The Place for Ubiquitous Computing in Schools: Lessons Learned from a School-Based Intervention for Youth Physical Activity

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ABSTRACT

With rising concerns about obesity and sedentary lifestyles in youth, there has been an increasing interest in understanding how pervasive and ubiquitous computing technologies can catalyze positive health behaviors in children and teens. School-based interventions seem like a natural choice, and ubiquitous computing technologies hold much promise for these interventions. Yet the literature contains little guidance for how to approach school-based ubicomp deployments. Grounded in our analysis of a large-scale US school-based intervention for promoting youth physical activity, we present an approach to the design and evaluation of school-based ubicomp that treats the school as a social institution. We show how the school regulates students' daily lives, drawing from work in the sociology of schools to create a framing for planning, executing and analyzing school-based ubicomp deployments. These insights will assist other researchers and designers engaging in deployments of ubiquitous computing systems in settings with established institutional structures.

Author Keywords

children, health, physical activity, school-based interventions, ubiquitous computing

ACM Classification Keywords

H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors

INTRODUCTION

The increasing number of overweight and obese children and adolescents is a key health challenge in 21st century America. Since the 1980s, rates of overweight adolescents have doubled, and rates of obese adolescents have tripled [19,42]. Medical research has also uncovered a phenomenon known as the "adolescent slump"; around age 12, physical activity levels drop dramatically, and in many cases never recover [40]. Adolescent obesity is the single biggest predictor of adult obesity, and the crisis has disproportionately affected lower-income and minority communities. There is general agreement in the literature that such a complex societal problem requires a holistic approach, and that successful health behavior change interventions must address adolescents' everyday lives [19].

In response, many interventions in this space choose the school as their deployment environment. Schools reach the majority of youth, regardless of the particulars of their home life. Schools have facilities and existing programming for physical activity, serve children 1-2 meals daily, and have trained adults available to facilitate health-related behavior change. Schools might be particularly adept at reaching children less accessible via parent and family-only interventions. Historically, most of these interventions have not included a computing technology component, but often require large commitments of staff, time, or space [41].

Ubiquitous computing technologies seem a natural fit for school-based health interventions. Ubicomp deployments have the potential to integrate with schools and the school day, leveraging computing power to let teachers, parents and students concentrate on the behavioral objectives of the deployment. They can extend sensing and feedback beyond the classroom and into students' lives after school and at home. Yet prior work offers little guidance for the design and study of ubiquitous computing deployments in schools. To address this need, we describe a case study of a school-based ubiquitous computing application aimed at increasing adherence to a behavior strongly correlated with risk reduction for obesity and a number of chronic diseases: engaging in regular low-to moderate- intensity physical activity.

This program, the American Horsepower Challenge (AHPC), was used over the course of three semesters by over 1400 American children in 61 schools. In studying this program, we saw that although many of the challenges facing all school-based interventions (even the ones with minimal or no advanced technology) also apply to school-based ubicomp, these deployments in schools offer new opportunities for engagement and have their own unique needs.

In this paper, we present an approach to the design and evaluation of school-based ubicomp intervention that treats the school as a social institution, one that regulates interactions through space, time, ritual and social hierarchy. We argue that schools—as established institutions with a set of rituals and norms—require new ways of designing and deploying ubiquitous computing interventions than what has been previously discussed in the literature.

In building this argument, we draw from studies of school sociology to show how ubiquitous computing technologies fit into school settings. We describe the rituals of the school day, including temporal, spatial, differentiating and integrating rituals, and show how each of these impacts ubicomp technologies. Throughout, we ground our discussion in our experiences studying a large-scale longitudinal school-based ubicomp deployment, providing real-world examples and data. We address the potential for school-based ubicomp deployments to extend beyond the school, and describe the challenges such deployments face in moving beyond the schoolhouse. Although our US-based study necessarily restricts our specific observations to American school settings, our findings will have relevance for researchers and designers in many countries. We conclude with a set of design recommendations for the design of ubicomp deployments in schools. Finally, while the focus of our study was a school-based technological intervention for increasing daily physical activity of American youth, the experiences, analysis, and guidelines presented in this paper apply to other ubiquitous computing technologies seeking a fit within established institutional cultures.

