Handheld Use in K-12: A Descriptive Account

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Abstract

This paper describes ways handheld computers have been used by students at four different Michigan schools. Regardless of age or environment, our experience has shown that the primary, and most powerful uses of handheld computers have not been for organizational purposes. While students do take advantage of the organizational abilities, handhelds are most often used as tools to aid in research, alternatives to paper-based tasks, group collaboration activities, and much more. In addition to describing student tasks, this paper provides a context as to how much time handheld computers are being used in each classroom. This framework of time use and task use provides a better understanding of what a classroom with handheld computers might look like.

1. Introduction

The Center for Highly Interactive Computing in Education (Hi-CE) at the University of Michigan has been exploring ways to use handheld computers in the K-12 environment since the fall of 2000. This paper describes four very different ways that handheld computers have been implemented in a variety of classrooms and subjects.

But why even put handheld computers in the classroom? Each of these schools uses a personal model of handheld use—meaning that each student has their own handheld to use at school and home. This situation allows students and teachers to take advantage of three key affordances that together are unique to handheld computing—permanency, accessibility, and immediacy. In virtually all of the four schools described in this paper, students have access to desktop computers at school less than one hour per week. As several national and regional studies have recently noted, without regular access to computers there can be little hope of this technology having profound impacts on the classroom [1-3]. It is also quite clear that many students suffer in school when they lose their work. Work done on the handheld computer has proven to be relatively permanent—meaning that the student can never lose their work unless it is purposefully deleted. Students have access to work from the early weeks of a unit that for many students is often lost using traditional media. Finally, handheld computers are "ready-at-hand" tools [1] that provide students with immediate access to their documents, data, animations, etc., as well as a variety of software and tools to support learning activities. Whether students are at home, in the classroom, or beside a river, they can get what they need right when they need it.

As we began to work in these four classrooms, two other interesting and important observations of educational handheld use emerged. The teachers in these classrooms are each teaching different grade levels in different environments and use different teaching styles, yet they have all managed to incorporate the handheld computers in a manner that suits their needs. The handheld computer is certainly a flexible device—able to do everything from helping 10 year-old students learn what Morse code is to assisting 14 year-old students graphing weather data.

Handheld computers in these classrooms have also made an impact on collaborative work [4]. The ease of simply aiming your handheld at your partner's to "beam" information has turned some typically individual activities into learning opportunities involving substantive discussion and peer-to-peer learning.

We describe the use of handheld computers in the order presented in Table 1—from the youngest students to the oldest. First we describe some of the activities third grade students undertake in Allen Park, Michigan. Next, we share handheld uses from a semi-rural 6th grade classroom. From there we move to a 7th grade science classroom in the Detroit Public Schools. Finally, we discuss activities involving 8th graders in an Ann Arbor classroom using wireless iPAQs are described. In Table 2 we summarize how handhelds are used in each of these classrooms. It should be noted that only the 3rd and 6th grade teachers have had previous exposure to handheld computers. Each of these teachers used handhelds in their classes to some degree during the 2001-2002 school year. This was the first year the 7th and 8th grade teachers have been exposed to handheld computers.

After describing how handhelds have been integrated into these different classroom environments, we conclude with a brief comparison of these approaches. We also discuss how lessons learned from these classroom experiences can guide future research into the effective use of handheld tools for learning.

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Table 1. Overview of Classrooms Studied

School	City	Grade Level	Number of Students	School Type	Demographics
Mead Elementary	Allen Park	3	22	Public	Blue-Collar
Hartland Farms Intermediate	Hartland	6	56	Public	Semi-Rural
Beaubien Middle School	Detroit	7	30	Public	Urban
Greenhills School	Ann Arbor	8	33	Private	White-Collar

Table 2. Overview of Handheld Use: Time and Tasks

School	General Classroom Application	Time Used at School	Time Used at Home
Mead Elementary	Integrated throughout curriculum	30 min/day	2 hours/week: reinforce daily lessons
Hartland Farms Intermediate	Integrated in curriculum, often as research tool	60 min/day	4 hours/week: Complete assigned work, study, personal use
Beaubien Middle School	Paperless science classroom	35 min/per daily 50 min science class period	30 min/day: homework and personal use
Greenhills School	Inquiry science tool	Varies greatly based on stage of science inquiry unit	2 hours/week: report writing, homework

2. Research Methods and Documentation

Our current research methods have given us a clear picture of how often students use their handheld computers, what sort of documents they produce, and how the handhelds are being integrated into the overall classroom context. We base our findings on the following three primary research methods: Observation, artifact analysis, and log file analysis.

