Project moveSMART: Integrating Physical Activity and Computer Science Learning in Elementary School Classrooms

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ABSTRACT

The Project moveSMART researcher-practitioner partnership (RPP) develops and delivers contextualized computer science and computational thinking (CS/CT) content in a Title I elementary school with a predominantly Hispanic student population. Project moveSMART is built around an educational game, designed to be played collaboratively by a fourth or fifth grade class, that integrates students' everyday physical activity with in-class academic learning. The class earns credit for physical activity in physical education, recess, or other in-school activities. The credit takes the form of distance traveled on a virtual journey along a physical route, and waypoints provide learning activities, including CS/CT activities that create new in-game features. For example, students program wearable activity monitors that become a physical activity data source for the game. Our experiences have surfaced multiple challenges that include pressures for all instruction to adhere to required standards, a lack of contextualization of CS/CT content, and unreliable at-home Internet that makes it difficult to reinforce lessons outside of school. By tying CS/CT to students' own physical activity, we address the dual problems of declining physical activity in children and a lack of contextualization of CS/CT content. To further address identified barriers, we co-designed game elements with classroom teachers to enable cross-curricular connections, including connecting CS/CT to language arts, cultural studies, music, etc. This paper will report on the structure of the RPP (which intentionally includes "specials" teachers like physical education teachers), the design of the game, and lessons learned in a first year pilot.

1 INTRODUCTION

Many efforts to integrate computational thinking and computer science in elementary education presuppose characteristics of school districts that may not be universally true. In this paper, we present the Project moveSMART effort, which is built around a researcher-practitioner partnership (RPP) that includes teachers from multiple schools and school districts to develop an educational learning platform that promotes both increased physical activity and computer science and computational thinking (CS/CT). The experiences reported in this paper highlight several challenges faced by school districts with traditionally underrepresented or underserved populations. In our preliminary work, we have elicited challenges that include the inability for teachers to integrate computing content that lies outside of a required curriculum, a lack of contextualization of computing material for students, and unreliable or unavailable at-home Internet infrastructure. These challenges coincide with more universal concerns about teachers' inexperience with and lack of confidence in computing material in general.

Project moveSMART and the associated RPP are part of Whole Communities Whole Health (WCWH) [21], a transdisciplinary research Grand Challenge launched by the Vice President for Research at the University of Texas. WCWH's guiding principle is the use of community engaged research, in which community members are involved in research from the outset: from defining research questions to designing and implementing solutions and analyzing results. For WCWH, the community consists of underserved children and families in eastern Travis county, Texas. For this project, therefore, the researcher-practitioner partnership includes researchers from the University of Texas and partner institutions as well as teachers, administrators, and children from the Del Valle Independent School District (DVISD). DVISD has 10,828 students, with 76% of the students rated as at risk of dropping out of school. More than 90% of DVISD students self-identify as ethnic minorities. Within DVISD, our initial partner school is Hornsby-Dunlap Elementary School (HDES). At HDES, 69% of the students are Hispanic, and 18.9% are African American. In the 2018-2019 school year, 27% of students met grade level expectations in science, and 42% met the expectations in math, with the school achieving a Texas Education Agency accountability rating of "C" [18]. The campus has been identified for targeted support and improvement. It is a Title 1 school, with high concentrations of poverty, as measured by the portion

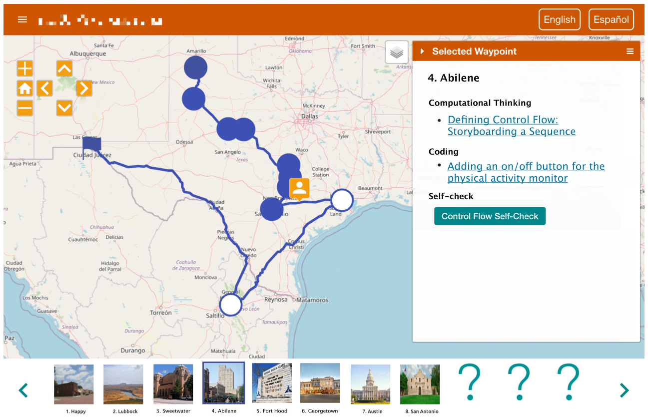

Figure 1: A Project moveSMART journey through Texas.

of students who receive free or reduced lunch. In a recent survey of 76 households in HDES, 80% reported that they had at-home access to the Internet, with only 65% having reliable, high speed access. In the households with access, 55% rely on a cell phone for connectivity. In contrast, the remainder of Travis County has 96% connectivity.

While students across all demographic groups express interest in learning computing, students from traditionally underserved groups, like those at Hornsby-Dunlap, often encounter structural barriers that limit access and exposure to computer science learning opportunities. They face social barriers as well, including stereotypes of who belongs in computer science and parents' and educators' beliefs that Black and Hispanic students are not as interested in pursuing CS [10, 20]. Given that the students in our community have very limited access to computers and the Internet in their homes, delivery of CS/CT material must occur during the traditional school day. While teachers at Hornsby-Dunlap Elementary are enthusiastically supportive of teaching computational thinking and computer science, their ability to add to the curriculum is constrained by the need to align with state accountability standards and to adhere to a provided curriculum. To address these challenges, we have forged connections with teachers, administrators, and students at Hornsby-Dunlap Elementary that have led to the partnership behind the Project moveSMART learning platform.

