An Investigation of Purpose Built Netbooks for Primary School Education

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ABSTRACT
This paper is a qualitative evaluation of student netbooks used in a classroom setting. Netbooks are thought to be one promising development in the next generation of learning devices, pairing everyday PC capabilities with a purposeful design built for students and schools. The findings suggest that the design is appropriate and engaging for the unique needs of individual primary school students. Nevertheless, the design and specifications of the netbooks do not yet address some classroom-level practices that are crucial to the success of the technology in classrooms. This paper describes some of the key findings of this evaluation, as well as a summary of design considerations for the future design of mobile PCs for education.

Categories and Subject Descriptors
K.3.1 [**Computers and Education**]: General

General Terms
Design, Human Factors

Keywords
K-12, one-to-one learning, one-to-one computing, user-centered design, netbooks, education netbooks, 1:1, 1 to 1, classmate

1. INTRODUCTION
Even with an increasing number of initiatives designed to bring laptops into the classroom, the hardware available to students are the same as the personal computers built for office and home use. New technological advancements have made laptops smaller, lighter and cheaper spurring a new mobile computing category of "netbooks." Like their laptop predecessor, these innovations hold renewed promises for technology in education; in no place is this more apparent than in the paradigm of one-to-one learning and the pedagogical approach of student-driven learning. This study evaluates the design effectiveness of netbook hardware in primary school classrooms in the United States. The research represents the first findings regarding the user experience of specifically designed student computing devices.

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First, we present the framework of mobile computing in education through the research on contemporary one-to-one laptop initiatives. We consider the goals of governments, teachers, and administrators in funding these programs and the challenges they face in the classroom. We also touch on the literature about our method and the benefits of including students and teachers in field research, usability studies, and the design process. Then, we will look at the distinctive attributes of netbooks and the hardware specifications for the device in our study. We discuss the demographics of our participants and the scaffolding for device deployment in the classrooms, as well as the ethnographic methods and research questions. Finally, we discuss the qualitative findings and outline some conclusions for enhancing this technology in the iterative design process. These insights are also valuable for educators who are designing classrooms with student computing in mind.

2. FRAMEWORK
The policies and tools for computer education are renewed constantly. Ideas have evolved from learning about computers to learning with computers, and, now, to learning anytime, anywhere with computers and other ubiquitous technology. Hardware design has become more robust, expanding the offerings from desktops to laptops and handhelds, and from wired to wireless connectivity [8]. These shifts in thinking and in design have made computing more prevalent in students' lives [9].

Today, the initiatives of one-to-one computing exemplify equitable personal computing aspirations for 21st century schools. Laptop hardware intends to meet the popular demands for teachers to present dynamic digital material, to research up to the second information, and to guide their students in self-initiated discovery [8]. The defining characteristics of one-to-one learning initiatives are:

1. To provide each student with the use of portable laptop computers with software
2. To enable students to access the Internet through the school's wireless network
3. To use laptops to help complete academic tasks such as homework, tests, and presentations [11]

Laptop initiatives for middle and elementary schools in the United States began slowly in the 1990's; by 2009 they have become widely established throughout the country [11]. Some students using laptops are a part of school or district initiatives, like in Fullerton, California [5], while others are a part of state-run programs in Maine [14], Texas [13], New Hampshire [2] and Florida [4]. The initiatives have some common goals: to increase academic achievement, close the digital divide, and shift the classroom from a teacher-centered model to a student-driven (or constructivist) approach [9, 10]. A synthesis of the research on one-to-one initiatives conducted between 2001 and 2006 provides early evidence of the effects in the classroom: improved student engagement, achievement in some subject areas, and increased efficacy with technology [10]. Teachers in one-to-one programs also made some changes to their teaching style and became open to a constructivist pedagogy [3,4]. A multi-site study in 2008 concluded that one-to-one initiatives changed literacy practices in classrooms. Writing became more public, collaborative, authentic, and iterative while reading tasks benefited from more scaffolding and epistemic engagement [16].

The research on one-to-one initiatives shows that laptops add value to the classroom, but require favorable conditions at the district and school level to implement [8, see chapter 3 for summary]. To effectively support one-to-one computing, schools need to provide a complex infrastructure and professional training [3, 8, 10]. Many of the reports on the initiatives conclude by calling for increases in teacher development programs, information for parents, and onsite technical support [for example 5, 8, 12, 13].