Two doctoral candidates work exclusively in single classrooms making observations, collecting student work, and interviewing students and teachers. Another graduate student rotates between a number of classrooms working with teachers and students, documenting lesson plans, student work, and collecting interviews and observations. These observations have proven useful to gauge the level of curricular integration, and the degree of student collaboration using handhelds.

For classrooms using Palm handhelds, we have developed "PAM" or Palm Artifact Management. This piece of software resides on the classroom computers to which the students synchronize their handhelds and student work is uploaded to a central server. Teachers, students, and researchers can access these artifacts. Similarly, the wireless pocket PC's send data to a special computer located in the classroom that also acts as a repository for student work. Using these systems to gather and organize artifacts allows us to compare versions of documents, and look for evidence of improvement, collaboration, and presents a clear picture of what documents students are producing—both school-related and personal.

Most recently, we have developed a piece of software that resides on the Palm handheld and records simple actions taken on the Palm computer, stamping them with a time and date. These log files are uploaded when the Palm is synchronized with the desktop and allows us to precisely determine exactly how much time students are spending on games, word-processing, and other programs. We can also determine what sort of handheld use is occurring at home versus school hours.

The combination of observations, student artifacts, and log files has provided us with exceptional insight into handheld use in these classrooms.

3. Third Grade Use of Palm Computers

In a blue-collar public school district, third graders at Mead Elementary School use their Palm computers almost every day for a variety of tasks. Their teacher, Janine Kopera, has ten years of teaching experience and has discovered a number of ways to integrate Palm

handhelds into her curriculum. Students in her classroom are often seen writing about the climax of a story, animating a scientific concept, or creating a concept map describing what they know about a particular subject.

Kopera structures most lessons around a theme. When students in her classroom learn about a famous person, a scientific concept, or mathematical process, it is reinforced in many subject areas. For example, when learning about Ben Franklin in social studies, they also read about him in language arts, try some of his experiments in science, and work with "Ben Franklin" story problems in math. Using the Palm computer, they also make summative concept maps about things they have learned about Ben Franklin. Kopera gives every student multiple occasions and ways to learn, and to express their learning. The Palm computers in her classroom provide another medium in which students can engage the curriculum.

3.1. Typical Use of Palm Computers in 3rd Grade

In this example, Kopera's students are broken up into small groups and placed about the room in "centers." Each center is a place where students engage in a particular activity related to a central theme, and after fifteen minutes or so, students rotate to the next center. On this example day, the topic is frogs and Janine hopes to reinforce the students' multiplication, writing, typing, and skills. She also hopes to further student understanding of the concept of energy transfer in a food web.

At the first center, students work on "Frog Food Chains." For this activity, they use *PiCoMap* to make a simple concept map about how energy starts with the sun and is passed to plants, insects, and finally the frog. Some students go a step further because they knew that some birds eat frogs and even some restaurants serve frog legs.

Over at the second center, students are exchanging "Frog Facts" using a program called *PicChat*. *PicChat* enables two or three students to instantaneously beam drawings to each other. It can be thought of as students sharing their own white board. For frog facts, students pair up and take turns thinking of multiplication problems. The problem instantly shows up on the other students Palm, and he or she solves it to the best of their ability. When there is a discrepancy, the students talk with each other and express their reasoning behind the solution they have given. For example, one student says the answer to 7 x 4 is 21. The student who created this problem knows it is incorrect and suggests that the answer should be 28 is because they know that 2 x 7 is 14, and 14 + 14 equals 28. If student groups finish all the multiplication problems they can draw flies, and the other person can draw a frog catching them.

We join the third center where students are engaged in spelling practice and creative writing. Janine's classroom has a small number of keyboards that students can use. At this center students place their Palms in the keyboards and the first task is to quickly type their spelling words so they can study them later that night. Once the spelling is completed, it is time to create a *FreeWrite* document called, "If I Were a Frog." Students are expected to write a short creative piece with some science facts in the story. Some of the boys write stories about all the "gross" things they would eat, and other students describe where they would live. When finished, students can aim their Palms at the Infrared printer in the room to print out a hard copy for themselves or the teacher, if the teacher so wishes.

Center four might be the day's favorite. Students are using *Sketchy* to make an animation of how energy is passed from the sun to plants, from plants to insects, and finally to the frog. Students become quite adept at making illustrations that are quite complicated. Granted, looking at most of these animations out of context, it would be tricky to tell what was going on, but with the pause and frame advance feature in *Sketchy*, students stop their animations and explain each drawing to their friend or teacher.