RELATED WORK

Our discussion of school-based deployments relies on related work from several disciplines. First, we discuss relevant work in technological interventions aimed at improving health behaviors, and the limitations of these systems when they used in K-12 environments. We then turn to a discussion of the sociology of education, and how it may provide guidance for the design and evaluation of ubiquitous computing in schools and other institutions with established norms.

Technology Interventions for Health Behavior Change

School-based health interventions come in a number of formats, and have been met with mixed success; many predate work in ubiquitous computing research [41]. Of particular interest is McCaughtry et al's [34] study of a cohort of elementary school PE teachers as they integrated analog pedometers into their classrooms over a period of six months. Despite initial teacher enthusiasm, over time they struggled with technical malfunctions and classroom disruptions related to the interfaces on the pedometers.

Technology-focused research projects have examined how exercise video games ("exergames") [3], mobile phone applications [14,15,22,24,33,37,39,44,47], and sensors [20,34,36] can be used to support positive health behavior changes in children and adults in a number of settings. Typically, these systems provide benefits through social support, reduction of monotony and boredom, or by providing new knowledge that can be incorporated into one's daily life. In addition to these research-focused applications, the past decade has borne a number of commercial fitness gaming systems, such as Konami Dance Dance Revolution, Sony EyeToy, Nintendo Wii Fit, and Xbox 360 Kinect; all claim to make video gaming a more healthy and active experience. In addition to promoting general health and wellness in broad cross sections of the population, specialized applications have been developed for the purposes of stroke rehabilitation [9,11,18,38,43], physical therapy [28], mental health care [46], increasing nutrition knowledge in low-income communities [22,23,24,25], and chronic disease management for conditions such as diabetes, cystic fibrosis, and asthma [5,10,33]. Despite the creation of research and commercial systems aimed at promoting positive lifestyle changes, it has been difficult to effectively integrate them into a typical K-12 school environment.

In particular, a focus on the use of mobile and sensor-based technologies in behavior change applications offers new challenges when integrated into K-12 schools. On one hand, mobile and ubiquitous computing technologies for encouraging healthy behavior changes seem like a reasonable medium because they are heavily used. In the United States, over 75% of teens have mobile phones, 93% are online, 87% use email, 60% have their own computer, and 97% play video/computer games [31,32].

On the other hand, using these technologies at school raises questions about liability and cultural norms. Studies of mobile phone-based deployments in schools have suggested that including these devices in the institutional setting of a school requires a radical paradigm shift from how "schooling is done" [16]. Although mobile technologies are used nearly ubiquitously among American children, schools have been reluctant to allow usage during the school day for educational or other purposes. Mobile technologies blur the boundary between the educational world and the outside world, and are difficult to monitor. Cramer and Hayes, for example, [16] note that mobile technologies have been viewed with suspicion and panic, starting with pager bans in the 1980s to current day concerns over using text messaging to send sexually suggestive content ("sexting"). Above all else, schools focus on making sure that students are protected. Mobile technology can be seen as a threat in some ways, especially to schools concerned with minimizing their potential liability. However, these concerns are not unique to mobile deployments; indeed all school-based ubicomp deployments must make the case for their potential utility compared with their disruptive potential. In the following section, we turn to a discussion of the sociology of education to as a framing to understand the opportunities and constraints of deploying ubiquitous computing technologies in schools.

Schools as Institutions: Using Sociology of Education to Understand Ubicomp Deployments

The sociological perspective on education, which views the school as an institution, provides many insights for understanding ubiquitous computing deployments in educational settings. Not only are schools places for learning intellectual skills, they are also are places for building political allegiance, assimilating cultural groups, and more broadly teaching the norms, laws, values, and behaviors of society [6,17]. Moreover, schools play an economic role in society by preparing children for eventual participation in the labor market [35]. Schools are in many ways variable in nature; there might be quite a bit of difference between the day-to-day functions of any two schools [2,6], particularly in the United States due to decentralized, local control of school operations [35]. However unique an individual school might be, schools as societal institutions have shared organizational characteristics. In particular, schools—across age groups and geographic boundaries—are places that are selective in what is taught, have a sequenced curriculum, and have distinct boundaries to the outside world [6].

For the discussion that follows, we have identified three particular facets of sociological research on education: status hierarchies, spatiotemporal rituals, and differentiating/integrating rituals.