In testing this new hardware we do not assume that form factor alone will make the hard work of using laptops in classrooms disappear. Studies confirm that teacher preparedness is the main factor in effective programs [3]. Instead, we conducted this field research to see how new designs are affecting practices and patterns in the classroom. By evaluating the first generation of this technology we hope to reveal critical student interactions that will define the next iterations of classroom netbook technology.

Many reports, concerned with an audience of policy makers and educators, evaluate the academic impact of technology rather than the user experience. Some reports do give accounts of fragile or heavy machines, limited desk space, inadequate battery life, software problems, data loss, and unreliable Internet access [For a review see 3]. However, no extended study of these machines, originally designed for home and office use, has been conducted around usability in the classroom. A user-centered design perspective can offer valuable insights about this new device, and how it addresses the unique needs of students.

In this context, user-centered design focuses on the challenges and benefits of children and teachers' experience to build technology specifically for them. It is important to involve students as users and testers in the design process. In studies that use children as design partners, they are the experts on what "excites and bores them" as well as what tools are appropriate and engaging for learning and play in their homes and schools [6]. The information students give can be critical to understanding their unique technology needs. For example, research conducted by Microsoft has found that children's usability is closely related to their enjoyment of the product and how the product retains appeal over time [7].

We have also chosen to use a holistic approach to this usability study. We hope to understand how people use learning tools in the actual context in order to design better technology to improve student learning [1]. Thus, this investigation uses children as hardware evaluators in their actual schooling environments.

3. HARDWARE

3.1 Netbooks

Netbooks, or mini-notebooks, is a relatively new PC category in which connectivity and mobility serve as notable differentiators from standard PCs. These devices, such as the Asustek EEE and Acer Aspire One, are significantly lighter and cheaper than traditional laptops. They have less processing power and energy, and a reduced ability to run complex programs. Cost and size make netbooks an attractive option for elementary school classrooms. Netbooks designed for young childrens' education include attributes such as durability, security, simplicity, and a more playful design language. Netbooks also significantly reduce the financial burden of one-to-one education in which schools bear the cost of providing a machine for every student.

This study evaluates the industrial design of the Intel® powered classmate PC (CMPC)[1] reference design (Fig 1). Many of its features such as the size, wireless adapter, processor, and storage are shared by other netbooks. Below are the specifications of the first generation of the CMPC:

- Customized mini chassis 245x196x44mm, with built-in handle and water-resistant keyboard
- Intel® Mobile Processor ULV 900 MHz
- Chipset- Intel® 915 GMS
- Memory- 512MB RAM
- LCD- 7in with 800x480 resolution
- Storage- 30GB HDD
- WLAN- 802.11b/g
- Power- 6 cell (approx. 4 hours)
- OS- Windows® XP

Figure 1: The Intel powered classmate PC used in this study

4. EVALUATION

This evaluation is focused on the design of the device and the educational, social, and spatial practices of the participants when the hardware had been introduced. We conducted an initial evaluation of the hardware design in six classrooms to determine the following:

- Which design features of a PC designed for education accommodate the unique needs of students?
- Do the features enhance the user's learning experience?

[1] The Intel® powered classmate PC (CMPC) is a reference design for independent local manufactures to build under different product names, such as the "2goPC".

- Do the features enable technology integration in daily classroom activities?

We answer these questions by conducting field research and organizing the data around specific product features from the users' perspective. This study focuses on questions of usability, usefulness, and the impact of hardware design on student and teacher behavior. As discussed below, curriculum software was chosen by the individual schools and teachers. The educational effectiveness of content was not evaluated in this study. Specifically, these features were the most important in determining the viability and suitability of these purpose-built machines:

- Form Factor
- Power
- Speed
- Connectivity
- Compatibility
- Software

4.1 Participants

The participants in this study consisted of students and teachers in six US classrooms: two 3rd grade classes in Oregon; one 5th and one 6th grade class in southern California; and one 3rd and one 4th/5th grade class in northern Texas. Each classroom had 20- 30 students and one teacher.

The three schools were public elementary schools and located in urban or suburban settings. The student body was representative of the diversity of each region. The sample included Caucasian, Hispanic, Asian-American, and African-American students ranging in age from eight to twelve. Four of the teachers were male and two were female.