During these center activities, the students spend just over an hour engrossed in their tasks at hand. They engage in a blend of math, science, art, and writing. They also have a mixture of individual and group-orientated activities. An added bonus is that every single assignment is stored on the Palm and accessible later that night and during the week for "Palm Homework Night."

The best night of the week in the opinion of many students is "Palm Homework Night." About once per week Kopera organizes a homework assignment that is quite similar to the center activities. There are usually four or five parts to the assignment and the students and work with their parents to complete their homework. "Palm Homework" may take well over an hour to complete, but the parents and students love it. Students share their work with their parents and enjoy teaching their parents many things about the Palm handheld.

3.2. Top Five Uses of Palms at Mead Elementary

1. *Sketchy* as an animation tool to express scientific concepts and reading comprehension. Figure 1 shows a student's animation about the phases of the Moon.
2. Third party software that fits specifically into a particular unit. For example, the *SMorse* program simulates a telegraph for students learning about inventions and Morse code. *Moon* is a program that shows moon phases students use when learning about the solar system.
3. *PicChat* for turning traditional drill-based work into a peer-to-peer project with substantive discussion.

4. *PiCoMap* as concept mapping for *assessment* purposes. Students have a visual medium to express their understanding of a topic.
5. Word processing using *FreeWrite* to make short stories, or to retell a story they read.

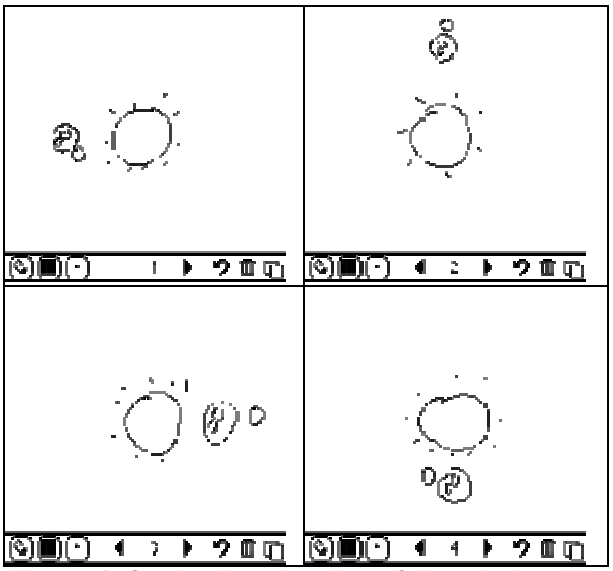

Figure 1. Student's animation of the relationship between the Sun, Earth and Moon

4. Sixth Grade Use of Palm Computers

Sixth graders in Hartland, Michigan, a semi-rural community, use their Palm computers in different ways than the third graders described above.

Monique Shorr, a public school science and social studies teacher, and her partner teacher, Shelly Gordinear, lead many project-based units. These two teachers try to coordinate their lessons so students do not learn each subject in isolation. The expectations these teachers hold for their students often revolves around group-based, multi-disciplinary projects. Often these projects tend to involve some level of research. For example, the social studies curriculum requires that students demonstrate knowledge in the area of ancient civilizations. A cumulating project for these sixth graders is building some kind of model of the seven ancient wonders of the world. Along the way to the finished product, students learn about ancient governments and relate it to our government today. They also research these ancient wonders and the civilizations responsible for building them.

How does the Palm computer fit in? While students in Hartland use their Palms in many ways, one of the most interesting and powerful is the way these computers are implemented into research projects.

This winter students learned about the polar regions of the earth. Their study of the Polar Regions was also supplemented in language arts class. Every student was responsible for learning about basic polar characteristics. Some straightforward uses of the Palm handheld involved using *FreeWrite* to record notes about glaciers, write summaries of climate reports, etc. Shorr arranged the unit with each student responsible for a basic level of polar understanding, but she also required that students, in groups of two, became "experts" in one polar animal.

Students used their Palms very effectively to make help make this unit a success. Some students used magazines such as *National Geographic* to learn some interesting facts and record them in their Palms. Students also used web-based resources and *FlingIt* to send web pages directly to their Palm handhelds, as shown in Figure 2. This information is beamed between partners so each student is able to go home with the same resources. An interesting side effect is that many students found sites they thought might be of use to another person in their class. Since the school only has 30 computers for over 700 students, time for web-based research is extremely limited. With *FlingIt*, students had their own off-line research library they could share and access in the classroom and at home.