Status Hierarchies

Schools are places with status hierarchies, where status can be obtained through either academic or non-academic means. They have standardized membership categories–e.g., “freshman” or “high school graduate”—allowing individuals who might have very different skills and abilities to be treated as equals [6].

Temporal and Space-Related Rituals

Schools have temporal rituals marking individual days as well as longer periods of time (semesters or a school year). So too are physical spaces arranged in a ritualistic manner. There is some amount of separation between students and staff (e.g., through teachers' lounges and playgrounds), and movement between spaces is highly regulated for students and visitors [6].

Differentiating and Integrating Rituals

Schools have other rituals that contribute to the maintenance of a moral order within the school setting. *Differentiating rituals* seek to celebrate students who conform to school norms and values (e.g., an honor roll). In contrast, *integrating rituals* produce a collective school identity (e.g., pep rallies or school dances) [4,6].

Ubiquitous Computing in Schools

With this framework in mind, let us consider existing ubiquitous computing projects in school settings. There have been a number of deployments that focus on everything from note taking in college classrooms [8] to behavior management in K-12 special education classrooms [27,29]. In neurotypical K-12 classrooms, ubicomp technologies have been explored for behavioral tracking of classroom activities [30], transmitting information about emotions between students and teachers [1] and using multi-touch or large collaborative displays for small-group collaboration in academic projects and storytelling activities [7,12,26]. Often these projects are built into the classroom, or designed for classroom-only use [1]. Other times, they have been explicitly built to be incorporated into existing school rituals. The Playful Toothbrush project, for example, was integrated into an existing tooth brushing break in a kindergarten to teach children how to brush teeth properly [13]. Similarly, Ervasti et al’s study of a technology for automating taking attendance in schools relied on existing rituals in the classroom [21]. In contrast to this prior work, we discuss a ubiquitous computing technology that addresses an important societal problem, but does not necessarily fit neatly into the day-to-day educational objectives of a school.

AMERICAN HORSEPOWER CHALLENGE: A UBICOMP INTERVENTION IN U.S. MIDDLE SCHOOLS

The American Horsepower Challenge (AHPC) is a pedometer-based pervasive health game for middle school students (approximately ages 9-13). This game, which aims to increase daily physical activity, was intended to broaden opportunities for children—even those with little skill in traditional sports—to compete in an athletic competition for their school. Developed by Humana Games For Health and sponsored by the Humana Foundation[1], the AHPC takes real-world step data and feeds it into a virtual environment. Through a combination of Bluetooth-enabled pedometers, an automatic upload station located within a school classroom, and a web-based game that showed a school vs. school race as well as individual performance statistics, the AHPC tracked students’ daily physical activity over several months and translated it into points in a virtual race among schools enrolled in the program. Unlike other exercise video games in which points are earned through interacting with the game system itself (e.g., Dance Dance Revolution, Wii Fit), players’ interaction with the AHPC online game portion did not earn them any points. Instead, all points came from real-world physical activity measured by the wearable pedometers; students were rewarded equally for low-, moderate-, and high-intensity activities. The design of the technology was intended such that it could transcend *status hierarchies* in the school; as long as a child could walk, he or she could participate equally in the game.

[1] The philanthropic arm of Humana, Inc., a health benefits company.

Game Technology

Humana distributed 20 pedometers and a base station to each school, and normally about 20 students at each school participated at any given time. Students joined or left the program for various reasons, including student transience and teacher preference (teachers often lost daily access to students when they started a new school year, and some teachers recruited new students for the second school year).

Steps from the wireless pedometers were automatically uploaded to the base station when in range (within a few feet) and available on the website within eight hours. Students could use the web interface to check their steps, and see their school's total compared to other schools. The website featured a "horserace" metaphor; each student's avatar was a customizable cartoon horse, and the horses sat in a customizable school bus, which traveled around a racetrack with other schools in the competition. The relative position of the school bus indicated a school's standing in the competition. Teachers had their own version of the website that allowed them to customize the school's bus, keep track of students' step counts, and perform basic administrative tasks.