The foundation of the CS/CT content delivery within Project moveSMART occurs through a collaborative educational game that integrates physical activity into the academic curriculum. Project moveSMART exploits an open-source gamification framework [13] that has been deployed in smart city games around Europe [14]. Notably, this framework has been used to implement the KidsGoGreen game [6, 9], on which Project moveSMART is directly based. Project moveSMART has been designed to motivate lasting changes to kids' participation in physical activity, while simultaneously exploiting the known positive correlation between physical activity and academic achievement. Project moveSMART is designed to be played cooperatively by a single elementary school class that takes a virtual journey on a physical route (e.g., the current 4^{th} grade game follows a route through historical sites of Texas, see Figure 1). The class makes progress by earning "steps", which are explicitly tied to distance traveled on the route. Students earn their 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, cultural studies, language arts, and computer science and computational thinking) placed in the context of each waypoint. As examples of this contextualization, when in the panhandle of Texas, students may read the book *Sarah Plain and Tall* and respond to writing prompts about the worries facing people living on the plains. When traversing West Texas, the students may unlock a science lesson about the impacts of wind erosion.

The researchers and administrators and teachers at Hornsby-Dunlap Elementary school have worked together to design Project moveSMART so that it addresses the needs of the 4^{th} and 5^{th} grade teachers, is responsive to the district's required curriculum, and supports and promotes existing in-class instruction, including the addition of new CS/CT learning activities. In this paper, we first describe the Project moveSMART platform (Section 2), then we describe the nature of the RPP (Section 3). We then report on our initial experiences using Project moveSMART to deliver novel CS/CT content tied to physical activity in active elementary school classrooms (Section 4). We conclude in Section 5.

2 PROJECT MOVESMART – THE GAME

Project moveSMART is an educational "game", delivered as a web application, that is played cooperatively by elementary-aged students within a class. Each class embarks on a virtual journey through areas relevant to their educational objectives (e.g., a 5^{th} grade class that is studying American History moves through a route across America, while a 4^{th} grade class focused on Texas state history moves across the state of Texas). In the Project moveSMART game, students receive "steps" for participating in well-defined physical activity "events" during the school day (e.g., physical education class, recess, or physical activity in the classroom). Students log physical activity data by self reporting their activity level on a four-point scale ("more active", "active", "less active", and "inactive"), designated by the colors green, yellow, red, and white. These levels are based on self-reflection reports that elementary physical education teachers commonly employ. In the deployed game, 4^{th} and 5^{th} grade students can log their physical activity in one of two ways: (a) using the game's web portal or (b) through a "check-in" box that uses RFID proximity cards and a set of four colored buttons. In addition, a teacher can enter aggregate activity for the entire class. In all cases, the activity levels are converted to distances within the game and are aggregated for the whole class either at the end of each day, or upon completion of a class activity. This approach promotes autonomy for individual students, while fostering collaboration within each class.

Figure 2 shows the Project moveSMART check-in box, which contains a Raspberry Pi, an RFID reader, and four buttons. On the one hand, the use of the check-in box may hinder the scalability of the game. However, our focus group and pilot studies made it apparent that the box itself, including its transparent design, was essential to capturing and maintaining the interest of the students. The fact that the box is made with inexpensive off-the-shelf components tempers scalability concerns; it is also conceivable that, in

Figure 2: Check-in box.

Figure 3: Project SMART, entering activity data.

the future, creating the box could be framed as a CS/CT learning activity. A student activates the box with a proximity card and then presses a button that corresponds to their activity level. The selection is transferred to the game, which computes the distance credit. RFID check-ins can be anonymous or pseudonymous [8]; in the former case, a set of RFID cards is associated with the class, and a student may use any card to check in; in the latter case, each student checks in with 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 privacy. As students check in, 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.

Figure 3 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. The main screen shows the column chart for each activity, where each column represents the number of PA entries at a specific activity level. The inset in the figure 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. A math learning cue is shown after every class physical activity event is entered; this 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). When students hover over a bar in the graph, a tooltip appears that explains how the corresponding entries were converted to distance within the game. Teachers can use these data displays to guide lessons on representing fractions and decimals, multiplying with fractions and decimals, representing rate, and interpreting graphs—all of which are learning objectives for Texas 4^{th} and 5^{th} grade students [1]. By integrating relevant and explicit computation activities related to students' own physical activity, Project moveSMART introduces students to data analysis in a way that is personally relatable.

As a class travels along its journey, it unlocks "waypoints" that contain educational content and assessments that incorporate curricular material from across disciplines. Educational content can either be embedded within the game, or be provided through links to outside resources. This flexibility allows activities delivered through Project moveSMART to take on a variety of forms. For instance, we have co-constructed learning material with elementary school content experts to align with grade-level Texas Essential Knowledge and Skills (TEKS) and Common Core learning standards. Preliminary focus group data showed that aligning the content explicitly with the required curriculum is a prerequisite for using Project moveSMART in the classroom. We have also explored tying these learning objectives into CS/CT learning activities. In a pilot study, described in more detail in Section 4, an activity that guided students through the creation of a physical activity monitor was delivered through Project moveSMART. Links in unlocked waypoints directed students to a set of tutorials and an online coding environment. Each tutorial introduced students to a specific CS/CT concept (e.g., variables, conditional statements) while guiding them through the iterative construction of a pedometer. At the end of each tutorial, students completed short assessments within Project moveSMART to solidify their understanding of the topics they had been introduced to.

