Project SMART: A Cooperative Educational Game to Increase Physical Activity in Elementary Schools

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Abstract

Children's rates of physical activity are declining at alarming rates, even given the wealth of evidence that participation in physical activity is positively correlated with better performance in school and long-term health protective factors. In this paper, we describe Project SMART, which directly targets childhood physical activity within the elementary school. The basis of Project SMART is a cooperative educational game originally designed to raise kids awareness of sustainable active transportation to and from school. In Project SMART, we adapt this game to focus on the health and educational benefits of moderate to vigorous physical activity, leveraging organized physical activity opportunities during the school day. In the game, a class cooperatively earns credit for performing physical activity. This credit takes the form of distances traveled on a virtual path (e.g., along Route 66 across the United States). As the class makes progress, they unlock waypoints that contain learning modules defined by their teachers to be directly tied to their curricular content. The paper describes the manner in which Project SMART has used community based-participatory research to develop a game that integrates with the school and community, and reports on the results of a pilot study carried out during the 2019-2020 academic year.

Keywords: Gamification, physical activity, community-based participatory research, pervasive computing.

1. Introduction

Participation in physical activity and fitness are associated with better performance in school [1, 2], but most children do not meet the recommendation of the 2018 Physical Activity Guidelines for Americans of participation in 60 minutes of moderate to vigorous physical activity (MVPA) daily. As an independent but interrelated construct, the prevalence of children's sedentary behaviors such as sitting and screen time are on the rise, as schools have become obesogenic environments, despite the known health benefits associated with physical activity engagement [3]. Active transportation—self-propelled, human-powered modes of transit such as biking and walking to school—as well as in-school physical activity opportunities such as recess and physical education, have been implicated as a means to increase the volume of physical activity participation, thus reducing health risk [4, 5]. However, only 35% of children in grades K-8 living within one mile of their school use walking/biking as transportation [6].

This paper describes Project SMART, an educational game that integrates physical activity into the academic curriculum, opening the possibility for lasting changes to kids' participation in physical activity. Project SMART is an educational game designed to be played cooperatively by a 4^{th} or 5^{th} grade class. The game is based on KidsGoGreen [7, 8], a game developed by another research group, whose purpose was to change the sustainable mobility habits of kids and families. Project SMART adapts the game framework to incentivize physical activity within the school day with the goal of improving child health, self-efficacy, and educational outcomes. In the game,

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the class takes a virtual journey on a physical route (e.g., the current 4^{th} grade game follows a route through historical sites of Texas). Just like in the KidsGoGreen game, the class makes progress by earning "steps", which are explicitly tied to distance traveled on the route. In KidsGoGreen, the students make progress by engaging in sustainable transit to school; in Project SMART, students earn steps by participating in in-school physical activity. The progress, calculated by class aggregate, unlocks "waypoints" that contain learning modules that incorporate curricular material from across disciplines (science, math, social studies, language arts, etc.) placed in the context of the waypoint.

While the KidsGoGreen project explored the potential for gamificiation to change the sustainable mobility habits of kids and families, in Project SMART, we investigate the potential for an active educational game to increase kids' awareness of and engagement in physical activity, in an effort to improve their healthy habits. In this paper, we describe how the collaborative KidsGoGreen game was adapted to work *within* the school day, including developing a mechanism for kids to "check-in" and self-report their participation during organized physical activity opportunities. Finally we report some initial results from a preliminary deployment and elicit lessons learned in that experience.

2. Background and Motivation

Physical activity is a health protective factor across ages and populations [9] and offers significant psychological and social benefits [10, 11]. For young children, physical activity is a predictor of adolescent health [12] and success in school [1]. Kids who are physically fit are more ready to learn [13], likely to attend school [14], and able to identify academic cues [15]. Because of the high coincidence of low academic performance and low levels of physical activity [16, 13, 17, 18], Project SMART attempts a school-based intervention to increase children's awareness of and participation in physical activity. However, because prior studies show that extending physical activity interventions to include families can amplify benefits [19, 20, 21], our efforts that will build on this initial work will attempt to reach beyond the school day and school walls to promote physical activity in the wider community.