Figure 2. A student "Flings" a website about Polar Bears that will help her research

Final reports were put together using *FreeWrite*. Students used *PiCoMap* to organize the structure of their Polar Animal Report and could draw upon notes taken earlier in the week, or from their *FlingIt* sites. Once this portion of the activity was completed, Shorr and Gordinear arranged for a trip to the Detroit Zoo, which was having a special exhibit on the Arctic.

Students headed to the zoo armed with their Palm handhelds, containing their information gained from the previous weeks. They also had a few Kodak PalmPix

cameras to share so they could document their trip and see if there was more to be learned at the zoo that could be incorporated into their research.

Figure 3 is a photo showing one day of students engaged in this unit. The students working on the big white bird are creating an albatross that will soon be on display. Students in the front of the room are taking notes about glaciers and polar vocabulary. It is important to point out that the woman at the right of the photo is not the teacher. She is a substitute, and knows nothing about Palms. In this classroom the Palm computer has become a very simple and natural extension of the student. Even though it is a "sub day" Monique Shorr would never consider putting the Palms aside for a moment.

Figure 3. Students use Palm computers as part of their everyday routine—even on "sub days"

4.1. Top Five Uses of Palms at Hartland Farms

1. Overarching research tool incorporating elements of note taking, data collection, off-line web sites from *FlingIt* and sharing this information with group members via beaming.
2. Word processing for two main purposes: Personal note taking and school essays, lab reports, and other documents that are to be turned in and graded.
3. Playing games on their own time.
4. Using various programs for personal uses such as starting chain letters, notes to friends, and scheduling birthdays and to-do's.
5. *PiCoMap* as a brainstorming, organizational, or prewriting tool.

5. Seventh Grade Use of Palm Computers

The science classroom at Beaubien Public Middle School in Detroit, Michigan, looks a little different than most classrooms you might see. Students put their overstuffed three-ring binders underneath their desks and on most days, the only thing you see students using is their Palm handheld. This classroom has become virtually paperless. Students get assignments from a "Table Palm"—handhelds dedicated to the dissemination and collection of work. The teacher has placed assignments (and any other communication like notes home to parents or test review questions) on the Table Palms, where students in each group beam to their handheld, and in turn, beam the assignment to other group members in a method the teacher calls "cascade beaming."

A typical Palm-based assignment taken from the "Table Palm" will include a warm-up activity, guiding questions, reference text, individual or group tasks for the day, and homework assignments. Once students have their assignment, they begin working eagerly. A typical day involves taking this framework provided by the teacher on the initial Palm computer and going about the day's lesson—whether they are performing group experiments, taking notes from lecture and reference materials or collaboratively working on various hypotheses.

Figure 4 shows a screen shot of part of a typical Palm assignment. In the example, the first question is used as the warm-up. The students write their answers directly into the *FreeWrite* document originally beamed to them. On this particular day, the teacher went on to discuss a demonstration from the previous class related to the concept that air takes up volume.

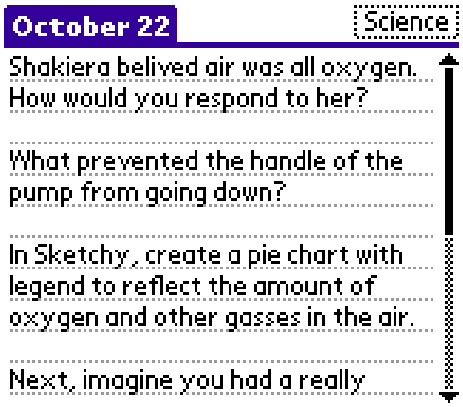

Figure 4. A framework to guide discussion, the day's lesson and homework

The teacher then asks students to use Sketchy to make a pie graph of the composition of Earth's atmosphere. While working individually, students converse with their groups such that at each table, the graphs end up looking quite similar and accurate. After this, they make a diagram that illustrates their understanding of the differences between "clean" and "dirty" air. This is the second of many opportunities these students have to do this, and each picture generally contains more

scientifically accurate information, thus making explicit student's growing conceptual knowledge.

5.1. Top Five Uses of Palms at Beaubien

1. Use *FreeWrite* to answer questions and fill out worksheets.
2. Create *Sketchy* drawings and animations to illustrate scientific concepts.
3. Make *PiCoMaps* as a way for the teacher to make summative evaluations.
4. Using the organizational tools available on the Palm computer for addresses, appointments and to-do lists.
5. Students, mostly boys, play many games and often look for games to download to their Palm handhelds from the Internet.