The participants were involved in this study based on their involvement in a pilot program wherein students had received PC netbooks to use in the 2007-2008 school year. The teachers were chosen by the school administration based on their interest in one-to-one education and willingness to integrate technology into their lessons.

4.2 Deployment

The computers were distributed to the classrooms with the understanding that the school would choose and carry out the curriculum and technology policies. Therefore, the machines were tailored by each district, school, and teacher in slightly different ways. For example, students in four of the six classrooms took their computers home every night or every once in a while, while those in the other two classrooms were not allowed to take their computers home.

The teachers had a diverse set of software and program uses, as well as the use of their own full sized laptop to connect all the student computers for lessons and supervision. One or more teachers instructed the students to use the computers for online research, online academic games, state testing, video editing, photo managing, Microsoft Excel, typing software, blogging and e-mail. All of the students used Microsoft Word and PowerPoint. Students were commonly seen typing notes, journal entries, stories and reports as well as preparing presentations on their computers. This is in line with research on one-to-one initiatives using regular laptops; word processing was common, but classrooms used more dynamic programs irregularly [3, 8].

When the study occurred, each classroom had been using the laptops for a month or more. At that time, we found that teachers and students had already developed substantial familiarity with the device and the school infrastructure intended to facilitate everyday use.

4.3 Method

At each school we spent four to five days between the two pilot classrooms. The students and teachers were observed as they went about classroom activities and academic lessons for each school day. During breaks and after school, we conducted formal and informal interviews of students and teachers. Employing the methods of ethnography, we were able to capture the patterns of use that are often not obtained from self reports and focus groups.

4.3.1 Observations

Notes were transcribed on the behavior of students and teachers in during classroom activities. Observations included academic lessons, as well as morning routines, social behavior, transitions between lessons, classroom management, and organizational tasks. These notes were supplemented with video and photos of the class in session. Researchers analyzed this material, including many hours of video footage, and parsed the information into themes associated with the product features. The observations were supplemented with interviews with selected participants.

4.3.2 Interviews

Formal interviews were conducted with five of the six teachers, and also included a number of follow-up and informal conversations. Often interviews were also administered with willing peripheral participants including parents, principals, technology staff, and district administration. Informal interviews were conducted with randomly selected students and staff, usually in the form of five to fifteen minute conversations.

Interviews with teachers and administrators were semi-structured. Generally, they began with questions of daily use, technical barriers, and classroom successes. In the case of parents, questions were also asked about home use and safety and security online. With a range of interviewees, we were able to assess the user experience at many levels, including the district, school, classroom, and individual level. Interviews lasted from thirty minutes to one hour. Some interviews were conducted in small groups, other individually.

Interviews were recorded for later analysis. Portions of the interviews which addressed the research questions were transcribed. Quotations from interview transcripts reproduced below were chosen as representative of overall findings.

4.3.3 Consent

All participants, as well as the minor participants' parents, were fully aware of the research study as part of the pilot program. Students and teacher participants in this study were willing to be observed, photographed, and video recorded.

5. FINDINGS

Findings were compiled through the analysis of qualitative data. These findings are the first concerning specially built mobile PC hardware for classrooms. Although the examples and anecdotes below are from individual instances, they are representative of the types of patterns and behavior we saw across many, if not all, of the classrooms.

5.1 Form Factor

As mentioned above in the description of the hardware, one of the most distinguishing factors of the CMPC is its size and shape. The form factor also included unique elements such as a handle and durable materials.

5.1.1 Overall Size

Students in our study had a positive reaction to the small size. In particular, students liked the size for its mobility. In comparison to larger machines, students were at ease with carrying the CMPCs, as this student illustrates:

6th grade student: "I like it that it's so small that you can take it anywhere you go."

Researcher: "Do you take it anywhere?"

6th grade student "When I go to my cousin's house I take it or if I go on a trip I take it. It's easy and light."

Micro-mobility, or more nuanced movement, was another key practice enabled by the laptop size. We observed students easily moving the device from the charging cart to their desks, walking around the classroom with the machine open, and handling more than one laptop at once. All the students were capable of holding and carrying their machines with no assistance, which freed up teachers for other tasks. When necessary, the teachers would easily stack the computers and carry many at one time. We observed that teachers easily lifted the device with one hand and worked with it standing up.