Participant Recruitment

After several prototype deployments, Humana conducted a large-scale field trial with 61 schools in 2009 and 2010, inviting our research team to study the game's impact and effectiveness during this period. After a one week pre-game baseline period in which baseline step data was collected, the game played out over two phases: Phase I occurred in Spring 2009 and Phase II spanned Fall 2009 and early Winter 2010. The top performing schools in each phase received grants to purchase fitness equipment. At the end of Phase II, 37 schools remained in the challenge.

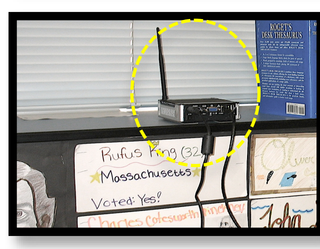
All participating schools were Title I schools (a US federal funding program targeted at "public schools with high numbers or percentages of poor children"[45]); many with a substantial portion of the student body receiving free or reduced priced meals. The schools were situated in a range of environments, from large cities to rural areas. Thirty-seven schools continued in the AHPC across both phases of the game. Overall 1465 students participated in the game. Most of the students were in US 6th grade (11-12 years old) when they began the challenge, and continued it into 7th grade (12-13 years old).

Research Methods

As part of a larger research initiative, our group independently evaluated the AHPC; full details of this evaluation are available in our tech report [20]. Note that our research team did not create the game, recruit schools, choose players, or take responsibility for the upkeep of the game. Nor did we have control over the length of time the game was played or the ways it was distributed to the schools.

In the course of the AHPC, we used surveys to collect information from the students, their parents, and the teachers involved in the challenge about participation in physical activities, attitudes toward non-exercise physical activities and structured exercise, perceived social support for participating in the challenge, demographic information, and neighborhood characteristics. In total, 577 students (33%), 380 parents (22%) and 19 teachers (51%) responded to our surveys. We also gathered website usage and pedometer log data from each child to supplement self-reports. In total, we examined 14 weeks of individual and aggregate data from two school years. To supplement the survey and log data, members of our research team also visited 15 schools participating in the AHPC, speaking with over 200 students and teachers. The profile of the 15 schools we visited is representative of the overall group socioeconomically, demographically and regionally. At each school, we conducted a student-only focus group, teacher interviews, and individual student interviews and wrote field notes with observations of interest. We analyzed these data using an iterative, inductive qualitative analysis approach in which all members of the research team worked to achieve consensus.

(a) Accelerometer is worn on shoe, storing the number of steps per day for up to seven days.



(b) Base station in high-traffic area of the school automatically collects data, uploads to web server

(c) Updated school position in the race and individual performance stats are shown on program website within 8 hours of upload.

Figure 1. Overview of the deployment technology

Results

Overall, the participants' physical activity levels increased during the game. The AHPC-enrolled students increased their daily step-counts during the game relative to a pregame baseline. The average student participant in the

AHPC recorded 4,193 steps per day (*SD* = 2347) during the deployment, as compared to an average of 3,416 steps during the pregame data collection period (*SD* = 3420 steps). We found a significant difference between the pregame baseline step counts and each round of the competition. Step counts in Phase I were significantly greater than the pregame baseline ($t(6764) = 24.48$, $p < .001$ (two-tailed); so is the first month in Phase II ($t(9018) = 12.99$, $p < .001$ (two-tailed)) and second month in Phase II ($t(13930) = 4.84$, $p < .001$ (two-tailed)).

Digging deeper, we found a diversity of approaches and local implementation strategies. As we analyzed the data, we started to see patterns emerge, ways in which these seemingly disparate practices were connected to a common set of needs and underlying social structures. In the sections that follow, we show how these sociological phenomena presented themselves in the case of the AHPC, and draw implications for the place of ubicomp in schools.

SPATIAL AND TEMPORAL RITUALS

The highly structured nature of school days leaves little room for additional activities including health interventions. In this light, ubiquitous computing technologies may have an advantage for incorporation into the daily rituals of schools. For example, pervasive sensors reduce the need to interrupt the school day to enter data, and mobile interfaces allow students to interact with the system between classes. Our analysis of the AHPC, however, shows a more nuanced picture. In the AHPC, the sensors collected data instantly and constantly, but students would often go days without viewing or analyzing the data. Additionally, because the AHPC was a behavioral intervention, the sensors were not there merely to capture existing behavior but to motivate students to increase desired behaviors. In schools where students gained the most steps, this dual purpose motivated the introduction of new rituals into the school day: both to acquire more steps and to collectively view and analyze progress.

