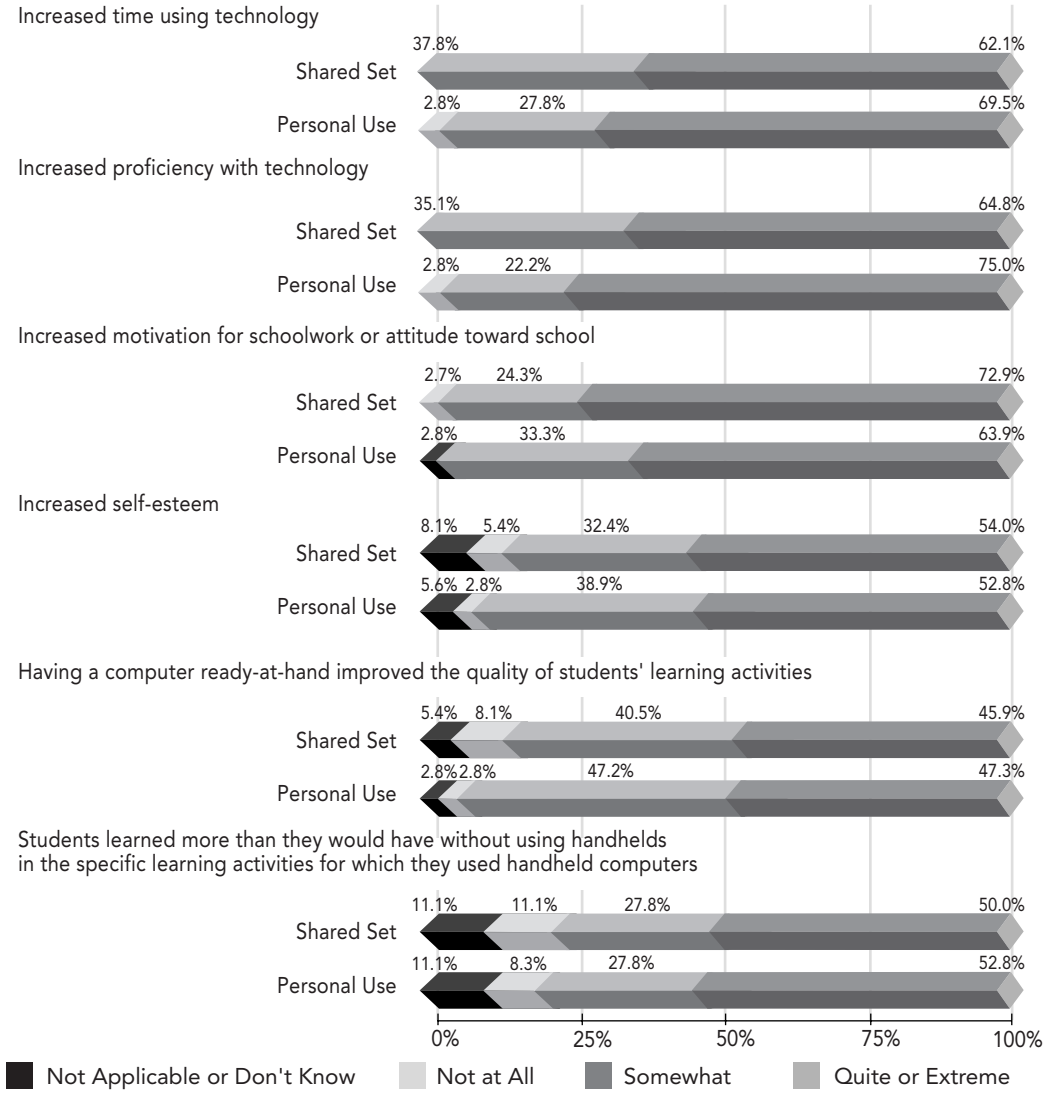


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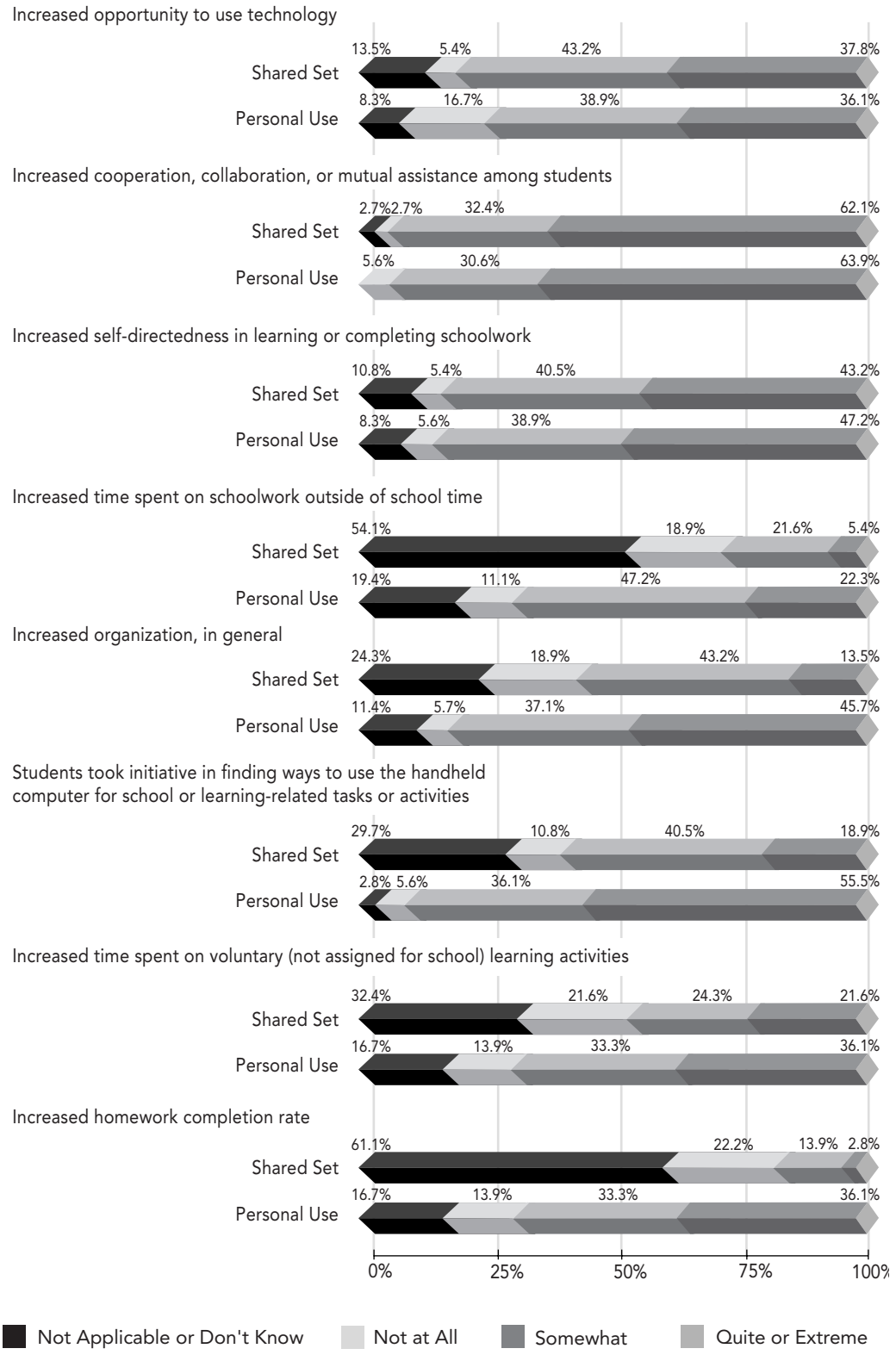
Figure 4.5: Teachers' Ratings of the Benefits of Using Handheld Computers, by Assignment Strategy (continued)



✓ *Strategies for Success*

Assigning Equipment to Students: "Ownership" or "Loanership"?

In introducing handheld technology into the classroom, one of the first issues a teacher faces is how to assign handhelds to students. The main ways that PEP teachers assigned handhelds were the following:

Shared Set Strategies:

- **Shared set**: A classroom set was shared by all students (in groups or individually), and handhelds were used only for specific periods or activities
- **Assigned classroom handhelds**: Each student was assigned a handheld computer; which was used only for specific periods or activities only

Personal Use Strategies:

- **Personal use at school**: Each student was assigned her or his own handheld to use throughout the day; handhelds were not taken home
- **Full personal use**: Each student was assigned her or his own handheld; students could take handhelds home

The shared set strategy is more like "loanership". Students cannot personalize the handhelds because their use and access is limited—the devices will be returned to the pool. Time and type of use are usually specified by the teacher in this approach.

With the personal use strategy, students can take “ownership" of the handheld. Students can enter and store personal information, use it to store and review their work, and can use the device on occasions and for tasks of their own choosing. Each of the equipment assignment strategies listed above has benefits and limitations, which we review below.

How to Decide?