Project SMART centers on a "serious game" that connects quantified physical activity with educational material aligned with and supplementing the school curriculum. Game-based activities within school can increase physical activity in adolescents [22], and social connectedness in a game amplifies the impact [23]. Recent studies debunk the myth that physical activity levels begin to decrease in adolescence; instead the decline begins in elementary school [24]. Few digital interventions to increase in-school physical activity have been attempted with elementary children, though preliminary work indicates that asking children to quantitatively analyze their own data improves statistical thinking skills [25, 26]. Further, prior work demonstrates that, rather than requiring dedicated time, activities to encourage physical activity can be integrated into the school day [27]. However, outside of data analysis, these efforts have not been tied to school curriculum.

Prior work has shown that it is possible to increase student engagement through gamification [28]. In this context, gamification uses game design elements in a non-game context to engage people and solve problems. Gamification in education is becoming more commonplace as a way to inspire learning [29]. Online learning environments facilitate social interaction [30], minimize teacher burden, and provide timely feedback [31]. In Project SMART, we build social supports via a classroom-based game by applying cooperative gamification strategies and unlockable content to motivate children to achieve collective and individual goals. Project SMART exploits an open-source gamification framework [32] that has been deployed in smart city games around Europe [33]. Notably, this framework has previously been used to implement the KidsGoGreen game [8], on which Project SMART is directly based.

3. Community Based Participatory Research

To develop Project SMART, we used *community-based participatory research*, a paradigm that transforms how research is conducted by giving voice to participants, focusing on social issues [34], acknowledging the uniqueness of vulnerable communities [35], and equitably incorporating all partners and their strengths [36]. In this model, community is defined as a unit that: (a) meets basic needs; (b) has a central social interaction; and (c) shares a symbolic identity [37]. The elementary school is a perfect match—in our preliminary interviews with stakeholders, one school principal told us, "schools are everything to these kids. We clothe them, feed them, and love them. We raise money to send backpacks of food home for the weekend because we know they have nothing to eat." The elementary school, including students, teachers, and parents, is an ideal location to explore community-based participatory research.

Project SMART undertakes community-based participatory research in the realm of *computing and technology*, a domain to which this style of research has not yet been applied. By starting in the elementary school, our goal is to reach the broader surrounding community. In this way, we both empower elementary-aged children to serve as influencers of the wider community and impact physical activity in an incremental and sustainable way.

Rather than designing solutions *for* these communities, as is commonly done for computing-centered research, we propose to design solutions *with* the community, using established community partnerships. We used a basic prototype of our game in a series of conversations with teachers and students. In particular, we solicited feedback from: (1) six elementary school teachers, including grade-level and content specialists and (2) a class of twenty 4^{th} grade students. Based on the inputs of these groups, we developed the initial Project SMART game and performed a pilot deployment in the 2019-2020 academic year[1]. Through this pilot, we worked with 85 4^{th} and 5^{th} graders who reported their physical activity levels for a period of six weeks in Spring 2020.

Initially, our intent was to mimic the approach of the KidsGoGreen game, which was deployed in Italian elementary schools to encourage active transportation to and from school. However, through teacher and administrator focus groups, we discovered that our partner schools lacked the readiness to encourage active transportation. At two schools, fewer than 5% of students actively transit to school. Further, one administrator was eager to have her students work with our team to co-construct the game but stated that using RFID badges for students to sign in to school to indicate active transport was likely out of the question, due to parental concerns relating to student data privacy, the potential for loss of the cards, risks of location tracking, and a lack of obvious benefits since most students come to school by car. The second school welcomed the opportunity for teachers, students, and parents to build the application together, including support for RFID-based logging; however, the school staff encouraged a focus on physical activity within the school day rather than on active transportation.