Sensing and Feedback

The AHPC's design is, in a sense, minimally disruptive to the school day. Wireless base stations that students had to pass in order to upload steps were placed in high-traffic locations already visited by the students in their daily schedules; they did not need to interact with an explicit interface in order to participate in data collection. Compared to analog pedometers or mobile phone interfaces that have been found to be distracting in school environments [16][34], the AHPC sensors have a minimally distracting physical design. The sensors contain no displays themselves, and feedback is provided via a website, which allowed schools to control whether and when students could interact with the interface during the school day.

How, then, did students become aware of their individual and collective progress? This information was available on the program website, accessible on any Internet-connected computer. From our interviews and site visits, we suspect that many students logged onto the site once or twice a week during the challenge (specific data on logins was not available from the project sponsor). On average, the students logged in to the AHPC website 9.2 times from Nov. 16, 2009 to Feb 5, 2010 (*SD* = 12.9). Few students reported logging in from home; for most students, access to feedback was determined by when they could go to a computer lab or use the classroom computer. Students would often go days without seeing if their steps had been uploaded correctly. In contrast, personal health informatics systems often rely on regular daily use. Diabetics, for example, often take several readings per day, and must code and interpret their blood glucose readings [33]. Fitness interventions, for example many commercial pedometers and the Ubifit Garden project [15], include a passive, pervasive information display.

The sensing and feedback mechanisms the AHPC present an issue of import to deployments in schools. On one hand, the lack of display on the sensors combined with tightly controlled access to feedback sessions can reduce disruption from existing activities within the school (for example, students comparing steps during lessons, as has been found in other pedometer-based interventions [34]). On the other hand, this style of sensing and feedback required the teachers to create technological workarounds as well as regular rituals surrounding physical activity and feedback about performance.

Structuring Time

Schools where the AHPC worked well, that is, where we saw little participation drop-off and step-counts were above average, answered the challenge of making time for successful gameplay by inventing more opportunities for physical activity during the boundaries of the school day. During the deployment, teachers in these schools would open the gym before school, during recess and lunch breaks, and even during regular instruction hours. As just one part of students' lives, the AHPC constantly faced the threat of being lost in the shuffle. Regular rituals served as reminders to participate in physical activity and provided reaffirmations of purpose.

In some cases, students lacked any recess time during the school day. At one school we visited, the students' lunch break was their only real free time during the entire school day. These lunch breaks provided a unique opportunity to encourage more physical activity. As their teacher told us:

> *[Students'] lunches are 40 minutes and most students will eat lunch in the first 15 minutes and that's pushing it. Usually they're done within the first 10. So whenever the weather is decent...they have four square stations and basketball.*

Additionally some teachers also opened the gym before school, making it available to any student but particularly encouraging the AHPC students to get in some steps during that time:

> *7:15 they'll come rolling in and unfortunately we don't know how many students are coming in one day to the next so it's hard to plan but we kind of think off of our toes real quick and come up with something. We average about a dozen that come in.*

This practice of opening up the gym was not uncommon, and teachers were able to be fairly creative with strategies for getting steps. At one school, the PE teacher opened up the gym to AHPC students during their study hall, even if another PE class was going on during that time.

The motivation by teachers and schools to extend the school day is, in some ways, unsurprising. Schools are very good at regulating time and coordinating activities within their own spaces. Schools did this in two main ways: through differentiating rituals and integrating rituals.

DIFFERENTIATING AND INTEGRATING RITUALS

Literature in the sociology of education distinguishes *differentiating rituals*, which seek to celebrate students who conform to school norms and values (e.g., an honor roll), as well as *integrating rituals,* which produce a collective school identity (e.g., pep rallies or school dances) [4,6]. In the AHPC, we saw evidence of both.

Differentiating Rituals

The AHPC technology was designed such that there were few differentiating rituals. Students could not view one another's step counts (unless physically looking over the shoulder of another student at a computer). Yet we saw differentiating rituals occurring, particularly in recruitment practices within the school. At one school, the AHPC teacher even ran the AHPC as a team, hiring and firing students based on performance. He "hired" and "fired" participants according to their performance in the Challenge. He found the strategy an effective one.