Choosing among these four strategies depends largely on three factors:

1. The number of handhelds available and the number of students who will need to use the technology
2. The frequency and type of use
3. Teachers' evaluation of the benefits and drawbacks of the different versions

1. **Availability and demand**. Obviously, the number of handhelds that are available and the number of students who will need a device can dictate the choice of assignment method. If there are not enough devices to go around, some form of sharing or restricted use will be necessary. The personal use strategy would not be possible.
2. **Frequency and type of use**. How often students need to use the handhelds and the nature of that usage also need to be considered. For example, when handhelds are used for episodic instructional activities, such as for environmental science activities, chemistry labs, or self-quizzes, having a classroom set of handhelds that are assigned to students in different periods can work. But if the activities require students to have continuous access to the handheld computer, the personal use strategy is preferable. This would include situations where students regularly use organization features, such as schedules, assignments, or contact information, or use the handheld across different settings (such as across different classes, or for home/school communication).
3. **Benefits and drawbacks**. We asked teachers to share with us the benefits and limitations they discovered with the assignment strategy they used. Teachers across all assignment strategies indicated that use of handhelds conferred a range of benefits on students (See discussion in this chapter). In general, teachers seemed to be most satisfied and successful with the assigned classroom handhelds strategy and the full personal use strategy. However,

teachers who implemented the full personal use strategy indicated a greater benefit to students in six out of 14 benefit categories. With this strategy, teachers reported that students were better able use the technology autonomously and spontaneously as a personal learning tool; spend more time on assigned and voluntary learning activities, and benefit from the increased time with the technology. The two main assignment strategy groups were very similar for the other eight areas in their evaluation of the benefits to students of using handhelds. Loss and theft of handhelds and loss of styli (the little pointers used for input) were rare overall, and there was virtually no difference in frequency between assignment strategies for these occurrences.

Shared Set Strategy

When handhelds are used episodically for instructional activities, teachers recommend a checkout system, in which students are assigned specific handhelds. Many teachers who did not assign specific handhelds to students reported that they difficulties in tracking and managing the handhelds.

With the shared set strategy, teachers report that they must set up the devices before activities, and "clean up" after activities (re-setting programs, collecting student work, cleaning off data, removing extraneous files, etc.). When the devices are assigned to students (rather than used by different students or groups each class) it is easier for the teacher to involve students in these and other routine equipment management tasks, as well as to track misuse of the handhelds.

The shared set strategies allow a teacher to share one set of handhelds across all students. This may be a significant economic benefit over the personal use strategies.

Classroom set version: Among teachers who implemented the shared set strategy, only 17% indicated that they had no problems with this strategy.

With the shared set, tracking equipment and students' work entailed some difficulties such as "students not clearing the note pad and having to worry about which student had not turned in their stylus," as one teacher reported. "I would consider assigning a specific handheld to each student so that more of the responsibility falls on them," this teacher added.

Assigned classroom handhelds version: Teachers who used the assigned classroom handhelds strategy were generally satisfied with this assignment strategy, with nearly 40 percent indicating that they had no problems. Nearly 30 percent of teachers, however, mentioned that this strategy, as compared to a personal use strategy, restricted students' access to the handhelds, and several indicated that they thought greater access to the handhelds would be beneficial to students.

Personal Use

The personal use strategies are best for instructional activities that require that students to have continuous access to the handheld computer, such as scheduling or communication.

This strategy seems to be preferable when there are enough handhelds for each student. The method gives teachers a great deal of flexibility in developing additional instructional strategies and activities for the handheld over the course of the academic year. Some teachers reported that students found ways to use the handhelds as a learning tool - going online to find dictionaries, using a calculator, or reading. In such cases the use of handhelds increased beyond the teachers' initial expectations.

Personal use at school version. . This was the least-used of the four main assignment strategies, with only about 10% of teachers opting to assign handhelds to students throughout the school day. Among teachers who used this strategy, about 30% indicated they had no problems with the strategy. The same percentage mentioned the importance of equipment management. Checkout or assignment of the devices seemed to be the main concern.

However, this strategy allows students more access to technology than classroom set versions. As a teacher who changed her assignment strategy to this strategy stated: "I limited Palm use to the class period originally. This limited the students'

(*continued on next page...)*

Assigning Equipment to Students: "Ownership" or "Loanership"? (continued)

accessibility to key staff and other students and community members. Later, students were able to check out the Palms during other class periods. Next year, after assessing the responsibility level of my students, I will be allowing checkout of the Palms on a daily basis: check out in the morning, check in at the end of the day."

Teachers using the personal use at school strategy reported that they perceived less likelihood of loss or theft when the handhelds are not allowed out of the school. (This assumption is not supported by the evaluation data.) On the downside, not being able to take handhelds home limits students' opportunities for out-of-school learning , as well as their ability to integrate it into other aspects of their lives.

Full personal use: The full personal use strategy was the most prevalent strategy (comments on it were provided by 43 teachers). In the main, teachers appeared to be satisfied with this strategy (about 37% of teachers indicated they had no problems with the strategy). Sixteen percent of teachers commented that they thought it important that students be allowed to use and adopt the handheld computers as *personal* devices. They felt that the full personal use strategy allows students to use handheld technology for learning both inside and outside of school. Many teachers find that students feel empowered to find software and resources relevant to their school work, often contributing to improved class activities.

About 16% of teachers who used this strategy mentioned equipment loss or breakage that they attributed to students. (Note that reports of breakage and loss did not vary by assignment model; see Figure 4.4.) Teachers using this strategy noted the importance of parental agreements regarding replacement of lost or damaged equipment. Additionally, with full personal use, students have ample opportunity to load additional software or let friends or siblings borrow the device. Therefore, teachers seemed to feel it was important to have policies and agreements in place to manage these situations and events.

PEP Projects: A Closer Look

Advanced Physics Using Handhelds

Project Information:

Grades: High School.

Teacher: Bill Rodriguez

Other resources used: PalmPix cameras by Kodak and Palm Portable Keyboard by Palm; MELD interface by Francis Deck and MELDField software written by Sean Brophy; WordSmith by Blue Nomad; MiniCalc by Solutions in Hand; Print Boy; Go 'n Tell by Hi-CE; AvantGo

Project Description:

The calculator based laboratory (CBL) is a common tool in the high school science classroom. While having many advantages over traditional science labs, CBLs are far from perfect. Students must switch from the CBL to the computer to write their reports, sharing of data is difficult, and data analysis is not immediate. By using handheld computers, students can collect, analyze, and report on data all from one device, and data sharing is as simple as beaming.

Bill Rodriguez and his colleagues at the University School of Nashville in Tennessee, with help from Sean Brophy of Vanderbilt University, recognized the possibility for handheld computers to not only improve CBLs in general, but to aid students in learning a particularly difficult topic: visualizing electric fields and their gradients. To test the effectiveness of handheld computers, Bill and his team compared results of a class using handheld computers to a comparison group that did not use handheld computers.

To take full advantage of the potential benefits of handheld computers to help students learn this difficult topic, Bill, Sean, and their team wrote a PalmOS application called MELDField. Students drew electrodes on a sheet of conductive paper using conductive ink, and then connected the electrodes to a battery. As students moved the voltage sensor, the handheld recorded the voltage and MELDField displayed the voltage as a shade of gray. This was found to be far superior to the traditional manner of students moving a voltage probe from point to point on an electric field, manually recording the strength of the voltage at these various points, and then sketching the equipotential lines and perpendicular electric field lines.

In addition to the use in this one lab, Bill's students used handhelds on a daily basis throughout the year. The handhelds were used to check syllabi on the Web (using AvantGo), beam experimental data back and forth, and write lab reports, as well as keep up with daily news. The PalmPix cameras were used extensively in the lab to record data (wave-tank experiment and optics lab) as well as to take pictures of experimental apparatus to include in a lab report.

When comparing the results from the class that used handheld computers to comparison groups, Bill reported that the students using handhelds outperformed the comparison groups by one grade level. In addition, handhelds provided a tool that allowed students to more easily collaborate on experiments, maintain up-to-date syllabi, collect notes and information more efficiently, and prepare and disseminate lab reports more effectively.

Finally, Bill reported on the importance of a support person on staff who can help out teachers who are having problems with the handheld computers. Trouble-shooting problems with hardware and software and installing software can take up large amounts of time sporadically throughout the year; having a support person can greatly ease this burden.

Handhelds provided a tool that allowed students to more easily collaborate on experiments, maintain up-to-date syllabi, collect notes and information more efficiently, and prepare and disseminate lab reports more effectively.

Chapter 5: Managing Classroom Handheld Technology

The handheld computer was originally designed and marketed to the individual, usually a businessperson. While popular use of the handheld as a business tool goes back to about 1996, use of handhelds as a learning tool in schools has only begun in the last few years, and on a small scale. However, it is quickly becoming clear that educators have many equipment-management needs that the individual user does not.

For an individual user, it is certainly not burdensome to unpack, synchronize, and set up a handheld computer, and then download and install any additional software needed. However, doing this for a classroom set of handhelds can be a significant task. Thus, for the classroom teacher using handhelds considerable time and effort must be given to developing procedures for managing the equipment.

Understanding and addressing technology-management issues is an important part of successful use of handheld technology in the classroom. Integrating handheld computers in the classroom involves a range of equipment-management tasks in addition to other instruction-related tasks such as designing learning activities and investigating peripherals and software. These equipment-management tasks include social or behavior tasks (for instance, creating "appropriate use" standards) and technical tasks (such as charging handheld computer batteries). Because handheld technology is new to schools and adoption is often at the classroom level, many districts and schools are unable to provide full technical support to teachers, which may require teachers to rely more on technical support from vendors, as well as on themselves. This makes it especially important for teachers to understand the technology-management tasks they will face when adopting handheld computers.