When students used the PC, they had enough space on their desks to have the netbooks open as well as a textbook or journal. The devices often stayed on or in students' desks during the school day when not in use. Students would push the CMPC to the top of their desks to work on paper assignments. We observed that even on the smallest student desk in our study, two devices could be placed open back to back and used without incident.

Finally, the small form factor reduces the height of the screen and allows teachers to see over the laptop lids when in use. Teachers mentioned that they valued making eye contact with students. Additionally, the design of the hinge allowed the lid to be opened halfway. Teachers utilized this feature in many of the classrooms when they required the attention of their students (Fig 2).

Figure 2: While instruction is given, students keep their screens closed. At this angle, the PC does not "sleep" and it also does not distract the students.

5.1.2 Keyboard and Screen Size

The small form factor reduced the size of the main laptop components, resulting in a keyboard 68% the size of a standard keyboard and a 7 inch screen.

The research showed that for most of the student participants, the small keyboard was a positive feature. A 5th grade student, said, "The keyboard is small. It's just the right size." Many students felt that the standard keyboard (which they had used on desktops or full sized laptops) was too big for their hands. One group of students mentioned that they with the CMPC they did not have to stretch their finger to use the shift button in typing practice.

Our data showed that the 7 inch screen was acceptable but not desirable for working with multiple applications, or for software and websites not built for 800x480 resolution. Students had the ability to change the aspect ratio and resolution when necessary. When the resolution was too big for the screen size, students had to pan left and down to see the entire application. Students were frustrated by words and images "falling off" the side of the screen. For some, it impeded the speed at which they could accomplish tasks.

Figures 3, 4, 5: A variety of handholds by students and teachers in our study

5.1.3 Handle

The built-in handle was widely well received. We observed that the handle enabled students to carry the laptop using a variety of different handholds. Students could slip their hand under the device and through the handle, resting the device on their arm while sitting or standing (Fig 5). Students also were able to grab the laptop from the back when it was open (Fig 4). Many of our student participants were familiar with regular-sized laptops. One 5th grade student pointed out that "those are heavier and they don't have the handles, so they have to have cases." A much smaller 3rd grade student showed us that with the CMPC she did not have to hold the device in a two-armed hugging motion that she used to carry a regular-sized laptop.

It was generally true that students needed no extra equipment to carry or move their laptops safely. Students who were allowed to take them home were often seen carrying the laptop by the handle in one hand as they left the school grounds.

5.1.4 Durability

We evaluated durability as the resilience of the hardware itself. We had occasional records of students throwing machines into their backpacks. It was also the case that we observed students being rough with other school tools, such as books, pencils and lockers. We gathered anecdotal evidence that students are “hard” on the machines in other ways, such as disturbing the operating system or downloading viruses. The durability of the OS and software should be considered in future studies.

From the interviews, we gathered evidence that durability was a critical element for student technology, and that a device perceived to be durable in its look and feel was desired. From all the participant groups, parents, administrators, teachers, and students, we heard anecdotes about careless students as well as concerns about giving students fragile technology. Teachers commonly feared that broken machines would mean not enough remaining for the whole class. Administrators were concerned with the number of years the technology needed to last. Students themselves did not self report misuse, but would cite examples of their more careless peers. A few parents worried that their child could drop or damage their work or home laptops computers.

Despite overall concerns, teachers reported no incidents in which roughness or an accident rendered a laptop nonfunctional. This could be due to the machine’s rounded edges and plastic material which functioned to keep it more protected than a regular laptop. Reports of limited rough use could also be attributed to the security enabled by the handle and an element of student responsibility.

5.1.5 Personalization and emotional connection

The data revealed many emotional connections with the device. The student participants felt that the size and look of the device meant that it was made just for them. One parent was happy to promote this idea. “It’s his machine,” she said, excited that she and her son could work on their personal computers at home at the same time. The students in our study also felt special and fortunate. They were cognizant of the opportunity to use the new and unique technology.

Students often personalized their machines. For example, a number of students gave their computers a pet name to distinguish one from someone else’s. Where the teacher allowed, students changed the desktop to a personal picture. In one class, the students wrote essays personifying their computer and the journey each took from China to their school in the US.

There was a sense of pride and responsibility that developed around the use of the CMPCs. Although students did not own the machine, teachers were quick to instruct them about proper care and student “ownership” for that school year. As one student said when she had to switch out hers for the classroom spare, “I like *my* computer… The one I have right now has a lot of pencil marks. So, I would like *my* computer back.”