6. Eighth Grade Use of Wireless iPAQs

Eighth graders at Greenhills School in Ann Arbor, Michigan, are using wireless handheld computers to support their activities in science class. Students use Compaq iPAQ handheld Pocket PC computers equipped with a wireless network cards that can access the 802.11b wireless network we installed at Greenhills. The network card allows students to go online and find information from wherever they are in the school area – whether they're outside collecting science data or in the cafeteria discussing questions over lunch. The students participate in a hands-on, inquiry-based science curriculum where they spend 8-10 weeks investigating the science of various topics, such as Weather or Sound.

Since the students at Greenhills primarily use their iPAQs as inquiry-based scientific research tools, it can be difficult to describe how they use their iPAQs on a "typical" day. Because the inquiry units are quite long, the role of the handheld computer changes according to the current activity. Table 3 outlines how the use might change over the course of a typical investigation.

Students use their iPAQs throughout their science investigation activities, and a typical unit might start with students using their handhelds to build a concept map to assess their initial understanding. When students studied Weather at the beginning of the school year, they used their handhelds and the *Pocket PiCoMap* program to first created individual concept maps and then exchange maps with a partner (via infrared beaming between handhelds) for a peer-editing activity. Figure 5 shows an example of one student's final concept map about Weather.

During their Weather unit, students also used their iPAQs to find background information and draw diagrams of windvanes before constructing their own as part of a lab project. Students then used their windvanes and other instruments to collect data about the weather for several days, and compared their lab results with those found online using the handhelds' web browsers. This data was charted and graphed using the handhelds, and students used this information to write reports on their handhelds about how factors such as temperature and humidity affect the weather.

Another common activity for these students during a multi-week investigation is to research, design, implement, and analyze their own experiment about some aspect of the inquiry topic that they are particularly interested in. During their investigation of Sound, students used their handhelds to go online and find background information for their own research projects, which included questions such as, "How does the range of human hearing differ with age?" and, "How well do different soundproofing techniques work?" Some of the students used the sound recording and playback capabilities of the iPAQs to conduct their experiments, and others charted and graphed their results on their handhelds. Students also used their handhelds to write their final experiment reports and to access their notes during their oral presentations to present their work to the class.

The wireless iPAQs are also used to support a variety of collaborative work, including the creation of concept maps in small groups using the collaborative tools in Pocket PiCoMap. We developed this software to allow multiple students to log into the same concept map in real time via the wireless network. In this collaborative work mode, changes made by one student instantly appear on all of the group members' handhelds. This collaborative activity prompts substantive discussions among students as they justify to each other why they added or modified particular concepts or relationships in the map.

To complete all of these inquiry activities on the iPAQs, students use a combination of the software tools that are provided with the handheld (including Pocket Word, Pocket Excel, and Internet Explorer) as well as other software tools that we have developed to support specific activities. These programs include *Pocket PiCoMap* to support concept mapping by individuals and collaborative groups, *Pocket Model-It* to support students in building and testing models of complex systems, and *ArtemisExpress* to provide a handheld-friendly interface to the Artemis Digital Library.

6.1. Top 5 Uses of Wireless iPAQs at Greenhills

1. Research tool for finding information online, collecting and analyzing data, and writing reports.
2. Note-taking.
3. Personal use (games, calendar, to-do lists, music).
4. Concept mapping.
5. Beaming class notes and personal files.

Table 3. Typical activities and iPAQ use during a 40-day scientific investigation (1 day = 50 minute class period)

Number of Days (out of 40) Spent on Each Task	Task and Typical iPAQ Use
15	Student-designed experiments. Students use Pocket Excel, Pocket Word, and Pocket AutoGraph to design, implement and analyze their experiments and to create reports to share their results.
10	Classroom discussion and exploratory laboratory experiments. Students use Pocket Word to take notes and beam information between handhelds.
5	Online research. Students use ArtemisExpress (a handheld interface to the Artemis digital library, available at http://webartemis.org) and their handheld web browsers to conduct online research.
5	Student Presentations. Students use Pocket Word and Pocket Excel to write their reports, and use a document camera to project their findings from the handheld screen to share with their classmates. Students also use Pocket Word to write and reference notes for their presentations.
3	Concept mapping. Students use Pocket PiCoMap to create, revise and share concept maps.
2	Testing. No iPAQ use.