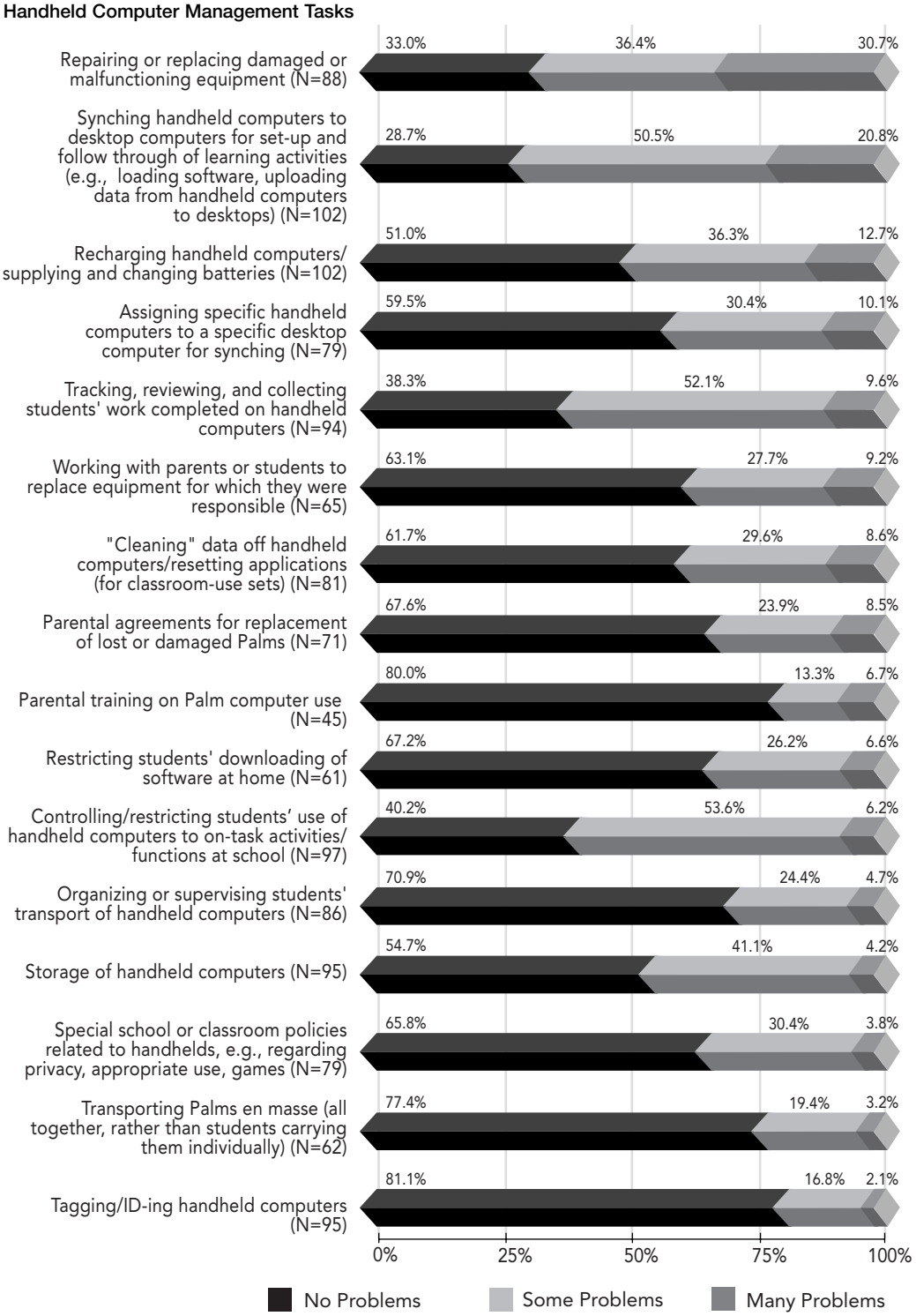
Adequate technical support, infrastructure, and maintenance of desktop computers are important to realizing the potential of computer technology in schools. No doubt the same is largely true for handheld technology, but there are likely to be some key differences between desktop and handheld computers. The handheld computer's affordability, size, and relative ease of use and maintenance make it possible for teachers to have a few "reserve devices" that they can use when one or more units are not working or are being repaired. This means the failure of one device need not affect classroom activities or students' access to technology. However, comparative research is needed on the relative frequency and inconvenience of technical problems before straightforward comparisons between handhelds and desktops can be made.

Based on PEP evaluation data from Spring 2001 and Fall 2001, we developed a list of key equipment-management issues and tasks, and verified this list in Spring 2002. To verify this list, we asked PEP teachers to indicate the relevance of each issue or task for their PEP project, and to indicate the three most important of these issues for successful handheld technology integration. In addition, we asked the teachers to tell us which of the task or issues they experienced problems with during the school year.

The next section discusses the key equipment-management tasks that gave teachers the most problems. Then, we present PEP teachers' rankings of the most important equipment-management tasks to address, and examine how these needs and pri-

orities differ for teachers who used different equipment assignment strategies. The Strategies for Success section (Keeping Handhelds in Hand) at the end of this chapter provides a detailed presentation of PEP teachers' strategies for addressing some key equipment-management tasks and avoiding problems.

Figure 5.1: Teachers' Reports of Problems with Relevant Handheld Computer Management Tasks



Handheld Technology-Management Issues and Challenges

Handheld technology management involves technical aspects, such as synchronizing handheld computers to desktop computers and installing and setting up software; it also involves social and behavioral aspects, such as instituting policies related to appropriate and effective use of the technology and setting up equipment check-out and check-in systems and routines. Some tasks span both the social/behavioral and the technical, for example, developing procedures for tracking, reviewing, and collecting student work completed on the handheld.

The development of handheld technology for education is progressing quickly; and some of the challenges that teachers encounter in managing classroom sets of handhelds have been and continue to be addressed by software developers. Products now on the market address some of the tasks, such as setting up multiple handhelds and creating user profiles.

PEP teachers reported on equipment-management problems they encountered, as well as the number of problems they had (some or many). In telling us which equipment-management tasks or issues were most important, the teachers also described some of the challenges they faced and why the issues were important. Following are the six equipment-management tasks with which the PEP teachers reported having the most problems. (See Figure 5.1 for a complete list of tasks and the frequency of problems with each task that teachers reported.)

1. Controlling/restricting students' use of handheld computers to on-task activities/ functions at school
2. Tracking, reviewing, and collecting students' work completed on handheld computers
3. Synchronizing handheld computers to desktop computers for set-up and follow through of learning activities (e.g., loading software, uploading data from handheld computers to desktops)
4. Storage of handheld computers
5. Repairing or replacing damaged or malfunctioning equipment
6. Recharging handheld computers/supplying and changing batteries

The challenges teachers encountered related to each of these equipment-management tasks are discussed briefly below. Strategies that teachers used for dealing with four key equipment-management tasks—tracking student work completed on the handheld, synchronizing handhelds, storage, and parental agreements—are described in the Strategies for Success section at the end of this chapter, Keeping the Handhelds in Hand.

Controlling or Restricting Students' Use of Handheld Computers to On-Task Activities or Functions

The fun of beaming notes to friends and the ready availability, through Internet download, of a wide variety of games can make the handheld computer a tempting off-task distraction for students. This may account for the fact that controlling or restricting students' use of handhelds to on-task activities or functions is the management task that teachers reported having the most problems with. Many teachers report that clear and enforced policies related to students' appropriate use of handhelds are very effective in preventing off-task use. Some teachers have reported that students' sheer pride and sense of status associated with being given a handheld computer to use prompts them to use their handhelds responsibly. (See the March 2002 PEP Evaluation Report for details on teachers' reports of types and frequency of students' off-task use of handhelds.) While establishing clear policies and practices regarding handheld use prevents some amount of off-task use, teachers nonetheless found the task a challenging one.

The following comments by teachers convey the importance of the issue for teachers and some of the challenges they faced in addressing it:

- Basically the only problem was keeping the kids on task all the time while using the units. I would have to make my lesson plans tighter.

- [On students using handhelds in other classes:] Other students thought they were a novelty and wanted to see them, play games on them, etc. Consequently, some students had their handhelds taken away by non-program teachers.
- [One of the] most important management issues that I have found to be associated with the use of the Palms [is] making sure that students are doing what they are supposed to be on the Palms, not playing games.

Tracking, Reviewing, and Collecting Students' Work Completed on Handheld Computers

Tracking, reviewing, and collecting student work completed on handhelds presents several issues not encountered with desktop computers. Handheld computers have a relatively flat directory and file structure, and therefore it is difficult to organize sets of student data from different periods. It is important to name files so that data files are not mixed up. Desktop computers in schools are often networked to a printer, so student work is easily printed and handed in. It is possible, with a peripheral device such as PrintBoy, to beam documents from a handheld to a printer. Without this device, it is necessary to synchronize handhelds to a desktop computer, and then print documents. Networked computers can be controlled from a central station, so that programs can be reset, student work can be saved to and retrieved from one server location, and student work can be quickly and easily reviewed. Such functionality is currently not commonly available with handheld computers.

Teachers' comments convey their needs teachers in regard to collecting and reviewing student work:

- Teachers need to have easy access to student-collected data. This can be difficult if multiple students use the same Palm.
- Being able to check student work. Printing student work. Cleaning off one class's work, then be able to move on to another class.
- [Next] year, we will label each data entry differently, so that those finding them will have an easier time of it.

Synchronizing Handheld Computers to Desktop Computers

Synchronization of handheld computers to desktop computers was a task with which many teachers had some technical difficulties. About half of all teachers who reported on this topic indicated that they had "some" problems, while about 21% stated they had "a lot" of problems.

One source of difficulty was the necessity for USB cables (not shipped with the basic handheld computers that were granted to PEP teachers) for use with Apple computers. Another source of technical difficulty was that security software installed on schools' desktop computers and operated through the network interfered with the operation of the synchronizing function. Teachers also found the "tedious task" of synchronizing multiple handhelds one by one to be problematic. Some teachers noted that they did not have local technical support from the district to address technical difficulties with synchronization and other tasks.

