PE++: Exploring Opportunities for Connecting Computer Science and Physical Education in Elementary School

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ABSTRACT

Around the world, many K-12 school systems are seeking ways to provide youth with computer science (CS) learning experiences. Often organizations aim to develop these opportunities by building capacity among science, technology, engineering, and mathematics teachers. In other instances, school may engage with language arts, history, and library teachers to teach computer science content. Seldom, however, do schools leverage the rich opportunities for integrating computer science with physical education (PE). This paper explores an on-going partnership among university researchers, and elementary school coding and PE teachers. During spring of 2021, the group designed and tested coding and physical movement related activities for students to complete across their PE and coding classes. The team iterated on those activities throughout 2021 and 2022. This paper highlights the utility of this unique collaboration and describes some of the initial designs that emerged. The paper also touches on preliminary evaluation of the activities, and notes some of the project team's plans for future iterations. Broadly speaking, the activities piqued student interest and helped advance new perspectives of themselves, CS, and their teachers.

CCS CONCEPTS

• **Applied computing** → Education; Interactive learning environments; • **Human-centered computing**;

KEYWORDS

Computing Education, Research-Practice Partnership, Sports, Sensors, Physical Computing

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1 INTRODUCTION

For many of us, science, technology, engineering, and mathematics (STEM) are the first topic areas that come to mind when we think about overlaps with computer science. Given the uses of algorithms, the engineering design process, and the types of mathematical expressions utilized in computer science (CS) this is quite logical [15]. Moreover, researchers in the CT-STEM [11, 17] project, for example, have found that integrating computer science instruction into existing STEM courses serves as a tractable way to ensure that more students gain exposure to CS, especially in instances where there is a shortage of teachers and/or limited time in the calendar to add CS-related electives. However, our inclination to primarily see CS as tied to STEM may cause us to overlook some additional opportunities to address the existing CS teacher shortage and the need to help youth see the broader applications and implications of computer science [5, 10, 16]. Hence, this paper describes on-going work to integrate computer science and physical education. Within this paper, we are particularly interested in answering two research questions. 1) What types of activities does a team of coding and physical education teachers create to help students experience connections between PE and coding? 2) In what ways do these activities support different forms of engagement and changes in perceptions among youth?

This paper describes our research-practice-partnership, some of the activities that we have developed to date, preliminary evaluations of student engagement, and some of the challenges that we are encountering. Before moving into a description of the curricular activities, we will touch on some pertinent prior work that informs this project.

2 PRIOR WORK

2.1 Culturally Responsive Computing

A driving motivation for this work is the need to develop learning experiences that center non-dominant cultural practices and identities. Furthermore, culturally responsive (and sustaining) pedagogies [7, 13, 14] highlight the importance of using computer science to advance aims and learning outside of computer science. In the current project, we position sports culture and the sports community as being scarcely represented within the computer science community. Moreover, we incorporate CS with the goal of improving youth and teacher experiences in physical education alongside goals of helping them develop computer science skills and competencies. Hence, we build on prior principles and practices from culturally responsive computing to develop experiences that center sports identities.

2.2 Sports Wearables and Learning

Significant prior research in the learning sciences and computer science has demonstrated the potential for effective learning experiences that bridge sports and computing [2, 8, 9, 12, 18]. For example, Lee et al. [8, 9] identified ways that elementary school students demonstrate inquiry alongside learning with wearables. Their work involves students using fitness trackers, heart rate monitors, and hip-based step counters while participating in athletic

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activities during recess. By analyzing user behaviors, researchers surfaced ways that the experience helped students create narratives around the data and supported them as they investigated personally motivating questions. The analyses also highlight ways that students developed and practiced data cleaning, data analysis, and question generation. Accordingly, this project builds on prior work that suggests using sports wearables can be generative for young learners.

Ching et al. [3] describes complementary work that examines emergent critiques that result from student participation with a virtual game that is based on student pedometer data. Students expressed concerns about bias in the type of physical activity that was being rewarded, and discontent over general device inaccuracy. Additionally, the long-term engagement with the wearables and the game provided a useful context for students to formulate concrete examples for describing otherwise abstract ideas. The current project similarly asks students to think critically about data, and advocates for long term engagement through a variety of activities.