We found evidence of increased interest in learning and engagement in activities, which we attribute to this connection with the device and the activities it affords. As one student said, “About the laptops, I think school became much funner when I came here. Before I didn’t get a lot of A-pluses. When I got here, it made my brain get more into school which made me get better grades. School was too boring and I wouldn’t focus and now…now it’s, like, you look forward to school.” This is one anecdote of increased student engagement. More research is needed to determine the overall impact on achievement and attendance.

5.1.6 Sociality and Collaboration

The small form factor affords some increased opportunity for collaboration at the expense of some others. Students were able to freely move about with their computers to get close to partners when doing collaborative work. The short lid also allowed for students to easily look over the screen at what their classmate was working on. On the other hand, the small screen size limited viewing from afar and the limited viewing angle prevented many students from looking at one screen. The clamshell lid, even though shorter than most laptops, still erects some barrier between students who are accustomed to performing work on a flat surface. When asked how a student displays her work now to others (a common classroom practice), she responded in an interview by using both hands to turn cumbersomely the entire computer around. This was commonly observed in the classroom as students working in groups would grab and turn the computer towards them to see the screen.

Figure 6: As they would switch papers, these students trade their machines to peer grade math work.

5.2 Battery Life

When students failed to remember to charge at home or otherwise did not have sufficient power to begin a lesson, they were often relegated to the walls of the classrooms, where outlets were, or to stretching the cords awkwardly along the floors and furniture. For the most part, teachers did not allow the students to fully deplete the battery, nor did they encourage students to use power cords at their desks. Because the battery would not last the full school day, we observed teachers imposing a procedure by which students would return their laptops to be charged. Generally, recharging the computers required small groups of students to leave their seats, walk to the charging cart, find the slot and cord, plug the machine in, and then return to their seats. Teachers would utilize a natural break in the school day, like lunch, for students to charge their computers.

These recharging exercises were part of the many “transitional moments” in the school day. In US elementary schools, for the most part, all subjects are taught in the same location, to the same set of students. These students have to get to many activities each day, and the teachers expend a great amount of effort to make the transitional moments more efficient. Our data showed that teachers would prefer that the device be kept on or in the desk for most of the day to eliminate unnecessary transitions. At the same time, the teachers were remiss to leave one student out of the lesson because they did not have sufficient power.

Finally, when a device was powered off, the battery level of the netbooks was difficult for teachers or students to determine. Often turning on the device and waiting for the OS to load was the only way to find an indicator for how long the battery would last. There was no easy way for teachers to determine if all the student computers had enough battery before beginning a lesson.

5.3 Speed

5.3.1 Boot and load time

Slow boot and application load time was observed to increase classroom inefficiencies. When asked what he would do to make the computer better, one 3rd grade student responded by saying, “Make them faster. So we can shut down and get to recess.” The teachers in our study did not want to lose any “teachable moments” in the two to three minutes of boot time. In many classrooms we observed students retrieving their computers group by group, turning them on, and pushing them out of the way. The teacher would then assigned paper work or give a lesson during boot time. Finally, after all the computers had booted up, the students would be instructed to use them. From the interviews we gathered that two to three minutes could mean introducing another standard, or grade level requirement, in what the teachers considered an already packed school year.

5.3.2 Pace-setting and automation

The data we gathered in the classrooms showed that the school day moves at a rapid pace. An office setting might operate in half-hour or hour increments, but classrooms in our study transitioned to a new activity at most every ten to twenty minutes. Teachers in this study used the CMPCs for pace-setting and automation. For example, one teacher had his students use aaamath.com, where multiplication problems were individually offered and assessed in timed intervals designed to keep each student on-task at his or her level.

The computers provided flexibility for individualizing work, and structure for when students needed to follow along as a group. We observed teachers using management software, which allowed them to automate and standardize what the students were seeing on the netbook screens. Computer and network speed play an important role in effectively using the computer to keep students on task. If the speed is not fast enough, students’ screens change at different rates.

Overall, the speed of the CMPC was acceptable for most of the classroom usages. Software requiring higher power such as photo editing, video editing, or educational activities requiring high resolution were not used on these devices but only on higher power systems located at the teacher’s station, at the peripheral of the classroom, or in the school computer labs. .