The following comments by PEP teachers illustrate some of difficulties with synchronization as well as teachers' views of the importance of developing effective procedures and logistics for synchronization. When asked to describe their biggest technical problem teachers said:

- Hot synching successfully and getting computers to recognize specific handhelds. In order to have any success, the district had to remove Microsoft NT, which means the security of the machines was compromised, and replace it with Windows 98. This is the only way we could get the software, the hot synching and further work be successful, although there were still problems. It made it difficult to look at work and print their data out.
- Identifying and enabling a desktop computer to be used for synching took some work due to the network security issues setup by the network administrator.
- Loading software onto each Palm was a long, tedious task.
- Synching so many handhelds (36) onto 11 computers (multiple users)-with little or no tech backup in school
- Depending on what software you have it can be very troublesome to [upload] data from multiple handhelds to a single computer.

Storage of Handheld Computers

Teachers told us that storing classroom handhelds was an important equipment-management issue to address. For some teachers, security was a key concern. Other teachers viewed storage of handhelds as an aspect of tracking their use and whereabouts; a hanging set of pockets, for example, or a clear container, could allow teachers to make a quick visual scan of the classroom set to see that all the devices were checked back in after a period of use. (This scenario is most applicable to the classroom set handheld assignment strategy.) A few teachers mentioned that storage arrangements, ideally, would be combined with charging of handhelds. A few visionaries mentioned the need for a carrying case with a built-in charger for multiple handhelds. Teachers also mentioned needs such as:

- For third grade...storage because the Palms MUST be kept locked up on a daily basis.
- Having a safe and orderly place to store handhelds is critical. I have a home-made wooden case with spaces for all handhelds, six recharging cradles, and space for keyboards. The box can be locked for security. I can check to see that all equipment is returned with one glance.
- Get Palms labeled and set up in a storage area that is able to be locked. Palms should be arranged in a way that missing Palms can be quickly identified and the student Palm list can be checked. I used clear plastic stacking containers…. Each container slot had a number that corresponded with a Palm number.

Repairing or Replacing Damaged or Malfunctioning Equipment

Many teachers reported difficulties in getting handhelds repaired (36.4% reporting having "some" problems, while about 31% reported having "a lot" of problems). Teachers' descriptions of difficulties encompassed a range of issues. In some cases, students were left without a handheld to use, or had to share a handheld, when a device was being repaired. Some teachers mentioned the importance of having one or more spare units for use as backup devices.

Recharging Handheld Computers/Supplying and Changing Batteries

Handheld computers are powered with either regular batteries (usually AAA) or an internal battery that is recharged using the hot-synch cradle. It is important that teachers create routines for changing or recharging batteries, whether this is done by students (at home or at school), teachers, or both.

Reported difficulties with charging had mainly to do with (1) the burden of supplying and changing AAA batteries; (2) the inconvenience of charging the classroom set of handhelds on a regular basis; or (3) the unfortunate consequences of a sudden loss of student data that results from a handheld's loss of charge. The remarks below present a good sample some of teachers' more challenging experiences:

- Keeping the handhelds charged is an important maintenance piece that makes classroom use more seamless. Palms that need to be charged halfway through the morning caused occasional problems. This is easily remedied if the teacher is attentive to this.
- Some of the children forget to check their batteries and lose all of their work. This can be a quite devastating event to manage.
- Getting all of the Palms charged between long field trips and classroom work was tedious and time consuming.
- If battery[-powered] units are used, keep a ready supply of batteries on hand. Remove batteries at the end of each day and replace with next use.
- The recharging got to be a little bit of a hassle because I used the Palms daily. I finally got a "Dream Team" of students who were in charge of setting the Palms in the cradles for recharging for the next day's classes. This worked out well for everyone and the kids were very efficient!
- Teachers should plan to have an appropriate number of outlets and/or power strips to accommodate the Palms.

The Most Important Equipment-management Tasks

Implementation of handhelds in the classroom requires teachers to address a fairly wide range of equipment-management tasks. In addition to the six equipment-management problems reported by relatively high percentages of teachers, a range of other tasks were also addressed in PEP classrooms.

To validate our list of important handheld equipment-management tasks (based on PEP evaluation data from Spring 2001 and Fall 2001), we asked teachers to indicate which tasks in our list were relevant for the PEP projects in their classrooms. All but

five tasks were deemed relevant by over half of all PEP teachers. Four tasks were rated as relevant by 28% to 45% of teachers, while one task was deemed relevant by only 15% of teachers.

Figure 5.2 presents the list of equipment-management issues we asked teachers about, in from highest to lowest in terms of the percentage of teachers indicating the item as relevant. (The total number of teacher responses (yeses and nos combined) for each item ranged from 91 to 87, with 90 being the most frequent number of responses). Teachers' reports of the relevance of these issues to their projects varied widely by the assignment model they used.

Figure 5.2: Handheld Computer Equipment-Management Tasks Deemed Relevant by PEP Teachers

TASK OR ISSUE	% THAT INDICATED AS RELEVANT
Recharging handheld computers/ supplying and changing batteries	84.6
Synching handheld computers to desktop computers for set-up and follow through of learning activities (e.g., loading software, uploading data from handheld computers to desktops)	78.1
Controlling/restricting students' use of handheld computers to on-task activities/functions at school	75.0
Tracking, reviewing, and collecting students' work completed on handheld computers	74.8
Tagging/ID of handheld computers	69.5
Storage of handheld computers	65.4
Repairing or replacing damaged or malfunctioning equipment.	65.1
Organizing or supervising students' transport of handheld computers	55.2
"Cleaning" data off handheld computers /resetting applications (for classroom-use sets)	54.7
Assigning specific handheld computers to a specific desktop computer for synching	54.3
Special school or classroom policies related to handhelds, e.g., regarding privacy, appropriate use, games.	54.3
Parental agreements for replacement of lost or damaged Palms	45.3
Working with parents or students to replace equipment for which they were responsible	40.2
Transporting Palms en masse (all together, rather than students carrying them individually)	35.2
Restricting students' downloading of software at home	28.0
Parental training on Palm computer use	15.7

The following issues were reported as relevant by over half of all teachers:

- Organizing or supervising students' transport of handheld computers
- "Cleaning" data off handheld computers /resetting applications (for classroom-use sets)
- Assigning specific handheld computers to a specific desktop computer for synching
- Special school or classroom policies related to handhelds, e.g., regarding privacy, appropriate use, games.

Teachers' descriptions of the specific challenges they faced related to these tasks, and their strategies for addressing them are described in the Strategies for Success section, Keeping the Handhelds in Hand.

The relevance of some of these equipment-management tasks or issues varied markedly by the handheld computer assignment model the teacher used. (See Figure 5.3.) For example, "Restricting students' downloading of software at home" was seen as an issue for about 65% of teachers using the full personal use model, although only 9% of teachers using the classroom set approach found this issue relevant, most likely because students using handhelds only episodically at school have limited opportunity to download software. Similarly, developing policies related to

Figure 5.3: Relevance of Handheld Computer Management Issues, by Assignment Model

	CLASSROOM SET (n = 23) %	ASSIGNED CLASS SET (n = 18) %	PERSONAL USE AT SCHOOL (n = 9) %	FULL PERSONAL USE (n = 33) %
Storage of handheld computers	72.7	64.7	77.8	59.4
Synching handheld computers to desktop computers for set-up and follow through of learning activities	85.7	64.7	66.7	80.6
Assigning specific handheld computers to a specific desktop computer for synching	61.9	44.4	66.7	45.2
Tracking, reviewing, and collecting students' work completed on handheld computers	90.5	66.7	77.8	71.0
Controlling/restricting students' use of handheld computers to on-task activities/ functions at school	61.9	58.8	88.9	83.3
Restricting students' downloading of software at home	9.1	5.6	33.3	64.5
"Cleaning" data off handheld computers/ resetting applications (for classroom-use sets)	66.7	38.9	88.9	46.7
Recharging handheld computers/supplying and changing batteries	90.5	82.4	88.9	80.6
Organizing or supervising students' transport of handheld computers	52.4	29.4	66.7	64.5
Tagging/ID of handheld computers	66.7	52.9	88.9	74.2
Parental agreements for replacement of lost or damaged Palms	31.8	11.8	66.7	83.9
Parental training on Palm computer use	18.2	11.1	11.1	25.0
Transporting Palms en masse (all together, rather than students carrying them individually)	47.6	52.9	33.3	25.8
Special school or classroom policies related to handhelds, e.g., regarding privacy, appropriate use, games.	28.6	52.9	55.6	71.0
Repairing or replacing damaged or malfunctioning equipment.	42.9	55.6	66.7	83.9
Working with parents or students to replace equipment for which they were responsible	22.7	22.2	44.4	74.2

appropriate use of handhelds was a concern for about 70% of teachers using the full personal use model, but only for about 25% of the teachers using the classroom set model. Tracking student work completed on the handheld, and tagging equipment, recharging the devices, and synchronizing handhelds to desktop computers were seen as concerns by teachers in roughly equal proportions across the four main equipment assignment models.

✓ *Strategies for Success*

Keeping the Handhelds in Hand: Managing Classroom Handheld Technology

Effective technology management is crucial to successful integration of handheld computers in the classroom. Having routines, policies, procedures, and tools in place for effective use and maintenance of the equipment can help teachers avoid problems and make it easier to focus on teaching and learning, rather than the technology.