We have designed the game in a way that is very flexible; each classroom can have a separate deployment that incorporates diverse modules that can include content drawn from different requirements or standards. In a given game, modules can include content from all academic subjects or simply from a subset as determined by the teacher, and individual teachers can curate the content for their particular classes. A Project moveSMART 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.

3 PROJECT MOVESMART – THE RPP

From the inception of Project moveSMART, we have leveraged a *Community Engaged Research* (CEnR) [7] approach. CEnR is a paradigm that originated in the health sciences and transforms how research is conducted by giving voice to participants, focusing on social issues [17], acknowledging the uniqueness of vulnerable communities [4], and equitably incorporating all partners and their strengths [19]. In the model that we adopt, a community is defined as a unit that: (a) meets basic needs; (b) has a central social interaction; and (c) shares a symbolic identity [11]. 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 engaged research.

Project moveSMART undertakes CEnR at the intersection of computing and health, a domain to which this style of research has not yet been applied. However, there is a natural and obvious synergy between the application of the CEnR paradigm in a school and the creation of a researcher-practitioner partnership. Project moveSMART fundamentally integrates practitioners (i.e., elementary school teachers and administrators) with researchers; our initial aims were to increase physical activity levels of elementary schoolchildren by directly connecting physical activity with the academic curriculum. While physical activity was the initial target, the academic curriculum is the conduit because teachers need to justify the use of classroom time to achieve specific learning objectives. Similarly, promoting computer science and computational thinking (CS/CT) in elementary classrooms often takes a backseat to more traditional curricular subjects. Through the Project moveSMART platform, we therefore seek to address all three goals simultaneously: increase elementary schoolchildrens' physical activity levels, engage students in the academic curriculum, and provide an early integration of CS/CT in elementary learning. By integrating CS/CT into Project moveSMART, we present CS/CT curriculum in a way that increases students' academic engagement and learning of computer science and computational thinking by directly connecting the academic topics to students' physical activity. In this way, when CS/CT learning is the target, physical activity becomes the conduit.

Initially, our plan was to mimic the approach of KidsGoGreen [6] and encourage active transportation to and from school. In this conceptualization, students would use RFID badges to sign in and out at the beginning and end of a school day and indicate their utilization of active transport. However, through teacher and administrator focus groups, we discovered that our partner schools lacked the readiness to encourage active transportation since very few 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. Another school similarly 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. To additionally address the first administrator's concerns related to the use of RFID cards to checkin to the platform, we also designed pseudonymous support for checkins, even with RFID cards.

Based on these initial learnings, we co-created the current Project moveSMART learning platform alongside teachers and students. From students, we have learned that they desire individual credit as a behavior motivator even though they are energetic about the cooperative aspect of working together as a class on a larger goal. Throughout the effort, students have also shared creative ideas about game incentives and motivators, including earning avatars and avatar accessories. Students themselves have expressed a desire to have a physical mechanism to "check-in" and log their activity rather than having data be passively or implicitly collected. Most interestingly, students have 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, students that are part of the RPP have also 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.

As part of the Project moveSMART RPP, we have worked with elementary school teachers, including both classroom teachers and physical education teachers to create initial game-based journeys for 4^{th} and 5^{th} grades and to develop learning modules aligned with grade-level curricula. The RPP also includes K-12 CS/CT content experts, who have co-created the computing learning activities. As parf of the RPP, the teachers identify learning activities that align with and enrich the existing curriculum and guide how and when they integrate with the students' journey in the game so that the timing aligns with the curriculum. Given today's standards-based focus in schools, the teachers also requested that assessment data be collected and tracked within the game.

In a now more stable form, the partnership includes elementary school administrators, physical education teachers, 4^{th} and 5^{th} grade teachers, a K-12 computer science teacher, broadening participation in computing researchers, computer science researchers, and health education researchers. We have further collaborated with the 4^{th} and 5^{th} grade students themselves as well as with an expert in elementary education equity. The development of the Project moveSMART RPP has demonstrated that having individuals from each of these roles has been essential to the success of the project.

The school administration is necessary to ensure the project is able to navigate the district's needs and requirements and identify key resources. Classroom teachers are essential to establishing the grade level curricular integration and understanding how game play can and does intersect with day-to-day education in the classroom. Physical education teachers are necessary to understand and navigate the interplay between academics and physical education and to identify appropriate opportunities for physical activity, while the computer science teacher assists with connecting CS/CT educational activities to existing curricula. We have found that expertise in educational equity is essential in contextualizing the activities to ensure engagement of the students. On the research side, expertise in computer science and software engineering are necessary for ensuring the feasibility of the planned interventions, while expertise specific to broadening participation in computing is needed to help ensure proper contextualization of the CS/CT curriculum for the target demographic. Finally, research that combines physical activity and elementary pedagogy is necessary to leverage the interplay between academics and physical activity, which is the linchpin for Project moveSMART.