> *I'd say, 'You're fired.' And I'd give the chip to someone else. I'd say, 'Now you're hired.' So I probably had to do that to maybe four kids last year. And that worked.*

In other schools we visited, teachers described how they chose students based on characteristics such as "responsibility" and whether they were "good athletes." In these schools, participation in the AHPC was, to some extent, a reward for meeting some desirable criteria. Yet sometimes, student selection choices were not made because the student would benefit the most from being in the program. For instance, given the lack of replacement pedometers and the long duration of the study, one teacher remarked that she chose students whose families were long-time residents in the local community, as well as students who were athletes or otherwise active in extracurricular activities.

> *I wanted kids who I knew would return the stuff [permission slips], and who would return the pedometer.*

The teacher knew that she was excluding students who could have most benefited from participating in the program. Yet given the long time span of the deployment, she intentionally chose students who would be most likely to succeed individually, lest their irresponsibility lead the program as a whole to collapse.

Integrating Rituals

Most schools attempted to deploy AHPC by making use of existing in-school rituals, for example, by placing their base stations in high-traffic areas. However, we found that top-performing teachers went beyond this step, and used integrating rituals—those that encourage a collective school identity—to encourage students in the program. In particular, we observed a school in which the two teachers in charge of the program were teachers of elective subjects. By incorporating AHPC-specific elements into their classes, the teachers automatically gained access to the rituals of school life, such as a regular meeting time and the legitimacy of an elective course. The teachers asked the children to walk past the access point during class if they had yet to do so, and then as a group, the teachers and children viewed their current standing in the competition by having the AHPC website projected at the front of the room. Through this daily ritual, the teacher and children watched the progress of a nearby school, to ensure that they were staying ahead of their rivals.

Additionally, because there were more children in the two classes than there were slots on the AHPC "team," the teachers at the school mentioned above created a parallel opportunity for the remaining students to wear analog pedometers during the hour they were in this class; at the end of each hour, they would record their step counts onto a sheet of paper. Thus all children, whether enrolled in AHPC or not, had a chance to participate as a group in this physical activity monitoring experience.

UBICOMP AND SCHOOL SCHEMAS

The school is an institution, but it is also a stakeholder, one whose interests should ultimately align with the goals of a school-based ubicomp deployment. As a stakeholder, the school is organized to deal with certain kinds of activities, and will attempt to incorporate new activities based on their conformity to known categories. Schools are equipped to deal with curriculum, clubs, sports, after-school programs; deployments that fit this *schema* will have an easier time becoming part of everyday school life.

But as disruptive embedded technologies, ubicomp deployments might not fit into existing schemas. The AHPC itself is a good example. By combining features of several kinds of deployments, the AHPC relied more heavily on schools' ability to incorporate it into their everyday schedule, and not all schools were able to do so. But more broadly, the deployment did not fit neatly into an existing schema for school activities. Was the AHPC a team sport? A club? A fundraising challenge? A part of the PE curriculum? A part of the Social Studies curriculum? We encountered schools that handled the AHPC in all these ways, and often found different answers within the same school. This designed ambiguity gave schools the ability to customize the deployment to their own needs, but also forced them to fit it into a pre-existing schema.

Ubicomp as Team Sport

The AHPC fits in a space between traditional games and fitness programs. In some ways, the AHPC operates like a school-based fundraising program, where the school receives a package of materials and, with a limited amount of support from the sponsor, runs the program themselves. However, the emphasis on performance and school rivalry sets the AHPC up to appear more like a sport. If anything, the AHPC most resembles a decentralized asynchronous cross-country team.