The PEP evaluation study aimed to document and understand the wide range of technical, logistical, and procedural equipment-management tasks that teachers faced as they innovated the use of this new technology in the classroom. As "pioneers," PEP teachers had little prior information about the "lay of the land"; the technology-management needs related to handhelds were discovered and solved in the classroom. With little knowledge to draw from, PEP teachers independently created and experimented with strategies for managing their equipment.

This section presents some of the distilled wisdom of these pioneers on the frontier of mobile computing in the classroom. It presents their strategies for dealing with four key equipment-management tasks. In addition, we present an extended inventory of the equipment-management issues that PEP teachers, based on a year or more of classroom use, identified as among the most important to address.

PEP Teachers' Strategies for Managing Handheld Computers

We asked teachers to share their strategies for addressing four key equipment-management tasks:

- Restricting students' off-task use of handheld computers
- Synchronizing handheld computers to desktop computers (hot synching) for set-up and follow through of learning activities
- Tracking, reviewing, and collecting students' work completed on handheld computers
- Devising and implementing parental agreements to be responsible for equipment

Just over 100 PEP teachers and their team members provided comments.

Restricting Students' Off-Task Use of Handheld Computers

An ever-growing number of games for the handheld computer are available on the Internet, many for free. Students found these games, as well as beaming notes to friends, to be tempting distractions (see Chapter 2, page 17, "Inappropriate Use and Its Prevention, for a description of teachers' reports of students' off-task and inappropriate use of handhelds).

In spite of these temptations, many teachers reported strategies for discouraging off-task use of handhelds that were very effective. Many of the teachers who reported that inhibiting off-task use was not a problem were teachers who used the classroom set assignment model, which gives students only limited access to the handhelds. Some teachers who reported off-task use by students also reported that off-task use declined as the novelty of handhelds and games declined. Two teachers described their preventative measures:

- We spoke a lot about this before the Palms were assigned, and just after when they were "new" to all students. We read a letter to them that was going out to all their teachers, and translated it into many languages. We read another letter to them that was going home to their parents (again, with translations). The principal was very involved. Other teachers literally NEVER reported this problem, so I think all our front-loading of prevention worked.

- Once students learned how to mask the sound, games did become an issue. I began allowing free time once tasks and activities were completed. With few exceptions, this agreement was honored. Students that still played lost use of their Palm for that day and had to complete their work differently or lost credit for that day. They always had a new start the next day. It worked well and was respected.

The most commonly mentioned strategy was establishing policies and rules regarding appropriate and effective use of the handheld computers and communicating these to students. Consequences for violations of the rules were usually included in the policies. A common sanction was not permitting a student who violated a rule to use the handheld for some time period.

The second most frequently mentioned strategy was monitoring of student use of the handheld computers during the class, or occasionally checking student Palms for games.

A few teachers described other strategies that they found effective:

- We implemented a "close the cover" rule when teachers were giving instructions. That seemed to keep off-task behavior and play to a minimum.
- I found some software called Invisible that would hide applications we were not using. It was pretty effective, for example, in hiding the calendar. But if the students pressed the hard button, the calendar application would still open. But cheaper than Restrictor [a similar software program]. The drawbacks are that each handheld must be turned on and off by hand. Meaning the teacher must handle each of the PDAs to set up the controls.

Synchronizing handheld computers to desktop computers for set-up and follow through of learning activities

Many teachers had students synchronize handhelds with a classroom computer or a one in the computer lab. Most teachers assigned specific computers to specific handhelds, and let students take turns synchronizing, either synchronizing just their own assigned handhelds or the entire class set. Some teachers had students synchronize during the class period, while teachers employing the personal use assignment strategy had students synch outside of the class time. Some teachers reported scheduling specific days for students to synchronize.

- Four to five students came in each morning before school to hot sync the entire class set of Palms and then pass them out to individual students.
- We were limited to four possible sites for hot synching so one student in each team would hot synch during the class period. We rotated this job so all were experienced.
- I required students to hot synch weekly in what I called a "rolling hot synch." Students would just get up and go to the computer when it was available, one at a time. During the 90-minute class, all students had to complete the process, and they did-with minimal class interruption.
- Students were assigned days of the week and synched with my computer on those days

The second most commonly reported strategy was for the teacher to synchronize all the handheld computers, using either their own computer or multiple computers at school.

- [I] beamed info to my handheld, then took it home and hot synched it to my desktop.
- I hot synch to one computer - mine - and monitor the data from the one machine. The lead teacher has also been hot synching so that we have a backup and so that she learns more about device implementation.
- In each case, teachers had access to a personal classroom computer. Typically, one cradle was attached to that computer and was used to sync all handhelds. This made the hot synch process very time consuming especially where pictures were included in data records.

The third most common strategy teachers reported was for teachers and students to share the task. A handful of teachers reported that they did not synchronize at all, mostly due to lack of

USB cables needed to synchronize handhelds to Macintosh computers.

Tracking, Reviewing, And Collecting Students' Work Completed on Handheld Computers

PEP teachers needed to check students' work for various purposes (for example, grading or checking that students have completed activities or tasks correctly), and at various phases of an activity. When more than one student or student group are sharing a handheld, it is also important that teachers have a system for keeping track of the work of multiple students on a handheld.

The most frequently mentioned strategies for collecting and reviewing student work completed on the handhelds were the following, from most to least frequently mentioned:

- Beam files to teacher's handheld
- Synchronize to specific computers
- Print out work
- Review work directly on handhelds computers

Most teachers used multiple strategies, depending on their purpose for reviewing the work and the nature of the work. They also used the strategies in combination - for example, having students synchronize their work with the desktop computer, and then printing it out for the teacher to review; or beaming documents to the teacher, who then synchronizes the student's work to the desktop computer and reviews it online. One teacher, for example, reported using nearly every strategy: "Student work is tracked and collected in several ways. Quiz responses and holistic scoring evaluations are beamed to the teacher. Concept maps and written responses in FreeWrite are printed or beamed. Class notes are checked by student monitors who view Palm Desktop software."

Beaming to teacher: Many teachers had students beam files to them once they were ready for review. Often teachers mentioned the importance students giving the files unique names. The importance of receiving or putting memo files in specific folders was also mentioned, as a way of tracking student groups or on-time and late work.

- They beamed to me all the time. I put grades in the computer right away, according to my rubrics for success. At the same time as I read their work (now on my own Palm for ease of transport and correction), I filled out little copies of the rubric-assessments to give back to the students so they would know how/where their grade came from.
- When students beamed assignments to me, I would place them in a specific category on my Palm for grading. Students were to include their name and date on the first line of each memo (along with title that was already provided) to help me identify completed works on a list view (rather than having to sort through an entire memo). I could then beam feedback to each student when grading was completed. Works that came in "late" went to the "unfiled" category, to prevent duplicated grading. All works were eventually deleted (and sent to the archive folder just in case) to clean up.
- When the students were finished with a task, they would beam me their finished product. Since they all took varying amounts of time finishing, it went very smoothly and efficiently.

Synchronize to specific computers (then review work on line or printed out): Many teachers had their students synchronize their handhelds to a desktop computer for collection, review, and storage of student work. Once on the desktop computer, teachers would review student files online or students print the work and hand it in. Synchronization could also be used as way for teacher to "pass back" comments about student work or completed rubrics for the work (see teacher comment below):

- I had the students use the Annotations feature of the Palm Reader to make their notes. As we finished each act, the students would do an "export annotations" and then HotSync to my classroom PC with their unique user ID. I could then go into each student's notes, grade them online, and return comments to them with their next HotSync. This was amazingly effective for me as a teacher, and the students enjoyed it, too.

- The lead teacher would have students hot synch to one of the four [classroom computers] and then physically move from machine to machine to review work.

Printing out student work: Printouts of student work completed on the handheld are usually made from a desktop computer, after the handheld has been synchronized with a desktop and the work uploaded. Alternatively, in some cases, teachers had an infrared port attachment for the printer, so that files could be beamed directly to the printer. Printing out as a way of reviewing student work was usually done in combination with other strategies.

- Synched to computer and printed on a networked printer in the classroom, or teacher collected Palms and graded work on the Palm itself.
- Sometimes students printed hard copy for me...usually I looked on with students as they worked or viewed [handhelds] on my own
- Students beamed assignments or reports to the instructor or they beamed documents to a printer for a hardcopy to turn in.
- Hard copies were printed once graphs/charts were created. Individual Palms were also checked for data entry.

Reviewing work on handhelds: Reviewing student work directly on the handheld was an approach that teachers often reported using for formative types of assessment, such as to check whether students had collected data correctly. Teachers also reviewed handhelds to check that students were using them or applications as directed. For example, teachers may collect handhelds to check that students are following directions in naming files or in using the handhelds for organization, such as entering due dates or events in the calendar or listing homework on the To-Do list.

- Students showed me their handheld and the work they did on it for any particular time. I was also able to check on their work on my own. Preliminary drafts were printed and shown, as were final copies of reports.
- We tracked their work during class time, checking what they had on the Palms. One teacher went through each Palm after the activity to make sure all work was complete.
- I looked at every handheld individually.
- I checked their work weekly when I met with them for personal subject conferences. They would come with journals or folders and their Palms and we sat together and reviewed their work.