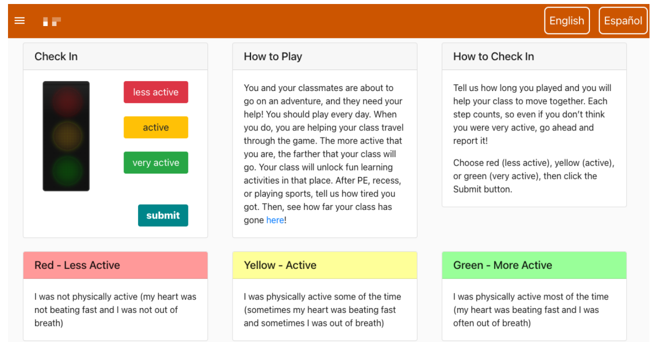

Figure 4: In-app messaging about check-in

4 PROJECT MOVESMART IN ACTION

Project moveSMART has three main goals: increasing students' physical activity, improving students' understanding of computer science and computational thinking (CS/CT) concepts, and delivering content that aligns with state educational standards. However, physical activity is a typically marginalized component of the curriculum, and Texas state educational standards do not dirctly address CS/CT. This makes accomplishing the first two goals difficult, because the effectiveness of Project moveSMART depends on teacher adoption and enthusiasm. Although students can interact with Project moveSMART independently, teachers play a key role by motivating students and integrating activities into curricula. Because teachers cannot justify dedicating classroom time to activities that do not meet state standards, all content delivered through Project moveSMART must align with these standards. Project moveSMART therefore addresses its three main goals simultaneously by integrating CS/CT concepts and student physical activity with content that aligns with state standards.

In this section, we describe first how we have incrementally refined the moveSMART platform based on interactions between the members of the researcher-practioner partnership. These refinements move the delivery of the game closer to simultaneously achieving the above three goals. Then we talk in depth about the CS/CT activities that are integrated into the moveSMART learning activities and report our initial results from our first deployment of the moveSMART platform in elementary school classrooms.

4.1 Game Refinements Based on the RPP

Interactions among the members of the rsearcher-practitioner partnership (RPP) have led to continuous enhancements of the Project moveSMART platform to improve accessibility for students and practicality for teachers. By integrating the voices of students, teachers, and a multidisciplinary research team, the RPP has facilitated the creation of a platform that is better able to address the needs of the end users and progress the goals of the project.

The subject matter experts and educational and computer science researchers of the RPP regularly meet to discuss the moveSMART platform and goals. These meetings have led to insights informing project development that might not have otherwise been discovered had the team been composed of individuals with similar areas of expertise. The educational researchers and subject matter experts of the RPP often identify in-game improvements that make Project moveSMART more accessible for students. For instance, through discussions with teachers, educational researchers identified the need to better support emerging readers. Even among the fourth and fifth grade audience of Project moveSMART, an assumption of fluent reading cannot be universally made. For instance, in our partner school, in 2019, 57% of students approached or exceeded grade-level standards in reading, leaving a significant number of students in need of additional support. To address this issue, developers optimized Project moveSMART for screen reader use and changed the content of the website and in-game activities using the Flesch-Kincaid readability test [15]. While the developers had the skill set to make these changes to Project moveSMART, they would not have been aware of these tools without the input of other members of the RPP. Members of the RPP also discussed the fact that 45% of the students in the school have limited English proficiency; for this reason, the platform has a switch to transition seamlessly between English and Spanish. Because RPP meetings are face-to-face, the developers of the moveSMART platform can respond with the feasibility and estimated time to completion of these features, and the team can prioritize effort for benefit. This improves the efficiency of the development process and makes it more likely that suggested improvements will be implemented because changes can quickly be discussed.

From the outset, physical education teachers have been part of the RPP. Through collaborations with these experts, we have designed the activity levels within the moveSMART platforms to mimic daily self-reflections that the PE teachers already asked students to do upon exiting PE. These reflections help students learn to think about their own physical activity and the intensity levels they should individually be achieving. We also worked with PE teachers to develop visual communication around the activity levels, including a poster that hangs in the elementary school gym and information included within the app's check-in page (see Figure 4). To help motivate the students to achieve high activity levels, we also worked with the PE teacher to implement class-level achievement badges, as shown in Figure 5. The PE teacher also created a bulletin board with space for each class to showcase the highest badge each class had earned. The goal of this display was to encourage a low-level of competition among the classes.