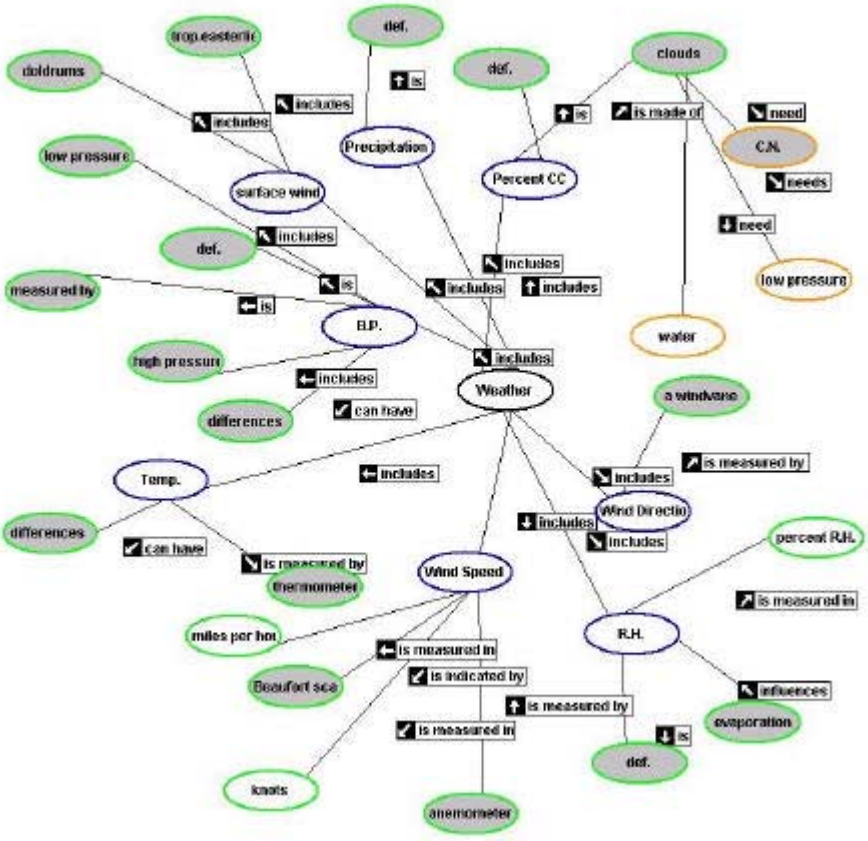

Figure 5. A student's concept map about Weather (shaded nodes contain additional student notes)

7. Conclusions and Future Work

Although the organization and curricula of the classrooms we described differ, all of the teachers have found numerous ways to adapt handheld computers to their own students. At Mead Elementary the third graders use handhelds to reinforce lessons from the district's core curriculum. They also use the handhelds to perform some tasks that would be difficult, if not impossible, to perform on paper. Examples are using *Sketchy* to animate scientific concepts and *SMorse* to "hear" Morse code. In Hartland, the sixth grade students use handhelds for nearly everything they do. In this classroom handhelds are powerful research tools and many students also find the handheld's word-processing abilities very helpful. Many students have also personalized their handhelds with other programs they have found to support their individual needs and interests. At Beaubien, Palms have allowed the seventh graders to create a nearly paperless science class where students have ready-at-hand access to information and tools, as well as increased opportunities for collaborative work. The eighth graders at Greenhills use iPAQs as a scientific inquiry tool for note taking, graphing, data collection, and writing scientific reports. These students also take daily advantage of the resources made available by having wireless Internet access in their hands.

To generalize, it seems one of the most powerful uses of handheld computers in these classrooms is as a tool to aid in research. Word-processing software also facilitates the easy creation, revision, and sharing of documents in all of the classrooms we described. Students report that they appreciate being able to store all of their work on the handheld, where it is readily available and students can review their work over time. Handheld computers also support collaborative activities and increase student-to-student interaction. Students are able to divide group projects and then beam their individual work to their classmates, allowing the entire group to benefit from individual students' expertise.

Clearly handheld computers are flexible tools that can be adapted to suit the needs of a variety of teaching and learning styles. In order to make the best use of this flexibility, we need further research to address two emerging challenges. First, we must examine more closely what is the educational impact of handheld tools. While handhelds are usable and flexible tools that have succeeded in supporting a variety of classroom activities, we need to examine the impact these tools have on student learning. The second challenge is to research the most effective methods for designing and integrating handheld software into K-12 education. By building on the unique affordances of handheld computers, including beaming, portability and permanence, we hope to create handheld educational software and curricula that can support learning activities at any time, in any place.

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