More recent work by Jones, Thompson, and Worsley [6] was also influential in articulating opportunities that bridge sports and technology. Their program, Data in Motion, involved youth completing a combination of structured and free-form activities using physical computing. After a one-week program youth showed an increased awareness of the relevance of computing in sports. Students also ideated ways to utilize wearables within youth sport contexts. Different from their program which researchers facilitated and took place during a summer program, the current paper describes activities co-designed and implemented by teachers as part of an in-school learning experience.

In summary, prior research has pointed to potential synergies between sports and computer science. This paper builds on these potentialities as instantiated in physical education and coding classes for elementary school students.

3 SPORTSENSE PRELIMINARY MODULES

We call the program SportSense because it merges physical activity with physical computing. During fall 2020, the research team developed a set of learning activities for middle school students in an out-of-school context. Those six modules were tested and iterated upon in early winter 2021. In preparation for the collaborative work, the research team shared the six-module curriculum with the teachers to surface possible learning activities that bridge sports and computer science. The first module, the 'Power of Sensors,' introduces youth to electrical sensors by highlighting ways that human senses inspired many of the technological sensors currently in use. By using this as a starting point, youth begin their journey into sensors from a more familiar context, and in a way that positions their bodies and prior experiences as valuable. The curriculum then moves into a unit on wearable technologies, called the 'Promise of Wearables.' During this module, youth learn about ways that professional athletes use technology to measure and enhance their athletic performance. The unit includes a collection of videos about common sports technologies (e.g., Catapult GPS wearable, STATSports Performance Vest, and UNO Playermaker) and how those devices are used in different sports. Students are also introduced to a low-cost motion tracker (Moov Now) that they test and critique before using a programmable motion tracker (BBC micro:bit). One of the micro:bit activities involves replicating some of the functionality of the Moov Now motion tracker and ideating ways to improve its utility. The third module, 'Take off That Silly Watch,' exposes youth to computer vision. Students learn about wearable-free technologies that can track and analyze their movements. Students test some existing commercial applications that use computer vision and learn how to replicate one or more of those applications in the Scratch programming environment. In particular, the module walks them through the creation of a reaction time game that was inspired by the Homecourt.ai basketball training app. The fourth unit, 'Designers Wanted,' highlights different strategies for brainstorming new technologies and features several videos about sports-related technologies developed and used by women of color. These examples help students see a broader set of applications of computer science in sports. They also showcase the diverse individuals who design innovative technologies. Furthermore, the showcased technologies also make evident that each student has an important contribution that they can make to the technology design space. The fifth module, 'Limitations with Wearables and Sensors,' discusses ways to hack sensors and the ethical implications of surveillance technologies. Students complete activities where they try to hide from facial recognition technology and discuss ways that this technology is used to criminalize Black people. The sixth and final module, 'Design Your Future,' supports youth as they innovate and build their own sports wearable prototypes using the micro:bit or Scratch.

4 THE EVOLUTION OF SPORTSENSE IN SCHOOLS

As previously noted, we initially designed SportSense for middle school youth in an out-of-school context. However, the current partnership involves elementary school students in an in-school context. Hence, from February 2021 through August 2021, the researchers worked with four physical education teachers and two coding teachers to bring SportSense to their classrooms. Collectively, the six teachers are responsible for teaching coding and PE classes at three elementary schools. For this paper, we are focusing on fifth grade students at two schools, which include approximately 120 students. One of the schools is a Title 1 school, while the other is not. The Title 1 designation is for schools where more than 40 percent of the families are low-income. From February until June, the team met two to three times per month to discuss, test, and reflect on preliminary testing of the 'Take off That Silly Watch' activity. At the end of June, the team participated in a focused week and a half long summer intensive. During that summer session, the team explored some of the other SportSense modules, tested out additional technologies, and began developing the core set of activities to be completed during the academic year. In September 2021, the teachers began implementing SportSense activities in their classes. Throughout the academic year, the research team and teachers have continued to meet on a regular basis and collaboratively make changes and additions to the learning activities. The team has developed an extended set of activities that connect with the core