Finally, to prepare for the initial deployment, the members of the RPP collaborated to develop relationships among the researchers, administrators, teachers, and students throughout the school year. This includes classroom visits (both virtually and in person) to introduce the students to the Project moveSMART platform and the integration of physical activity with classroom learning activities. It showcased the universal buy-in for the platform by the school

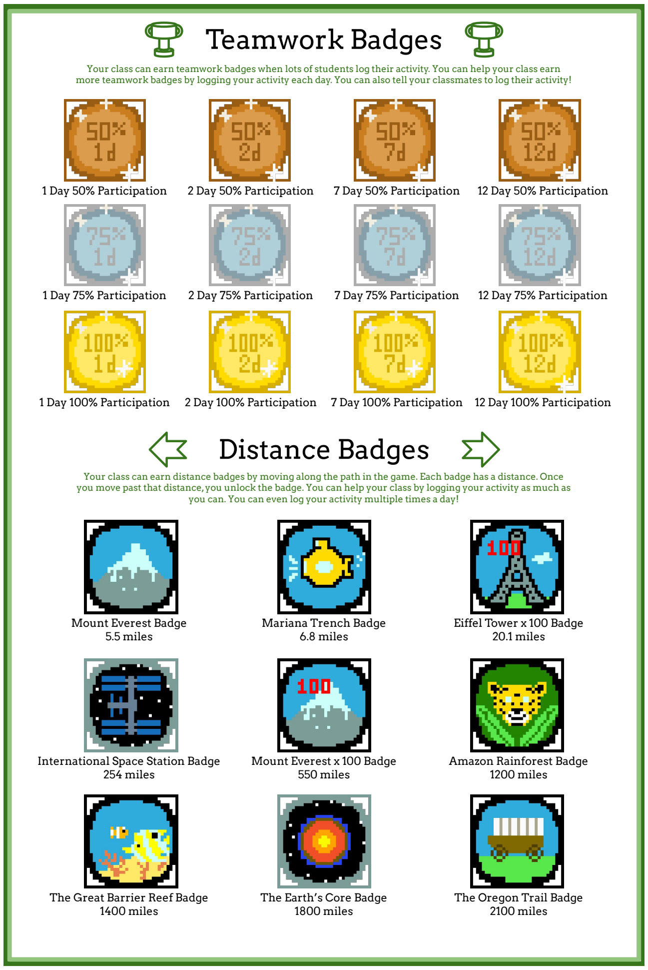

Figure 5: Poster used in the elementary school to display badges

and their teachers (including their physical education teacher), and it introduced the students to the research team in preparation for the pilot deployment. During these visits, the team led students through a physical activity and walked them through logging that activity in the Project moveSMART platform, including modeling how to self-reflect and assess their own physical activity intensity. These visits also gave students the opportunity to ask question about how the game worked and how it was developed, to seed their interest in the coming CS/CT learning activities.

4.2 Integrating CS/CT Content in moveSMART

We initially launched the moveSMART platform with an integration of physical activity and classroom learning activities tied to standards across the curriculum. However, since CS/CT is not a state learning standard in the state of Texas, we did not initially integrate CS/CT learning in the platform. As part of the effort of this RPP, we developed and piloted a series of learning activities through which students create their own wearable activity monitor and integrate its reports of sensed activity levels into the Project moveSMART game.

These learning activities rely on the BBC micro:bit [2], a small computer built for educational purposes. The micro:bit is equipped with accelerometers, 25 red LEDs, and two buttons, among other features. The CS/CT learning activities we designed for Project moveSMART are meant to be completed in succession, as each one builds upon concepts introduced in earlier activities.

Using the expertise within the Project moveSMART RPP, we connected each of the CS/CT learning activities to grade-level state-learning standards and to grade-level components of the K-12 Computer Science Framework [12], a set of guidelines used to develop computer science educational standards and curricula. The K-12 CS Framework consists of both *concepts* and *practices*. Practices describe behaviors and ways of thinking that are expected of computationally literate students. Concepts are the major computer science content areas that are relevant for computationally literate students. Concepts are divided into the core concepts: *Computing Systems*, *Networks and the Internet*, *Data and Analysis*, *Algorithms and Programming*, and *Impacts of Computing*. Each core concept is further delineated by subconcepts. For instance, the Computing Systems core concept includes the *Devices*, *Hardware and Software*, and *Troubleshooting* subconcepts. By completing the moveSMART educational content, block-coding exercises, and post-tutorial assessments associated with each of the learning activities, students can quickly build an understanding of fundamental CS/CT concepts.

In general, the learning activities each start by introducing students to relevant CS/CT content delivered through age-appropriate embedded videos, text, and examples. These materials were developed through the RPP by leveraging the expertise of elementary education researchers and practitioners. After viewing this educational content, students are routed to a walk-through in the Microsoft MakeCode platform [3], a coding environment in which students can use code blocks to create programs to run on a virtual micro:bit. As an example, Figure 6 shows an intermediate step of the second learning activity, which the students undertake after learning about accelerometers in general, and how the accelerometer on the micro:bit works. As you can see in the figure, MakeCode provides a playground in which the students can experiment. The MakeCode tutorial environment also allows us to embed "hints" (see the lightbulb near the top right of Figure 6). The moveSMART research team developed a dedicated set of tutorials for MakeCode, along with moveSMART programming abstractions that allow us to hide some of the complexities of programming, which the learning activities incrementally remove as the students' programming competence and confidence grow. As an example, in Figure 6, the students use the "show number of steps" block and the "increase step count" block from the "MoveSMART" tray in MakeCode. The reason for these abstractions, at this point in the curriculum is because the students have not yet been introduced to the concept of *variables*, which is introduced later in the learning activity. At the end of each walk-through, students can easily download their completed program onto a physical micro:bit to see their program in action.