Devising and Implementing Parental Agreements to Be Responsible for Equipment

Developing and implementing parental agreements for equipment responsibility was a management task that was of greater concern to teachers using the personal use assignment model than the shared set assignment model (see Figure 5.3). Many teachers reported having such an agreement signed by parents (and sometimes also by students). The agreement typically laid out responsibilities for lost or damaged handhelds. Some parents were asked to pay $50 to $200 for replacements, while others were not made responsible for any amount of the cost of replacement devices. Some teachers were unwilling to implement parental agreements for financial responsibility among low-income families. Parents' refusal to enter into an agreement was also mentioned by some teachers. Additionally, several teachers noted problems in getting parents to comply with the agreements, when necessary.

- A formal authorization was filled out in order to allow the students to take the handhelds home. If the equipment was damaged or needed to be replaced, a check for $200 was to be made out to the school.
- All the parents signed our agreements but we did not require them pay for lost or damaged Palms due to income considerations.
- Students were not allowed to check out a handheld unless parents signed off on an agreement to pay for or replace lost or damaged units.
- Each child and parent signed a contract before receiving a Palm. A few students began the year using a Palm that remained at school, until they

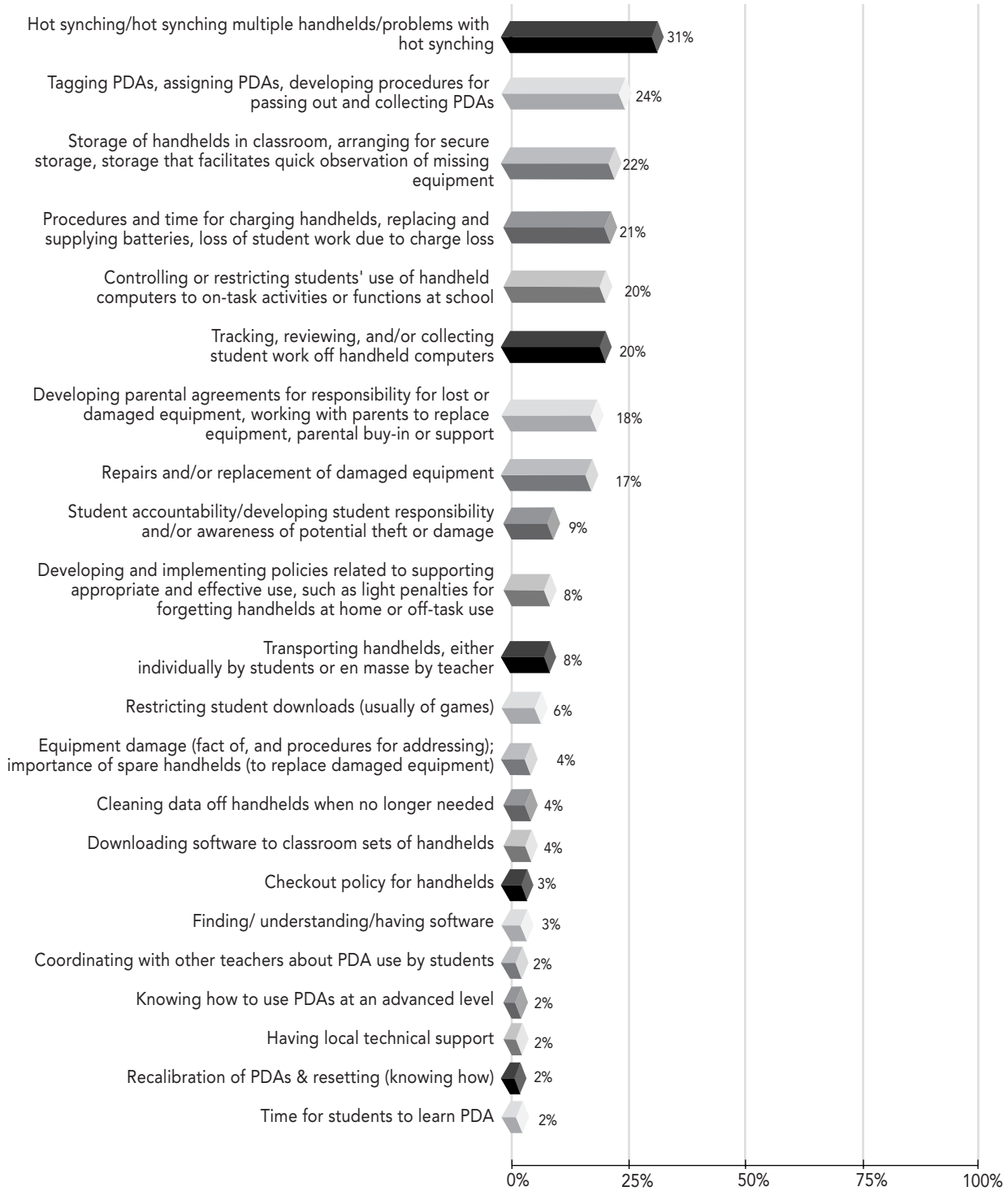
could prove they were responsible enough to take one home (parent's decision).

- Agreements were signed and parents followed through with payment.
- A letter and permission slip [were sent} home. We had no problems.

Most Important Equipment-Management Tasks

We asked teachers to name the three most important handheld computer equipment-management tasks. Figure 5.4 presents the ranking of the key equipment-management tasks, in order of their frequency of nominations by teachers. The importance of these tasks vary by the handheld computer assignment strategy used (see Figure 4.5, Teachers' Ratings of the Benefits of Using Handheld Computers, by Assignment Model). In addition, the percentage of teachers nominating any one task as among the three most important is relatively low, and the list of tasks is fairly large. This indicates that teachers' opinions about the *three most important* tasks varied fairly widely. Partly in spite of, and partly because of, this wide range, we believe this list will provide useful guidance to teachers who are planning and prioritizing tasks for the integration of handheld computers in their classrooms.

Figure 5.4: Percent of Teachers Nominating Three Most Important Equipment-Management Tasks



PEP Projects: A Closer Look

Building Vocabulary in the ESL Classroom

Project Information:

Grades: Elementary, 2nd - 4th.

Teacher: Ellen Rock

Other resources used: A dictionary, a thesaurus, and word games, such as "Hungman," a variation of "Hangman".

Project Description:

The "Word Wall" is tool that many teachers use to help English-language learners acquire new and unfamiliar vocabulary. As a physical place in the classroom where words and definitions are listed, the "Word Wall" is limited in that it can only be accessed in the classroom, and is not available to students where and when they are most likely to need it. By putting the "Word Wall" on a handheld computer, students can have this resource ready at hand, to review and practice anytime. Each student enters her or his word list into the handheld, then can use it to complete assignments, carry the list from class to class, and even take it home to study and use.

Ellen Rock and her colleagues at Miller Wall Elementary School in Marrero, Louisiana, used this approach with their second, third and fourth grade students. These students used handheld computers to carry their "Word Walls," in conjunction with an English as Second Language curriculum by the Scott Foresman publishing company. Ellen and her colleagues introduced their students to handheld computers by teaching them to use its basic applications: Memo Pad, Calculator, To Do List, Calendar, and Graffiti, the special text input system it uses. Students then began to use the handhelds as part of their daily learning activities, most centrally for vocabulary lessons. Students added words to the lists on their handhelds several times a week. Each student also had a dictionary and thesaurus on their handheld, too. Teachers and students then extended their use of handhelds to include creative writing, math word problems, and data-taking from science inquiry activities. Once teachers and students were familiar with the handhelds, additional classroom uses were easy to develop and implement.

Teachers reported that as a result of this project:

- Students developed greater confidence in making oral presentations as well as in posing questions in a whole-class setting.
- Teachers became more creative in their lesson planning and curriculum development. Teachable moments were more easily seized as opportunities for learning because handhelds were ready at hand for use in writing, looking up words, or reviewing notes.
- Initial drafting, editing, and final draft writing were much easier than with pencil and paper.
- The lower-grade students began asking higher-level questions, and the upper-grade children began writing on their own.
- ESL students won numerous academic awards for above-average class work.

Students developed greater confidence in making oral presentations as well as in posing questions in a whole-class setting. And initial drafting, editing, and final draft writing were much easier than with pencil and paper.

Chapter 6: Conclusions, and Implications for the Not-Too Distant Future

The PEP program has found that teachers are surprisingly positive about the use of handheld computers in their classroom. We say "surprisingly" because today's handheld computers were designed primarily for the business professional, not the K-12 educator and student. What accounts for this enthusiasm? And what can we expect in the not-too-distant future?

We believe that much of this enthusiasm stems from the fact that handhelds finally allow unobtrusive, affordable 1-to-1 computing in the classroom. Without handhelds, teachers must rely on:

- **The computer lab**, which must be scheduled in advance, and requires the teacher move her entire class to a new location for the classes activities
- **The few computers in the back of the classroom**, which requires that students share a small number of computers
- **Laptop computers**, which are expensive and, while small enough to be portable, are large enough to be obtrusive when each student has a laptop computer on her desk.

Each of these factors contributes to computers being used only occasionally in the classroom, limiting the possible impact on education.

Conversely, handhelds are inexpensive enough to allow us to envision a true 1-to-1 student-to-handheld ratio in the not-too-distant future; are portable enough to be put in a pocket and taken anyplace the student goes; are powerful enough to run most computer software; and do not have a significant startup time. Combined, these features allow the possibility of frequent technology use, integrated throughout the curriculum[i]. This means that teachers and students can take advantage of productivity software, interactive simulations, drawing tools, and other tools at the precise time and place that they can have the greatest impact on learning.

Our evaluation shows that these benefits have an impact on the classroom. PEP teachers report increased technology use, greater student engagement, and more effective instructional activities when handheld computers are thoughtfully integrated into the classroom. Additionally, teachers who allow students full personal use of handheld computers find handhelds more effective than teachers who limit handheld use. This provides further evidence that technology is more effective when it is accessible at the time and place that students perceive the need for technology use.