We also conducted a focus group with a 4^{th} grade class (20 students) to identify what motivates students in the realm of gamified physical activity. After viewing a demonstration of a prototype game, the students identified a need for individual credit as a behavior motivator but were also energetic about the cooperative aspect of working together as a class on a larger goal. Students had creative ideas about game incentives and motivators, including earning avatars and avatar accessories and the ability for a student to "drive" the class's bus for a game segment. The children expressed a desire to have a physical mechanism to "check-in" and log their activity rather than having data be passively or implicitly collected. The students suggested novel ways to integrate the game with their curriculum; for instance, they suggested math problems that would use their data, and they suggested having the ability to look in on their data midday so they could "plan for how physically active to be for the rest of the day." Finally, the students shared ideas for connecting game content to other in-class activities, for instance using a tabletop experiment when exploring a wetland region or earning a dance party when the class reaches a goal.

These initial focus groups and conversations led us to more closely engage the community in developing the game; during Summer 2019, we worked with elementary teachers from three schools to create initial journeys for 4^{th} and 5^{th} grades and to develop learning modules aligned with grade-level curricula. The primary contribution from the teachers was the identification of learning activities that were aligned with and enriched the existing curriculum. The teacher encouraged us to integrate bonus way points so they could control when the students would be able to unlock the learning activities. Given today's standards-based focus in schools, the teacher requested that there be assessment data collected and tracked within the game. For example, weekly vocabulary test and 2-minute math fact check-ups be part of learning activities within the game. Without such curricula alignment, the teachers could not justify spending time playing the game. This style of direct co-construction fulfills the goals of community-based participatory research and enables a result that is aligned with the needs of the community.

4. Project SMART Development

We have developed a prototype Project SMART game that we have piloted in an elementary school during a portion of the 2019-2020 school year. In the Project SMART game, students receive "credit" for participating in well-defined physical activity "events" during the school day (e.g., gym class, recess, or brain breaks). In the deployed game, 4^{th} and 5^{th} grade students and their teachers could log physical activity data in one of two ways: (a) using a

[1]The in-school pilot was put on hold in March 2020 as a result of COVID-19; we are resigning the game to support remote education.

Figure 1: Project SMART, entering activity data.

the game's web portal or (b) through a "check-in" box that uses RFID proximity cards and a button that the student presses to indicate their activity level on a four-point scale ("more active", "active", "less active", and "inactive"), designated by the colors green, yellow, red, and gray. These levels classify self-reflection reports that elementary physical education teachers commonly employ. The game displays the class's activity levels in a column chart and converts the duration of the activity and the activity levels into a distance traveled using a function that maps activity level to rate (in mph), as shown in the inset of Figure 1.

Figure 1 shows a pair of views from a mock game for a class of 32 kids in which the class has recorded five physical activity events (two Physical Education (PE) classes, one recess, a quick in-class "brain break", and transit home from school). The main screen shows the column chart for each activity; for each activity, the number of kids who checked in at each activity level (green, yellow, and red) is shown as a column. The inset view shows a popup that appears when the teacher or students finalize an activity. Each activity level is associated with a speed; the speeds and duration are used to compute the distance traveled by the class for each activity. In particular, in this example, students participating at the green activity level are attributed an activity rate of 3 miles per hour (mph). This math learning cue helps students quantitatively analyze their individual contributions to the larger goal while still maintaining student privacy (i.e., physical activity data is not individually identified).