To fully integrate the CS/CT learning activities with the moveSMART platform, we also developed in-app assessments. These were requested by the practitioners within the RPP for all learning activities in the game, but they were essential for the CS/CT activities because no other forms of assessment existed for these in the

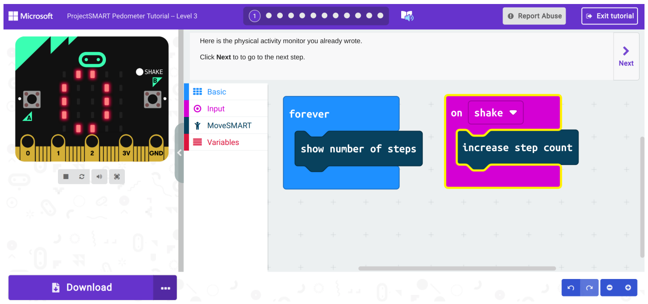

Figure 6: The second CS/CT learning activity in moveSMART, delivered through the MakeCode tutorial platform

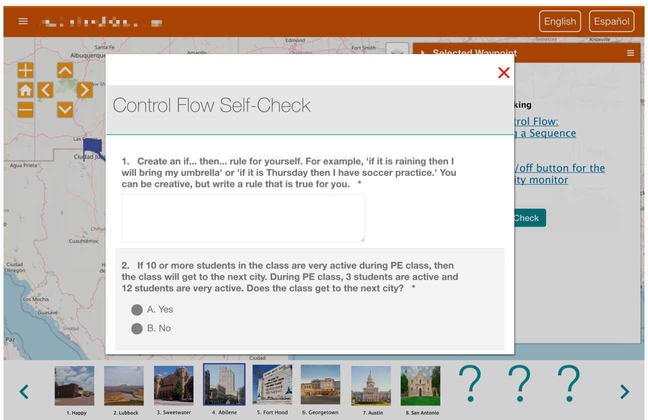

Figure 7: An assessment embedded into the moveSMART platform

curriculum. These assessments integrate concepts learned during the CS/CT activities with concepts that align with state learning standards. We also leveraged the assessments implementation for evaluating the research itself, as described in greater detail below. Figure 7 shows an example of these assessments integrated into the game, in particular the assessment that follows the fourth learning activity, which introduces the students to control flow. Additionally, students used the products of their CS/CT learning activities to complete physical activity related tasks.

Below, we overview the seven CS/CT learning activities we have designed for the game. To date, we have identified these seven activities and we have integrated the first five into the moveSMART learning platform, including defining and integrating assessments associated with them. In addition, as described in more detail below, we have piloted the first two learning activities in our partner elementary school during the 2020-2021 academic year.[1]

Learning Activity 1: Introduction. The first learning activity acclimates the students to the micro:bit and MakeCode environment and guides them through creating a timer. When the timer is complete, the students work in pairs to time how long it takes each of them to complete a *Trail Making Test* [16], a cognitive flexibility measure.

Learning Activity 2: Sensing. In the second learning activity, we introduce the students to the concept of sensing, as the students create a step counter that uses the micro:bit accelerometer. Students then use the step counter to measure their physical activity during a collaborative game.

Learning Activity 3: Variables. The third learning activity introduces the concept of variables and guides students through refactoring their step counter program to use variables to store information.

Learning Activity 4: Control Flow. This learning activity introduces students to the importance of sequence and control flow in computing and connects this concept to the importance of sequence and logical flow in reading and writing. During this activity, students refine their step counter to include an on-off button.

Learning Activity 5: Rate. This learning activity introduces the concept of rate, independent of any CS/CT concepts. Students then refine their step counter even further to calculate and display their step rate by dividing the number of steps counted by the time elapsed since a button press.

Learning Activity 6: Complex Conditionals. This activity starts with a physical education lesson that demonstrates the relationship between rate and physical activity intensity. The students then refine their activity monitor to map their step rate onto a moveSMART activity level (i.e., the red, yellow, and green in Figure 4).

Learning Activity 7: Communication. In the final learning activity, the students change the Project moveSMART game itself. Rather than checking in to log their activity either with an RFID card or with using the web-based checkin, the students use a radio link to send their activity level to the checkin box shown in Figure 2.

4.3 Initial moveSMART Pilot

In the final week of the 2020-2021 academic year, we added the first five CS/CT learning activities to our active moveSMART deployment at Hornsby-Dunlap Elementary School and made them available to two 4^{th} grade classes and the entire 5^{th} grade. We joined the classes in person for their physical education lesson and guided them through the learning activities. Students worked on the CS/CT activities in pairs during a 50 minute class period. While progressing through the tutorials, students could ask teachers and the other RPP members in attendance for assistance. We worked with the two fourth grade classes in person on the first day, though because of the COVID-19 pandemic, only 9 4^{th} grade students were in attendance in person. One member of the research team engaged the virtually connected students via the remote learning platform, but they did not complete the activities with a physical micro:bit. After the visit to the fourth grade generated excitement in the school, we worked with the entire 5^{th} grade on the second day. The 4^{th} graders had been engaging with the moveSMART platform throughout the school year, so they could easily navigate the login process and were familiar with the map and navigating the website. The 5^{th} grade students had no previous exposure to the moveSMART platform.