5.4 Connectivity

5.4.1 Network reliability

Our data revealed that unreliable connectivity is a major barrier to effective classroom computing in general. Connectivity is not just important for Internet use, but for linking the computers to each other for collaboration and to the teacher computer for management. While specially designed student computers will not always be used in a 1:1 ratio, the design specifications for connectivity should facilitate as many computers as there are students in the room.

Fidelity of connectivity can be assessed by both the adapter within the device and the infrastructure outside: the bandwidth from the source and the number and strength of the wireless access points. All the devices used the WLAN 802.11b/g as the adapter standard. In some cases, the wireless access points supported all 20-30 adapters. However, the wireless and Internet infrastructure provided by the different schools varied. In other classrooms, small network failures greatly disrupted daily use. In one classroom, individual users would be “kicked off” the network during lessons. Students, believing that they needed to be closer to the wireless access point for a stronger signal, would leave their desks with the device and stand next to the access point, or lift the computer high above their heads.

Figure 7: Student hold their devices above their heads to receive better wireless signal while the teachers conducts a lesson.

Supporting technology networked to the 30 machines also struggled. In one classroom, a networked printer was set up to handle all of the job requests from the students. In an office environment, this printer would not have faltered, where workers printing randomly over time. In a classroom, we observed students print all at once, right before an assignment was due. A frustrated teacher made this exasperated proclamation: “You could have printed the night before, you could have printed at lunch, you could have printed yesterday- You DON’T print the day that it’s due!” He proceeded to make a cumbersome impromptu procedure for allowing only five students to print at once. However, the technology should support student printing habits without interruption to the school day. In this case, the technology of the netbook was not the likely source of the printer problem. This example does illustrate that design considerations for the classroom as a whole are necessary for computing to be effective.

5.4.2 Sociality and Collaboration

Being on the network or connecting via mesh connectivity (which was not observed, but is a feature of some netbooks) is fundamental for synchronous online collaboration and sociality. In our observations, most of the classrooms did not use this capability on a regular basis, or at all, for peer-to-peer collaboration. When students collaborated, they would do so around one device and share their devices with each other. When they needed to exchange content, they would do so asynchronously over e-mail. We saw some instances of instant messaging use during class, but this was not endorsed by the teacher or used to accomplish a school task. In one blogging exercise associated with a language arts lesson, where students were collocated, the website updated much too slowly and students reverted to leaving their seats to talk with their partners.

5.4.3 Management

Connectivity allows for the teacher's computer to connect and "see" the screens of the computers in the classroom. For the most part, the teachers in our study used this feature to present lessons and distribute short assignments, rather than monitor all the computers. In the interviews, the teachers reported being happy to have the feature, but mostly to let their students know that the teachers were always watching. Even though one teacher used the software, she remarked, "I don't look at it."

This element of connectivity needs to be explored further as it relates to sociality, collaboration, and management. These features are enabled by the hardware, but their effectiveness depends heavily on the classroom policies and the usability of the software.

5.5 Compatibility

Schools often cannot update their technology as frequently as offices or homes. Therefore, new technologies purchases often have to fit legacy systems and previously acquired content. For the most part, educational software has been developed for larger screens and high powered computers. Additionally, software installation using CDs is still prevalent, and most netbooks do not have optical drives. In our study, there were a few critical incompatibilities with software that teachers wanted to use. If this form factor becomes more commonplace, software will have to become customizable to the small screen and low power and be readily available for download over the Internet or on a USB drive.

Beyond software, compatibility addresses the complex classroom systems already in place. These systems include the technological infrastructure, as well as the curriculum structure and social rules and expectations of the classroom. Most of teachers in our study had little control over the larger network of computers and technology in the school. Most often, when one or all of the thirty computers was not compatible with the larger system, the teacher was not capable of changing it. Consistent usage, as well as experimentation with new digital activities, is determined by the teacher's efficacy within their own classroom. As one administrator remarked, the goal of technology integration was figuring out "what can we provide so that the classroom isn't a management nightmare."

While devices like this push toward more student-centered classrooms and differentiated learning, the teachers in our study retained traditional classroom lectures and management style. Their ability to effectively use the devices on a daily basis was in part due to their willingness to integrate the tools into their previously established classroom practices. As one teacher said, she must "stay with the curriculum" of the state, whether she incorporates these tools or not. In effect, the teachers worked constantly to harmonize their teaching and classroom rules with the added benefit of digital materials and interactive programs, rather than to dramatically change their pedagogy.