Teachers' inclinations to create rituals and AHPC-related experiences touches on an issue that pervasive fitness applications might face, particularly if they are deployed in school settings: the lack of "events." The AHPC uses racing metaphors and language—each cycle is a called a "heat," and virtual buses zoom around a virtual racetrack—but includes no support for the in-person practices central to most sports. A majority (72%) of student survey respondents agreed that their school collaborated as a team, yet many told us in interviews that AHPC was not a sport. While not exactly a contradiction, this difference is striking. Students generally felt they were "on a team" but that did not necessarily translate into feeling AHPC was a sport. Part of this was the lack of access to students in other schools. Students saw each other only at the end, when schools in the same metropolitan area gathered to receive prizes. As one student put it:

> *The only time we actually saw [students from other schools] was when we received the check, and nobody talked to each other. They just like stopped in, the people in the other school…it would be nice to know who you're competing against.*

We described earlier how the AHPC teacher at one school treated the deployment as a team sport explicitly, hiring and firing students and instilling a strong team spirit. This strategy seems at odds with the AHPC's goals of using technology to help ordinary students get additional physical activity throughout the day, and although it appears to have increased motivation in this case, the strategy has an obvious downside in its potential for humiliation or shame.

Ubicomp as Curricular Project

Another approach was to treat the AHPC as a class project. Teachers were sometimes able to integrate the AHPC into their curriculum. This integration was especially important for non-PE teachers, who often felt they had to justify spending class time on the AHPC. One particularly innovative example of curriculum integration came from a school we visited. The AHPC teacher at this school was a Social Studies teacher. She worked an AHPC challenge into a lesson on the Civil War. Students re-enacted the Battle of Gettysburg, which involved literally walking a mile in the soldiers' shoes. Said one student:

> *It was a mile off from where the Confederates were from the Union…we walked through a mile of fields and we pretended to get shot.*

It would be interesting to see how the AHPC would change if it was presented as an extra-curricular activity. Even if the actual step accumulation took place outside the regular meetings, we suspect that engagement and retention would improve, and that schools would be able to more easily administer it. On the other hand, the AHPC would then directly compete with other activities such as sports practices, musical ensemble rehearsals, or tutoring programs that are particularly common in Title I schools.

It might not always be possible to find a genre of school-based activity that exactly matches the features and patterns of use of a ubicomp deployment. But understanding the school's schemas can help smooth a technological introduction into the school environment.

DISCUSSION AND DESIGN RECOMMENDATIONS

Within schools where the AHPC was deployed, typically 1-2 teachers took responsibility for administering the AHPC program; other teachers might have been supportive of the program but had no day-to-day responsibilities. The teachers in charge performed much of the stakeholder coordination required for the AHPC to function. They selected students, worked with administrators for gym or computing resources, contacted project managers at Humana to coordinate technology, set up the base stations and distributed pedometers, and monitored students' progress using the website. As authority figures with a limited ability to adjust the daily schedule, the AHPC teachers became instrumental in finding ways around time and space constraints embedded in the school day.

Fit Into the School Day

We found two factors that characterized teachers who led successful deployments: whether the teacher had regular access to the students, and whether this interaction occurred in a single class or was distributed throughout the day. Schools used a variety of methods to choose students for participation. Some schools enrolled all children in one classroom; in other schools, the children might not have had a single class as a group. The variety of enrollment practices afforded us the ability to see opportunities and constraints associated with incorporating physical activity interventions into school settings. We found that when all of the AHPC students met in a single class, the teacher had an easier time providing opportunities for structured physical activity options, as well as access to computer resources. In sum, daily access allowed the teacher to make arrangements for computer availability, monitor technology malfunctions, and to create meaningful rituals surrounding the program.

One issue with physical education in K-12 schools in the United States is that there is no guarantee that children *have* PE classes on a regular basis. PE requirements are determined at the state level, and even with state requirements, schools may interpret and enact requirements in different ways. Most schools we visited experienced more severe funding constraints for PE relative to academic subjects. The teacher survey indicated that although the student population in the AHPC schools ranged from 140 to 2000, the number of PE teachers ranged from 1-3, creating an average student-to-teacher ratio of 247:1. Thus, if physical activity interventions are to reach a maximum number of children, we might consider alternatives to the traditional PE class, particularly for schools that might not be able to offer each student daily physical education.

Where in the school day might AHPC fit other than PE class? On our site visits, we saw indications that participants were most satisfied with AHPC when it was incorporated into classes that have some degree of curriculum flexibility. We spoke to teachers in "non-core" subjects (e.g., those not subject to standardized testing requirements) who had more flexibility incorporating AHPC into their classroom activities. We found that teachers of topics less frequently subjected to standardized testing scrutiny (e.g., history, science), with support from the school's administration, might have flexibility to include physical activities into daily lessons. For instance, they might take children on a nature walk in a science class or have them re-enact a historical battle outdoors in a history class.