[1]Because of significant changes to elementary instruction in 2020-2021 due to the COVID-19 pandemic, most of our interactions with the elementary school were via virtual channels. However, in the last week of the school year, we did have one class period each with the 4^{th} and 5^{th} grade classes, where we piloted the CS/CT learning activities, with real micro:bit devices and the in-game assessments.

As a result, most of the 4^{th} grade students completed the first two CS/CT learning activities. In contrast, most, but not all, of the 5^{th} grade students completed the first CS/CT learning activity. None of the 5^{th} grade students completed the second CS/CT learning activity.

Based on these interactions and our experiences engaging these students with moveSMART throughout the school year, we made the following observations: (1) even a short intervention using the micro:bit-based learning activities has the potential to improve students' coding attitudes and (2) incremental deployment of features helped maintain engagement. Further, because the micro:bit tutorials also include physical activity components and concepts that align with state learning standards, they could be easily integrated into teachers' curricula.

Importantly, we also received feedback from the teachers with respect to the learning activities. One teacher (a physical education teacher) told us: "Initially, I thought, computer science in elementary school, it doesn't matter. After watching [the students] doing it, I was fascinated with how much they loved this activity. They initially didn't think they were capable of doing it. They had so much fun, this opened their minds to doing computer science and they really believed in themselves."

4.4 moveSMART Professional Development

A significant part of the RPP is the creation of professional development (PD) programs centered around Project moveSMART. In our initial work with elementary school teachers, we found them eager to introduce CS/CT concepts in their classrooms, but reticent to do so, primarily because of a lack of their own confidence in the material. For instance, when we asked teachers what their biggest fears about integrating CS/CT content in their classrooms were, they shared fears centered on potential technical hangups and their own (lack of) confidence in CS/CT material. For instance, one teacher characterized their fear as "comprehending enough to be able to explain it to the students", while another expressed a similar fear as "not being able to answer all of the questions". A physical education teacher expressed that they didn't want to "sacrifice skill development for a math lesson", while a classroom teacher expressed a fear of "incorporating stuff that's not in the curriculum". Therefore, the professional development sessions were designed to bolster teachers' capacity, capability, and confidence to integrate CS/CT content in the elementary school classroom in a way that dovetails rather than interferes with the regular curriculum, including the regular physical education curriculum.

Professional Development Session 1. The first of our PD sessions were hosted (virtually) in Summer 2021 across two sessions. Both sessions involved 9 participating teachers from three school districts; 6 teachers participated in both sessions. In the first session, the content focused primarily on demonstrating how to introduce CS/CT content while reinforcing the regular classroom instruction and encouraging physical activity. We presented two examples of learning activities that bring together the three principles of the Project moveSMART approach:

Activity 1. We had the participants play a modified version of the class CS Unplugged Battleship game[2]. However, rather than playing a generic version of battleship, we reframed the activity around a different 5^{th} grade learning standard: learning about explorers who visited the United States. In this activity, the students learn through gameplay about the importance of algorithmic thinking when searching and sorting. As part of the exercise with the teachers, we discussed other ways to contextualize the activity within their curriculum, including connecting to ordering relations in mathematics or to Native American tribes along the Texas/Mexico border.

Activity 2. We introduced the participants to the CS concept of conditional statements and to the importance of sequence in computing. We then asked them to create a conditional statement describing their own participation in physical activity (e.g., "**if** it is Tuesday **then** I will have soccer practice" or "**if** I run for exercise **then** I will drink more water"). Based on these starter sentences, the participants were then challenged to write a story, with details, and represent it in a six-frame storyboard. They were then asked to think about the importance of sequence in their story and then create a "buggy" version of the story by mixing up the frames. As a large group, we "debugged" the story by putting the frames back in order.

To present the learning activities, we used a variety of content, from short child-friendly video clips, brief descriptions at an elementary reading level, and guided instruction. The first activity involved the participants *being* physically active, while the second activity involved the participants *reflecting* on being physically active. Both were directly connected to grade-level state learning standards; in the first activity, the focus was on cultural studies, while the second focused on reading and writing.

After each activity, the PD session held time for discussion among the participants about how the activity could be incorporated into their classrooms, providing opportunities for peer learning and bolstering the teacher participants' confidence.

Professional Development Session 2. The second Summer 2021 professional development session was specifically focused on helping the teachers grow more comfortable and confident with the micro:bit platform. Because of the COVID-19 pandemic, the session was held remotely, but we shipped each participant a micro:bit device ahead of time. Prior to the activities, we opened the session with a group discussion about how their students can benefit from CS/CT instruction and the ways in which they already integrate some aspects of CS/CT. One of the classroom teachers told us "The kids in the demographic at our school, they don't get a lot of exposure to computer programming and the things that they can do. I've used animation in my class and coding with scratch" and that coding helped demonstrate to students "why it is important for story telling in a sequence and to be able to recall information or retell stories in a sequence." A physical education teacher relayed integrating technology in PE class, saying "I used a heart monitor and projected their activity into the gym, including the target heart rates they were shooting for, and gave them feedback on it. This seemed to especially really get girls involved and moving more." The same teacher expressed a struggle faced as well, saying "I also emailed parents about how and what [their students] were doing.

[2]https://classic.csunplugged.org/searching-algorithms/

This helped parents get involved in caring about PE, but the biggest thing we fight in our district is Internet access."