These advantages may be enough to account for much of the PEP teachers' enthusiasm. However, to continue to develop and extend the benefits of handheld technology for teaching and learning, it is important to understand the characteristics of handheld computers that make them far more than "tiny computers." In the following section, we examine several advantages to handheld computers that can be particularly relevant to education.

Portability: New Possibilities for Learning Activities

As discussed elsewhere in this report, one of the most productive uses of handheld computers among PEP teachers was for environmental science: typically students used probes and sensors to analyze the health of a local stream. Teachers reported for example, that with real-time data display, students can immediately notice disparities in their measurements, and raise important questions about unexpected results or differences: What have I learned that could explain these differences? Are there any characteristics of this stream that would cause these differences? Are our probes miscalibrated? Should someone else verify my reading? That is, *students were acting like scientists*, an occurrence that happens all too infrequently in the typical science classroom.

In this case students were acting like scientists, we believe, because they had the right tools at the right time, and in the right setting, just like real scientists. This is why handheld technology is so powerful for many learning activities: It allows students to focus on the problems and questions at hand, rather than on the logistics of completing the activity.

For example, some PEP projects had students collect data about their community (such as the price of sneakers, or the location of different species of birds). By using handhelds, students could collect their data, aggregate it, and even upload the aggregated data to their desktop computers for further analysis. By having computing technology available in the course of their inquiry activities, students were able to concentrate on the learning tasks ("What are the trends in the data?" "What are disparities in the data?"), without getting lost in the irrelevant details ("Where did I put those survey forms?" "I can't read what I wrote here." "Who is going to enter all this data into the computer?"). This is not to say that the handheld computers "do the work"—students still have to create the data collection instrument, collect the data, and analyze the data. However, handhelds facilitate students' focus on compelling questions and problems that motivate their learning.

We can envision in the near future "seeding the world" with learning objects that learners interact with using handheld computers. For instance, imagine a nature walk with beaming stations. Each of these stations is indexed by national science standards and common student investigations. Instead of students getting a one-size-fits-all pamphlet about the area, students are beamed information and learning activities directly relevant to their age and interests. (See http://www.cimi.org/whitesite/ for an overview of the impact that this type of functionality is already having on museums.)

Assessment: Using Handhelds to Understand What Students Know

There are significant drawbacks to using handhelds for assessment. PEP teachers reported that one of the main drawbacks of using handhelds for classroom assessment was inappropriate use of beaming, including students attempting to cheat on tests. Clearly, this is a concern for teachers attempting to use handhelds for tests. Additionally, many standardized tests will not allow the use of devices that provide students the capability of storing text or other data.

While a few solutions that address some of these drawbacks are already available on the market, we see the area of formative assessment as better suited than summative assessment to take advantage of the functionality of handhelds. Formative assess-

ments often do not result in a grade; they are used to determine the progress a student has made and point to areas where improvement is necessary.

Portfolio assessment is an example of formative assessment that has gained wide acceptance as a desired practice: students create a portfolio of their work, which the teacher can use to judge the students' strengths and progress. Currently, portfolio assessment is too time-intensive for most teachers. However, if handheld computers were integrated across many learning activities, electronic portfolios could be easy to create and maintain. Students could beam their portfolio entries to the teacher, who would no longer have to collect 30 manila folders, each stuffed with student work. There is still some work to do before this becomes a reality, however. Although some PEP teachers did use handhelds for portfolio assessment, this application would be greatly facilitated by software designed help the teacher to collect, organize, and grade student portfolios; such software currently does not exist.

Another form of formative assessment that teachers engage in frequently is the common "whole class question" such as "Who knows the function of the mitochondria? Anyone? Maria, please share your answer with the class." Although a common occurrence, this is not necessarily an effective way for a teacher to determine how much the class has learned. An existing technology that enhances this scenario is the ClassTalk system[ii]. It allows students to respond to teacher queries electronically and, if appropriate, anonymously. The student responses are then aggregated and displayed in a histogram, allowing the teacher a better understanding of how much the class has learned. We can soon expect a powerful form of this type of functionality on handheld computers, in a way that takes advantage of the handheld computer feature set.

A Personal Learning Device

PEP teachers have pointed to the following benefits of students having a personal learning device:

- Support of autonomous learning
- Support of student responsibility for learning
- Support of cross-disciplinary long-term projects.

Support of autonomous learning

PEP teachers have told us that giving students their own handheld computer promotes autonomous learning. Some teachers report that students devise new ways of using handheld computers to support their own learning, such as creating flashcards, creating practice quizzes to beam to each other, and using handhelds to track their assignments. In addition, students often find relevant resources and applications that their teacher didn't know about. For example, one teacher reported that a student said, "We need dictionaries on our handhelds so we can look up words we read. I went on the Internet and found this one." After evaluating the students' choice, the teacher agreed that it would help her students.

Support of student responsibility for learning

Some PEP teachers have reported that students become almost visibly empow-

ered upon accepting a handheld for personal use. It is as though the combination of trusting students with a personal learning device and the implicit accountability implied in having a single device to store, track, and complete most assignments results in an acknowledgement that they are now responsible for their own learning. Perhaps most important, when they have their own personal learning device, students are equipped to work on learning tasks when and where they chose.

We begin to see evidence of this in Chapter 2, Figures 2.6 and 2.7: About 84% of teachers said that using handhelds increased students' self-directedness in learning, about 77% said that students showed initiative in using handhelds for learning, and among projects where students were allowed to take handhelds home, approximately 75% of teachers report an increase in homework completion.

Support of cross-disciplinary long-term projects

A few PEP teachers have reported that a personal learning device that can be used across tasks and across curricular areas allows for more long-term, cross-disciplinary projects. For instance, students can use their handheld device to create a concept map about water quality and pollution; sample water quality at a local creek; collect survey data on people's opinions about local pollution levels; analyze data sets; and write reports on their findings. Even as students change classrooms, teachers, and applications, their technology tools remain consolidated in one handheld device that stays with them. This may help students avoid over-compartmentalizing knowledge[iii], allowing them to create more integrated understandings.

New Forms of Collaboration

The synergy between collaboration and autonomy

Many PEP teachers have reported that handhelds allow increased collaboration. These were often the same teachers who reported that handhelds allowed increased student autonomy. The fact that teachers can use handhelds as both collaborative devices and autonomous learning devices shows that the combination of features found in handheld computers allows for versatility in moving between individual student work and collaborative group work.

Because handhelds are unobtrusive and portable, students are able to quickly and easily move between different classroom formats. As a result, when the class moves between individual work and group work, there is no special treatment of the technology–it simply moves with the student from one classroom format to another. Because the handheld screens are small and directional, they are relatively private. As a result, students are able to privately reflect, explore, and experiment, without concern that someone else will see their unfinished work. Then, once students have a final product that they are proud of, they can easily share it, either by beaming to other students, or by passing around their handheld. PEP researchers have observed this exact behavior: a student is concentrating on her work, even to the point of telling other students to "stop bothering" her. Then, within minutes she makes a discovery that she is so excited about that she shares this with all nearby students. The student suddenly transforms from an autonomous worker fully absorbed in her own task to a collabora-

tive team member, sharing insights and discoveries with fellow students.

As researchers and educators become more sophisticated in using handheld computers in the classroom, we expect that we will see the creation of many activities that allow students to work alone until they are comfortable with their work, then share and explain their work to team members, then cycle back to revising their work autonomously.

New types of simulation activities

With the wide availability of handheld computers and other small computing devices, a new type of simulation activity has emerged, called *participatory simulations*[iv]. In traditional simulations students watch, and occasionally act on a simulation of some phenomena. As an example, let us take the outbreak of a disease. Students can typically set parameters, such as the incubation period, amount of interaction, etc. and then observe how these parameters affect the spread of the disease.

In participatory simulations students don't watch the simulation-they enact the simulation. Parameters can be set on the students' own device, then they physically walk around the room, interacting with their classmates and other devices. As they interact, their computing device supports their investigation: It records their status, and stores other relevant data as the simulation unfolds, to allow reflection about the activity. One such participatory simulation used by PEP teachers was "Cooties" (available at: http://www.handheld.hice-dev.org/download.htm). Cooties can be used to change the way students learn about health and science issues by allowing them to *experience* instead of *watch*, and then *reflect* upon their experiences. We expect that participatory simulations will soon be developed for many other subject areas, bringing the power of experience to a wide range of classroom activities.

Beaming and other networking technologies

The primary collaboration tool used by PEP teachers was infrared (IR) beaming. As new forms of wireless networking become available (802.11 and Bluetooth, for example), it is important that we understand the value of beaming, and why it will remain important even when these networking technologies are widely available.

Perhaps the most important feature of beaming is that there are no cumbersome steps between the physical parties and the act of collaborating. Beaming does not require that one look up an email address, remember an alias, or choose a name from a buddy list. Instead, beaming simply requires that the collaborators are physically near each other, and a beam is initiated through a simple button click or menu selection. Because of this, beaming is often felt to be an "intimate" action, almost like shaking hands. This may partly explain why beaming is so compelling to students: students are not required to translate between the person they are facing and that person's network name: instead they interact directly with the person in front of them.

Beaming also allows the recipient to have control over what is being beamed. If you don't want to accept a beam, you can simply turn away or turn off your handheld. Or, if someone does beam something unexpected, the recipient has the option of rejecting the beam. As evidence of the importance of this, the PEP research team has never

received a "junk beam" (although we have rejected the occasional "stray beam"), but we receive many "junk emails" every day.