Overall, due to the teacher's central role in managing the school environment and schedule, it is imperative that regular student-teacher contact be prioritized for ubicomp deployments in schools, and that for physical activity interventions, there is sufficient flexibility to teach in ways that allow for activity.

Participation Boundaries: School-Based vs. -Delimited

One of the benefits of school-based ubicomp is the ability to deploy holistic interventions that meet youth where they already are. The AHPC was intended to reach into kids' lives by being school-based but extending into after-school and weekend life. However, our research indicates that it might have had limited effects outside the school environment. Despite the mobile nature of the sensors and the social support provided by parents, the AHPC appeared to minimally impact the home environment, and although many students told us they worked together to get steps, we saw little evidence of regular after-school play or exercise routines directed specifically at the AHPC. Instead, schools that obtained the most steps tended to be ones that had made provision for in-school step-accruing practices.

We heard this distinction in our qualitative interviews and site visits, but indications of this limitation can be found in the step data as well. The step data, binned into 24-hour periods, revealed higher physical activity levels during school days compared to weekends. Participants consistently took more steps on weekdays than weekends before and during the AHPC (during Pre-game baseline period: $t(1857) = 12.63$, $p < .001$ (two-tailed); during Phase I : $t(9213) = 39.36$, $p < .001$ (two-tailed); during the first month in Phase II: $t(4252) = 29.89$, $p < .001$ (two-tailed); during the second month in Phase II: $t(3729) = 28.90$, $p < .001$ (two-tailed)).

One might expect the opposite pattern of activity; students typically have more leisure time on the weekends, and the structures of the school environment that might inhibit step-counts (sitting in class, little time for recess) are not present. But these findings indicate that the students who wore the pedometers on weekends did less physical activities during days off than they did during schooldays. Whether the reason for fewer steps logged during weekends compared to weekdays is due to opportunities and organization of physical activities or competition with other leisure activities (or a combination of both), we have to consider whether in-home ambient displays might be interesting for short term competitions, or whether one should just not expect the program to extend beyond the school day. That being said, these results indicate that there still is a larger space for increasing activity levels during weekends.

When considering ubicomp deployments for schools, in addition to thinking about the school itself, researchers and designers also must consider the negative space: the school's blind spots and limitations. The school extends its influence outside its physical boundaries in many ways: homework, clubs, or sports teams, for example. But just because a deployment is mobile or pervasive does not guarantee it will cross the boundaries of the schoolhouse.

Designing For Group Experiences

The AHPC, as it was designed, does not impose any specific physical activity events or goal setting on participants. It is up to the participants to set their own goals, collect steps, and use the website. This flexibility is both a benefit and a problem. On the one hand, it allows teachers to integrate the program into the school day in whatever ways best meets local needs. On the other hand, if teachers are not proactive about providing ways for the children to participate, then the burden is on the students. Given the highly structured nature of a secondary school day, this burden might create a higher threshold for participation as the students have to be especially enthusiastic to create the time and space to participate.

In schools that left the AHPC as an individual experience—for instance, where students could use the website on a classroom computer when they were finished with other school work—we did not see as much enthusiasm about the program as compared to those with teacher-sponsored group experiences. These experiences, which typically involved the teacher leading the students in examining some aspect of their performance as a group (e.g., comparing aggregate step counts to a rival school), reinforced participation and excitement about the program.

Teacher-centered rituals that are brief and frequent work well in schools; they overcome technological and time constraints (e.g., not enough computers in a classroom or having to make special and disruptive arrangements to visit a computer lab). Teacher-centered rituals also control the experience of the game; they remove any potential of outside-world communication that might be perceived as threatening or harmful to students (e.g., like scares over social network safety for minors).

CONCLUSIONS

In this paper, we provided guidance for introducing ubiquitous computing technologies in institutions with established norms and rules, based on a study of a school-based health intervention for American youth. Drawing from work in the sociology of schools, we showed how the school regulates students' daily lives, and how this regulation impacts the planning, execution, and analysis of school-based ubiquitous computing deployments. We then provided recommendations including designing for group experiences, tempering expectations surrounding out-of-school impact, and supporting teachers in "making space" for the technology in a typical school day.

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