We use the class's total distance from a physical activity to move the class as a group on a virtual journey. The class reaches pre-defined locations that contain learning modules with content that cuts across their regular school curriculum. The example in Figure 2 (a 4^{th} grade journey across Texas) has been co-constructed with elementary school content experts to align with the grade-level Texas Essential Knowledge and Skills (TEKS) and Common Core learning standards. Preliminary focus group data showed that aligning the content explicitly with a state's required curriculum is a prerequisite for using Project SMART in the classroom. We aim to design the Project SMART app in a way that is very flexible; each classroom will be able to have a separate deployment that incorporates diverse modules that can include content drawn from different requirements or standards. In a given game, modules will be able to include content from all academic subjects or simply from a subset as determined by the teacher. Individual teachers

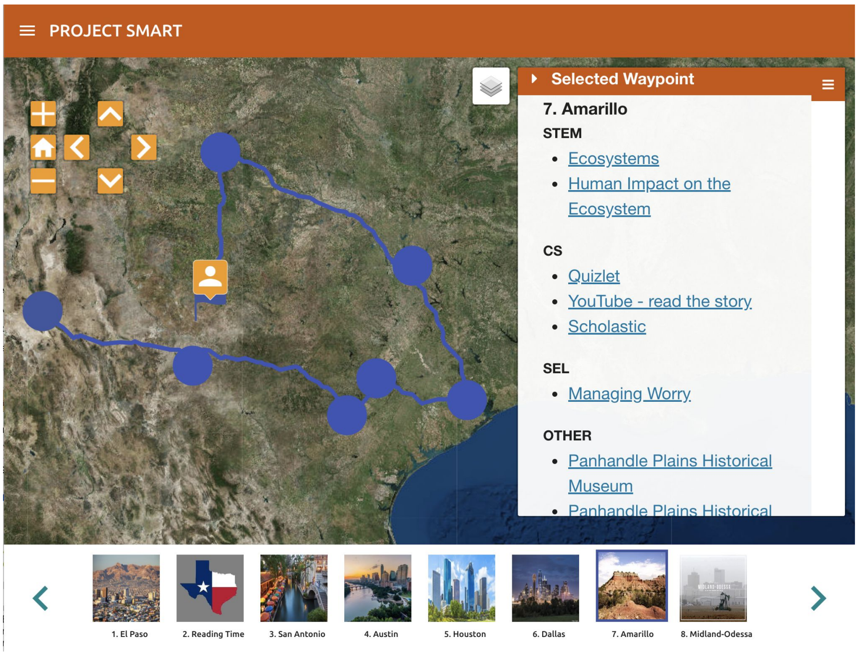


Figure 2: A Project SMART journey through Texas.

can curate the content for their particular classes. A Project SMART journey can also include "bonus" waypoints along the route that teachers can enable when the class's progress slows or when they want to inject new content on-the-fly. Even though each class may be playing the game in a different way, they all still share a unified goal: to increase participation in physical activity.

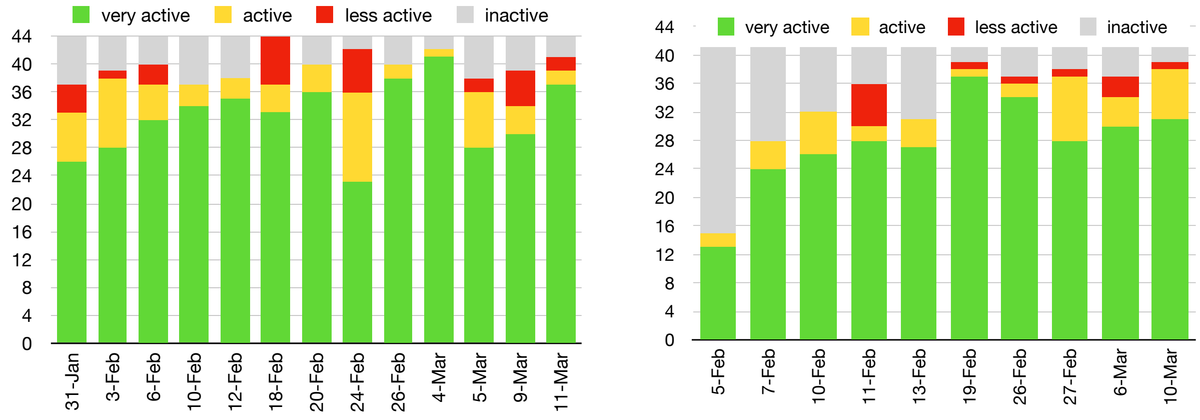
We have developed a basic physical activity "sensor" in the form of a "check-in" box that containing a Raspberry Pi, an RFID reader, and four buttons (Figure 3). A student activates the box with a proximity card and then presses a button that corresponds to his or her activity level for the given event. The selection is transferred to the game, which computes the distance credit. RFID check-ins can be anonymous or pseudonymous [38]; in the former case, a set of RFID cards is associated with the class, and a given student may use a different card for each check in; in the latter case, each student has their own card. This design allows us to collect both aggregate data for the game and individual data that can be mapped to students' physical fitness and academic achievement for research purposes, while safeguarding student identity and ensuring cyber-security.