Of course, as PEP teachers have found, there are limitations to beaming. The built-in beaming functionality does not provide "broadcast" beaming, in which a document is beamed to the entire class at the same time; for students to hand in their work they must each synchronize their handheld or line up to beam their work to the teacher; and the range of beams is only about three feet (note that there are IR solutions to these issues on the market).

We expect that, as wireless networking for education matures, we will see solutions to the currently unmet needs of educators. However, beaming will not disappear when new wireless networking technologies become widely available. Instead, educators and educational technology developers will determine whether beaming or some other networking technology is the best choice for their situation.

Integration with Existing Technology

When giving presentations about the future of handheld computers in education, we are often asked whether we believe that schools have wasted their money on desktop computers, because handhelds will just take their place. We believe the answer is an emphatic "No." In fact, as educators become more sophisticated in integrating handheld technology into their classrooms, we believe that use of existing computers may actually increase due to the use of handhelds. As discussed in Chapter 3, Integrating Handheld Technology in Instruction, although some reported a decrease in desktop computer use, most PEP teachers continued to use desktop computers while they had handheld computers and used handhelds in conjunction with desktop or laptop computers.

The typical student-to-computer ratio in schools is currently about 5:1[v]. As discussed above, this means that students must either share a computer lab, or share a small number of computers in the class. In either case, there is a significant barrier to integrating technology throughout the curriculum. Once handheld computer are introduced, technology can be integrated throughout the curriculum, and teachers and students can determine which technology to use for a given activity. Just as professionals now move between handheld computers, desktop computers, and traditional paper notebooks, we can expect teachers and students to do the same.

We have already seen one example of this: PEP teachers' use of AvantGo and FlingIt, two programs that allow material to be downloaded from the Internet onto handheld computers. Desktop computers are more suited to browsing the Internet than are small handheld computers. However, some information from the Internet can be downloaded to handhelds, to allow students access to this information off-line. We use the metaphor of "peeling off" to describe how students can use the desktop computer for specific, targeted tasks, and then move the relevant information to their own personal handheld.

Another example of "peeling off" can be found in students' using handhelds for data collection and analysis. In many activities, students each collect individual data sets, and then synchronize and aggregate into the full class data set. This aggregation typically occurs on a desktop computer, which has the screen size and power for

large-scale data analysis. Students can then "peel off" the data that they are most interested in, to conduct further analysis of subsets of the data. By moving between the desktop and handheld computer, the class is able to use the most appropriate tool for any given task.

Final Thoughts

PEP teachers have shown that handheld computers can have a positive impact on student learning and can improve the quality of learning activities. While PEP teachers may not be representative of all teachers generally (perhaps being more technologically savvy on average), nevertheless, they do represent a broad sample of teachers, with a wide range of technology proficiency levels, training, experience, and student populations. We believe these characteristics (among other considerations) make the PEP program findings largely applicable to students and teachers in general.

PEP teachers have also shown that effectively integrating handhelds into classroom activities requires time, resources, and planning. Teachers, administrators, and technology coordinators must:

- Learn how to use the handheld technology
- Spend significant time integrating handheld technology to achieve instructional goals
- Investigate, purchase, and become proficient with third-party software and peripherals
- Create appropriate use policies, including parental agreements in some cases
- Create policies and practices to minimize logistical problems in the classroom (such as practices for synchronization and battery charging or replacing; checkout and handheld tracking systems)
- Tune and refine their classroom activities to accommodate and best take advantage of the new technology (such as finding efficient ways to hand out and collect assignments from students)

Clearly, successful integration of handheld technology is not effortless. But looking across the key findings of the PEP program evaluation, we conclude that PEP teachers have demonstrated the potential of handheld technology to make teaching and learning more *meaningful*. Using handhelds enables teachers to make learning activities more authentic. Students can study problems in context and have tools at hand to address complex questions when they arise. In the classroom, in the community, at home, or in the field, students can use powerful computing and digital content when they are ready to apply them. The timing and occasion of students' technology-supported learning activities need not be dictated by the availability of the computer lab or a classroom desktop computer. Students' collaborative exploration of the world and sharing information and resources become an easy and natural part of learning activities.

We have also seen that giving students a personal learning device can make learning more meaningful to them. Using handheld computers allows students to take more ownership of their work products and learning. With a handheld computer to use at any time, students become more autonomous in their learning. They have a

technology that they see as relevant and powerful—one that support learning in ways that they discover and devise. Students' engagement in powerful, teacher-designed learning activities can extend beyond the 50 minutes of a class period–with a handheld, students can easily continue collecting and analyzing data, writing, quizzing themselves, or collaborating with classmates beyond the formal instruction time slot.

With students' autonomy in learning facilitated and enhanced, a teacher's instructional role can shift to supporting and orchestrating students' learning. Handheld technology supports teachers' efforts to individualize instruction as well as to promote collaboration among students. It becomes easier for teachers to allow and manage students' self-paced work. At the same time, students can easily share their work, information, and ideas. Teachers can give students the means and opportunity to extend their learning beyond the classroom and beyond the curriculum, and integrate this learning with classroom activity, through collaboration with students.

Will handheld technology transform teaching and learning? For many PEP teachers, it already has.

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[i] See also:
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Tinker, R. (1997, July 7). *The whole world in their hands*. Concord Consortium. Available at: http://www.concord.org/library/ pdf/future.pdf

[ii] Dufresne, R.J., Gerace, W.J., et al. (1996). Classtalk: A classroom communication system for active earning. *Journal of Computing in Higher Education*, Vol. 7, pp. 3-47.

[iii] Linn, M. C. & Songer, N. B. (1991). Cognitive and conceptual change in adolescence. *American Journal of Education*, 99(4), 379-417.

[iv] See, for example:
Wilensky, U. & Stroup, W. (1999). Learning through participatory simulations: Network-based design for systems Learning in Classrooms Computer Supported Collaborative Learning. Paper presented at Conference on Computer-Supported Collaborative Learning (CSCL '99), Stanford University, California, December 12-15, 1999.

Colella, V. (2000) Participatory simulations: Building collaborative understanding through immersive dynamic modeling. *Journal of the Learning Sciences*, Vol. 9, No. 4, pp. 471-500.

[v] Cattagni, A. and Farris, E. (2001, May) Internet Access in U.S. Public Schools and Classrooms: 1994-2000. National Center for Education Statistics, U.S. Dept. of Education. Available at: http://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2001071

Appendix A: Additional Software and Hardware Used by PEP Awardees

The following hardware and software solutions were specified as being important to project success by at least one PEP awardee:

SOFTWARE APPLICATION	VENDOR
Chess/Checkers/Backgammon	(multiple vendors)
eBooks	(multiple vendors)
Synonym program	(multiple vendors)
Doodle Board	Amin Patel
Ebony Ivory	Arcosoft
Noah Dictionary Lite	ArsLexis
AvantGo	AvantGo
PrintBoy	Bachmann Software and Services
WordSmith	Blue Nomad
Chemicalc	Chemical Concepts Corporation
Chem Table	Chemtable software
Album To Go	Club Photo
Coffeepot Software	Coffee Pot Software
CCProbe	Concord Consortium
QuickWord	Cutting Edge Software
QuickBooks	Cutting Edge Software
Quicksheet	Cutting Edge Software
Documents to Go	DataViz
HanDBase	DDH Software
Solus Pro Earthmate GPS	DeLorme
Expedition	EddieSoft
BugMe	Electric Pocket
Robot Mover	Ellams Software
Filemaker Mobile	FileMaker, Inc.
WriteHere	Foundation Systems
Four zero student	Handmark
ThoughtManager	Hands High Software
Bubble Blasters	Hi-Ce
Cooties	Hi-Ce
FlingIt	Hi-Ce
FreeWrite	Hi-Ce
Go 'n Tell	Hi-Ce
PiCoMap	Hi-Ce
Sketchy	Hi-Ce
TinySheet	Iambic, Inc.
ImagiMath	ImagiWorks
ImagiProbe	ImagiWorks
PowerOne Graph	Infinity Softworks

SOFTWARE APPLICATION	VENDOR
PalmPix	Kodak
Jfile	Land-J Technologies
Jtutor	Land-J Technologies
Easy Grade Pro	Orbis Software
Diddlebug	Palm, Inc.
Giraffe	Palm, Inc.
Palm Reader	Palm, Inc.
dbNow	Pocket Express
Quizzler	Pocket Mobility
PARENS calculator	Rick Huebner
Classroom Wizard	Scantron Corporate
SplashPhoto	SplashData
Messier!	Star Pilot
MoonPhases	Steve Kienle
Tealpaint	TealPoint Software
thinkDB	ThinkingBytes
Tiny Logo	Timothy Lipetz
Memo Pad	VizSync
MusicEar	Wilson Cheng/MusicEar
2sky	Zerpec, Inc.

HARDWARE/PERIPHERAL	VENDOR
Parallel port IR convertor	Bachman Software
C-Pen	C Technologies AB
DAS-1206 data acquisition unit	DataStick Systems
Earthmate GPS	DeLorme
MELD Interface+R[-49]C	Francis Deck
ImagiProbe interfaces and probes	ImagiWorks
PalmPix camera	Kodak
GoVox digital voice recorder	Landware
Go Type Keyboard	Landware
Otter Box	Otter Box
Modem	Palm
More stylus	Palm
Palm Ethernet Cradles	Palm
Folding Keyboard	Palm, ThinkOutside
Digi Vox Recorders	Shinei
Probes	Vernier, ImagiWorks

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