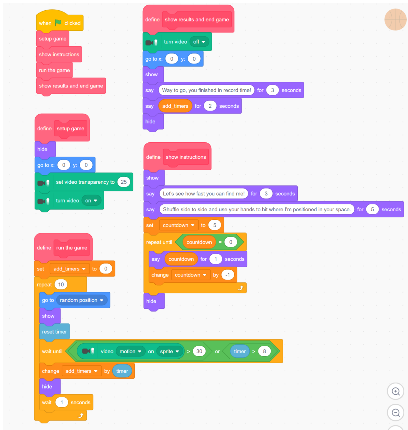

Figure 1: Scratch code for long version of 'Take Off that Silly Watch' module

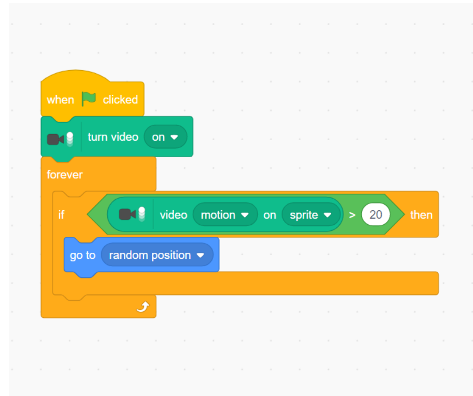

Figure 2: Scratch code of simplified 'Take Off that Silly Watch' activity

concepts described in the initial SportSense modules. In the section to follow, this paper highlights four iterations of programming associated with the 'Take off That Silly Watch' module.

4.1 Adapting 'Take off That Silly Watch' to Coding Class and Physical Education

The first goal for the research-practice partnership team was to facilitate some initial explorations into a combined PE and coding experience for elementary school students and teachers. The research team shared the existing SportSense activities with the elementary school teachers to surface initial activity possibilities. Upon learning about the example modules and influenced by the realities of COVID-19, which limited teacher ability to easily distribute and troubleshoot wearable technologies, we elected to develop a set of activities around the 'Take off That Silly Watch' module. In this module, youth create an interactive game where basketballs appear in random locations on the screen and go away after the program detects player motion near the location of the ball on the screen. The game uses the computer's camera and the optical flow implementation in Scratch's Video Sensing extension to support interactivity.

To begin, the coding teachers took the existing out-of-school module and converted it into content for two class sessions. Each session consisted of step-by-step instructions that were analogous to the tutorials that students completed in Tynker, a popular youth coding platform. The teacher-developed instructions also included questions that asked students to think about what different blocks contributed to the operation of the interactive game. Teachers planned for the execution of the activity to require two class sessions for coding and one class session for youth to test their classmates' designs and provide feedback. For many students, this time allocation was sufficient for them to create the basic functionality of the game and add customizations that reflected their individual personalities and interests. For instance, many students elected to change the initial background and add music. However, for other students this activity proved to be daunting. This motivated us to help students build a simplified version of the interactive game.

4.2 A Simplified Version

While some students experienced success with the first version of the activity (see Figure 1), some students found it to be overwhelming. Those students experienced significant difficulty following how the program worked. Additionally, several students missed the first session, which made it challenging for the teachers to support them during the second session. In response to these needs, the team developed a reduced version of the interactive game (see Figure 2). The initial version included instructions for the player, the player's final score, and various inspirational messages. In the simplified version, the primary objective was for youth to program the game's base functionality. This included a ball appearing randomly on the screen, and having that ball move to a different location any time the player-generated movement near the location of the ball. We anticipated that this reduced version would take 20 minutes or less to complete. During the second session, students selected which version of the game they preferred to complete. Several of the students chose the long form version, while approximately one-third of the students chose the reduced version of the game. Both the long and short versions of the game were then shared and tested within the students' PE classes. During those PE-based sessions, students completed short feedback forms about possible modifications to the game. This practice of critiquing computational artifacts and getting feedback from peers [4, 15] is one example of computational thinking practices taken up in PE class sessions. Teachers reported students from both design groups being equally excited about their completed interactive games. While this game was motivated by the Homecourt basketball app, the next section describes a programming challenge inspired and developed by a PE teacher.