We also designed a generic API for integrating physical activity data that is agnostic to the mechanism used to measure activity, whether via self-reported data, RFID "check-ins", or some other technology that might be designed in the future.

Figure 3: Prototype check-in box.

5. Pilot Study and Lessons Learned

During a portion of the 2019-2020 school year, we piloted Project SMART in UT Elementary School, a charter school and a research demonstration school affiliated with the University of Texas. We have agreements in place to pilot projects, including an IRB approval for the in-class studies, and the teachers are experienced in cooperative research. At UT Elementary, 43% of students met grade level expectations in science, and 45% met the expectations in math, with the school achieving a Texas Education Agency accountability rating of "B", *meets expectations* [39]. It is Title 1 school, with high concentrations of poverty, as measured by the portion of students who receive free or reduced lunch. We have forged connections with teachers, administrators, and students at this school, and we have



(a) Fourth Grade

(b) Fifth Grade

Figure 4: UT Elementary Physical Education Class Check-ins, Spring 2020. Each column shows one day's check-ins, depicting the fraction of students who self-reported their activity level as "very active", "active", "less active", or "inactive". The inactive counts include all students who did not participate in P.E. class, whether because they were absent or because they sat out.

performed preliminary measurements of physical activity of these students, which found that children participated in a daily average of 14 minutes (SD$\pm$2.53) of moderate to vigorous physical activity during physical education class at UT Elementary.

In Fall 2019, we deployed a pilot game by collaborating with the physical education teacher at UT Elementary. We deployed two instances of the Project SMART game: one for the fourth grade and one for the fifth grade. At UT Elementary, each grade level has two classes of 20-25 students each. In each game, all students in the grade level contributed collaboratively to a single journey. Students participate in physical education instruction multiple times per week. We placed the Project SMART check-in box in the gym, and students were each assigned a numbered RFID card and pseudonym. At the end of each physical education instructional period, students were asked to activate the box using their card then select one of the three colored buttons: green if they felt they had been "very active" in class, "yellow" for somewhat active, and "red" for not very active. Students who were not in class or who did not participate were logged using the white button. The box was deployed in November 2019 and used through March 2020.

In addition, our team visited the elementary school periodically throughout the period to collect ground truth physical activity using chest-worn accelerometers. We performed one week of data collection using the Project SMART app and box in November 2019, including one day of accelerometry data collection. We then worked with the physical education teacher through December and January, and restarted data collection for six weeks in February and March, collecting data through mid-March.

For the November 2019 pilots, of the 44 students in fourth grade and 45 in fifth grade, 62% of the students identified their physical activity participation as very active by selecting the green button, when in fact, the accelerometry data on the same days indicated that only 39% of the students had participated in moderate-to-vigorous physical activity for more than 50% of the physical education class. Before continuing data collection in the spring, we worked with the teacher to design some quick lessons to increase the accuracy of the student self-reports. The teacher provided specific verbal prompts for each color and stood near the box while the children checked in at the end of class. As a result, the teacher observed that the students' check-ins for the spring pilot data collection were a more accurate reflection of their actual activity.