These discussion fortified the community-based approach of the Whole Communities–Whole Health effort that Project moveSMART is a part of, and the importance of integrating CS/CT instruction in the regular school day rather than relying on extracurricular activities.

After this opening, the session moved into the activities:

Activity 1. We started with the classically silly *Robot: Make me a Sandwich* activity[3] as a simple ice breaker to get everyone thinking about computer programs as instructions in sequence. After this, the participants discussed the many ways in which sequence is important for the classrooms. One teacher observed that there are many such sequences in our lives: "cooking, getting ready in the morning, all kinds of daily activities that we don't even think about" and the physical education teachers in the room discussed the importance of sequences of steps in skill development like dribbling and throwing.

Activity 2. For the first programming activity within this session, we had the teachers complete the second learning activity in the moveSMART game itself, i.e., they followed the tutorial instructing them on using the micro:bit to make a timer. Once everyone had completed the timer, we shared the idea of having the students use the timer for activities in class and asked the teachers how they thought it might be useful. One teacher shared that the students have a list of 1000 sight words to learn; the students could use the timer while working in pairs to time how fast they could get through a partial list. Another teacher expounded that the students could also make another program that counted when the button was pressed, and the students could use a second micro:bit to count how many of the words they got correct. The physical education teachers immediately recognized the potential to use the student-built timers for pieces of the FitnessGram [22], in particular for the PACER test. Finally, several teachers wondered about using the approach to create countdown timers to help students with focus and periodic breaks, to help with social emotional learning and classroom management.

Activity 3. In the third activity, the teachers extended their approach to build the basic step counter using the micro:bit (which is analogous to learning activity 3 above).

At the conclusion of the session, the teachers again reflected on their experiences. We challenged them to continue working with the devices and shared additional grade-level appropriate resources for them to explore CS/CT concepts on their own. In the closing informal discussion, one teacher, whose class is a dual-language English-Spanish fifth grade class, wondered constructively about ways the CS/CT content could be tied into reading and writing, in particular to reading comprehension. This teacher explicitly focused in on the connection for the attention to detail in sequences from the peanut butter and jelly sandwich activity as a starting point.

[3]https://www.scientificamerican.com/article/robot-make-me-a-sandwich/

4.5 Looking Forward: the Future of the RPP

In the past, interactions between members of the RPP have directly informed design decisions within the Project moveSMART platform. This is a continual process, and more recent interactions between RPP members have led to insights into ways to further improve accessibility and usability. In addition to the feedback from all RPP members, during the deployment of the five micro:bit tutorials in the 4^{th} and 5^{th} grade classes, we were able to observe students' interactions with Project moveSMART. These observations allowed us to identify specific problems that hampered student progress. Currently we are working on addressing these problems by implementing new features.

Many students, especially those who had not interacted with Project moveSMART to a great extent, had trouble logging in because they could not remember (or did not know) their moveSMART-specific username or password. To address this, throughout Summer 2021, we have implemented single sign-on authentication using ClassLink Launchpad [5], which the students and teachers in our partner school district already use to access many digital learning resources. This integration allows a smooth login process for all students in Project moveSMART.

As students completed micro:bit based CS/CT learning activities, some were confused after clicking links that led them to outside educational resources. Additionally, some students had difficulty returning to Project moveSMART once routed to an external resource, or would continue to explore links within the outside resource instead of returning. For instance, students would continue to watch recommended videos after finishing a YouTube video included within a CS/CT learning activity. To minimize this, we added functionality that allows embedding most learning content directly within the game. Now, students can access external content such as Google Docs or YouTube videos without having to leave the Project moveSMART page. Instead, these resources appear in a modal that is overlaid on the moveSMART map page. Additionally, we disabled video recommendations within embedded YouTube videos.

We also observed that some students had difficulty reading and understanding content during the delivery of the micro:bit tutorials, despite our previous efforts to address student comprehension concerns, e.g., by optimizing the platform for screen reader use and rewriting content to have grade-level appropriate readability. In the future, we will explore improving accessibility by including audio aids within the Project moveSMART platform.

5 CONCLUSION

This paper presented the first report on the workings of the Project moveSMART Researcher-Practitioner Partnership (RPP). This partnership was designed around an existing learning platform that combined physical activity with standards-aligned classroom learning for 4^{th} and 5^{th} grade students. Through the RPP we have both developed deeper relationships among the practitioners and researchers and meaningfully integrated computer science and computational thinking (CS/CT) activities. Based on preliminary feedback from teachers and our observations from a small initial pilot, we hypothesize that this three-way integration of core curricular content, physical activity, and CS/CT learning will provide emphasis and engagement across all three areas of learning. The partnership continued to grow even through the COVID-19 ravaged 2020-2021 academic year, with virtual engagement among all of the RPP partners, including the elementary school students. The team completed a small pilot of the three-part moveSMART platform, with valuable pilot feedback for refinement in the summer. The team further prepared for a full roll-out through summer professional development sessions that elicited important insights and directions from the practicing teachers and opportunities for the researchers to support the teachers' growth in competence and confidence in teaching CS/CT. These efforts situate the RPP team for a full deployment in the (in-person) 2021-2022 academic year.

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