5.6 Software Operating system

The devices used Windows® XP, as opposed to Linux or a specially built operating system such as the Sugar OS (built for the One Laptop Per Child device, the OX). The teachers liked introducing "real" applications, even if, as some noted, the applications would be outdated by the time their students entered the work force. The students were excited about using XP for schoolwork and using "fun programs, like Word and PowerPoint" (5th grade student).

On the other hand, the Windows XP file structure and menus were not intuitive tools for these students. When content was about bridges and algebra, lessons would often turn to instruction about how to have two programs open at the same time, or how to find where a downloaded file went. Arguably, over time, these tools would become second nature to students. Still, teachers often found the complexities of the operating system irritating when it overshadowed the academic lesson being taught. Finally, we observed instances of work "disappearing" when students did not properly save or placed a file in the wrong drive (or often used this as an excuse for unfinished work). One class mantra, recited frequently and in unison throughout the school day, was "Save Early, Save Often." Alternatively, another class found themselves always reverting back to paper to avoid the pitfalls of the OS: "If you print, you don't have to save" (3rd grade teacher).

5.7 Discussion

The small, lightweight netbook drew a mostly positive response from the users. The handle, size, and weight allowed movement with the devices, and students were able to freely situate themselves for learning alone or with peers. Students carried the device without needing help or a special case to protect it. The form factor also allowed students to feel like the devices were specially made for them, which increased feelings of ownership and responsibility, and, possibly, use and engagement. The extra durability allowed adults and students to feel more at ease, while at the same time preventing hardware malfunctions from occurring. The design and hardware accommodated each young user in our study.

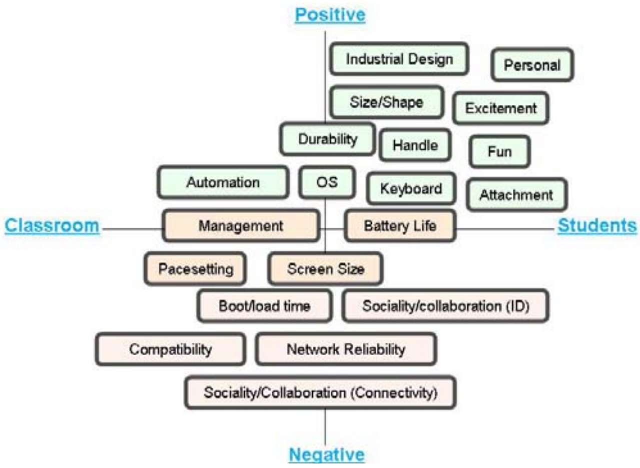

Figure 8: Summary of findings

Battery life was not long enough for use during the entire school day, so teachers were vigilant to keep all computers charged before lessons began. Teachers were also quick to address the problem of slow boot time by filling the time with planned instruction. When problems arose over network connectivity or compatibility with legacy systems, often it would mean that one or a few students were left out of the activity, or that teachers would abandon the activity altogether. The teachers in our study developed new practices to manage and minimize inefficiencies so that the whole classroom could stay on task.

6. CONCLUSION

We surmise that the teacher is more likely to think of the student devices as part of the system, rather than 30 individual machines. As one teacher plainly put it, "I have 30 different brains out there and if they *all* can't use it easily, it doesn't work for me." Many of the usage problems that were exposed in the research were symptoms of the classroom, not an individual student. In the example of wireless connectivity, the specifications were acceptable for one student on the network, but not for thirty students using the Internet at once. This was also true at times for the connection to peripheral machines, for the boot time, for battery life, and for the speed needed to facilitate collaboration and management.

The design of tools for students must consider the needs of the individual student, as well as those of a classroom of computers working together. Design questions like "Can a student's hands fit on the keyboard?" are just as important as "How fast can the entire class retrieve and boot up their computers?" We found in our research that there was much to be learned about the systems and practices of classrooms that impact the design of effective student notebooks. As teachers and students adapt their practices to the influx of new technology, the hardware design should preempt as much of the complexities as possible. For example, the new WLAN standard 802.11n, which boosts the current wireless capabilities by more than 1000%, is a perfect feature for the classroom.

Although one-to-one learning and the associated hardware allows individual students to learn in new and dynamic ways, these students and computers are both part of a larger organism - that of the classroom itself. Attention to the classroom as a user must be an integral part of the future design of personal computing for education.

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