Figure 4 shows the check-ins logged in Spring 2020 for the 44 fourth graders and 41 fifth graders across two classes for each grade. As expected, the student's check-ins reflect the fact that the duration and intensity of physical activity varied across different physical education lessons, but it was the increased accuracy of the student reporting that was most encouraging. We performed four objective observations of physical activity across the spring pilot using both accelerometry and compared these measurements to the RFID-based self-reports. On average, 35% of the children in 4^{th} grade and 25% of the children in 5^{th} grade accurately reported their physical activity as more active, active, less active, or inactive. Among 4^{th} graders, 35% of the students *overestimated* their physical activity participation, while in 5^{th} grade, 63% of students *underestimated* their physical activity participation across the observations. We learned that the physical education teacher needed to do several things to improve the accuracy of the student perceptions of engagement: (a) provide verbal prompts during the lesson about how hard the students should be working (e.g., run as fast as you can, walk at a fast pace), (b) provide visual cues at the time when the students checked in (e.g., describe what green (more active) looked like in this lesson), (c) show the students the aggregate data after the entire class had checked into the game, and (d) stand nearby the check-in station to remind the students about all of the activities they had done in the lesson. When school was dismissed on March 13, the fourth grade classes has completed 915 miles on their virtual journey, unlocking four of their six virtual waypoints' learning activities, while the fifth grade had achieved 672 miles, unlocking two of their nine waypoints.

In summary, this pilot effort has generated many valuable lessons. As indicated above, our early data collection efforts indicated that students were not reliable reporters of their physical activity levels. Rather than reporting the degree to which they were physically active, they tended to report the degree to which they were compliant with the teacher's instructions. For instance, in a class period focused on basketball dribbling technique, many students reported that they were "very active", even though the class activity was not particularly vigorous. We were able to recognize this early and provide both the teacher and students coaching on how the degree of their physical activity should map onto the four colored levels. We observed improvement in the accuracy of the student self-reports. We also found that the game, while intuitive, required more hands-on training with the teacher before leaving it unattended in the classroom. This was remedied for the pilot by providing one-on-one training with the teacher, but it made obvious the need for more careful and complete documentation as well as teacher trainings prior to deployments.

6. Conclusions and Future Directions

This paper has described the development of the Project SMART collaborative educational game with the intent of increasing moderate to vigorous physical activity among upper elementary school children. This work is directly motivated by previous findings that demonstrate positive correlations between childhood physical activity and academic achievement. Through our pilot study reported here, we demonstrated that it is feasible to deploy the Project SMART game in a public school in the United States. We described our use of a community based participatory research approach, which is essential to ensuring that the game is tied to required curricular components, which we discovered was a prerequisite to teachers being able to employ the game in the classroom.

Through this pilot study, we have opened many possible avenues for future work. While we have focused to date on physical activity opportunities within the traditional school day, it should be straightforward to extend Project SMART to other physical activity opportunities, whether in active transit to and from school or in extracurricular activities like sports. We hope that by extending the scope of Project SMART outside of the walls of the school, we will be able to involve the broader school community, generating healthier and safer community environments.

The current Project SMART game relies on explicit student check-ins, in large part because the focus group of students emphasized that the public act of "checking in" was an important part of their participation. However, in the future, we will also explore more implicit ways of collecting and validating physical activities, for instance through wearable devices connected wirelessly to the game. To keep the kids involved, however, we plan to create a learning module. *within the game itself* wherein kids can design their own wearable activity monitors using low-cost computing kits. The goal is to achieve a full integration of physical activity with the STEAM (Science, Technology, Engineering, Art, and Math) curriculum.

Finally, the transition of the Spring 2020 school year to online learning has motivated us to investigate using Project SMART for remote learning and at-home engagement. We plan to create ways for kids and families to engage with the game and its content at home. All of these efforts are focused around the primary goal of Project SMART: to use innovative educational mechanisms to increase the physical activity of elementary aged children.

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