4.3 Juggling Challenge

One of the partner schools implemented the Scratch activities one week earlier than the other school. To get the groups' schedules re-aligned, one of the PE teachers developed an additional activity for their students. Within that school, students had recently completed a unit on juggling. For this reason, the PE teacher decided to start making an interactive juggling game (see Figure 3). This first

Figure 3: Screenshot of the teacher created juggling game

began as a way for the teacher to develop more hands-on experience with motion detection games in Scratch, but later served as a starting point for student debugging and coding practice. The PE teacher's version of the juggling game asked students to use their mouse (or finger) to keep three balls from falling to the ground. The coding teacher presented this initial version of the game to the students and shared that the PE teacher was interested in getting some help from the students. The teacher suggested several modifications that students might consider. Some of the suggested enhancements included keeping score and having the game reset if a ball ever reaches the bottom of the screen. Students spent the class period remixing the PE teacher's juggling game. At the conclusion of the class session some of the students shared their designs with the class. They also shared them with the PE teacher in their subsequent class sessions. This juggling challenge provides clear integration with the existing PE curriculum. The next, and final, design activity represents another way for using student-designed interactive games in PE.

4.4 Warm-up Games

Near the conclusion of the spring pilot, and during our summer teacher intensive, one of the PE teachers noted an opportunity for youth to design interactive warm-up activities using Scratch. The PE classes previously utilized online videos or random activity selectors to do warm-ups. These activities might include jumping jacks, push-ups, and stretching, for example. Upon learning about the capabilities of Scratch as a platform for creating interactive gesture and pose-based games, the teachers decided that they would invite youth to create warm-up activities that use some of the computer vision capabilities students explored in the 'Take off That Silly Watch' activity. Teachers implemented this lesson during the first semester of the academic year and described being extremely pleased with the high level of engagement, excitement, and creativity that students brought to their warm-up activities. Additionally, teachers have decided that for the foreseeable future, these PE integrated activities will replace their previous Scratch curriculum.

5 PRELIMINARY EVALUATION

The research team has identified some notable observations. These preliminary findings are based on discussions with the teachers, virtual visits to classroom sessions, and initial analysis of student-created Scratch projects from throughout the two calendar years. Our ongoing analysis involves examining the different computational thinking concepts, practices, and perceptions [1] that are evidenced within student projects. However, the focus of these initial findings will center around youth engagement and perceptions. This paper highlights three focal observations: engagement among previously disengaged youth, students gaining confidence in their coding, and participants seeing their teachers in a different light.

5.1 Fostering youth engagement

Two interesting observations were made while looking through student-created Scratch projects from the past two years. First, within the set of activities students completed before doing the 'Take off That Silly Watch' activity, many students included sports-related sprites. These appeared in many projects where students were introducing themselves to their peers. This, therefore, signals that several students recognize their interest in sports, and are willing to bring that identity to their coding class. Second, for some students, their SportSense projects were the only Scratch coding projects they completed the entire year. This was certainly not the case for all the participants but was noticeable for multiple students. This increased engagement aligns with teacher observations that the 'Take off That Silly Watch' activity was the first time some students turned on their cameras and/or did a screen share in Zoom. Beyond instances of increased engagement, teachers also noticed differences in how students engaged in coding and PE class. For example, one student described sweating for the first time ever in coding class. Other teachers noticed the ways that students were trying to hack, or trick, sports hardware and software in PE class. Collectively, these preliminary observations point to ways that the designed activities supported new and different forms of youth engagement.

5.2 I never knew I could make something like this

In addition to seeing preliminary instances of youth engagement with the activities, there were also indications of students realizing new levels of agency. For example, shortly after completing the 'Take off That Silly Watch' inspired Scratch project, one student shared that "he never knew that he could make something like this." Embedded in this statement are shifts in how the students see themselves, the relative accessibility of some programming platforms, and the rich interactivity of what they created. Other students similarly expressed surprise and delight at their ability to create interactive games that their peers found to be enjoyable. This was particularly the case with the warm-up games that students created and tested in PE with their teachers and peers. In a similar vein, students also realized new opportunities to create physical movement-based games and took steps to include video sensing into other Scratch projects that they created. These examples suggest notable shifts in student perceptions of themselves and of coding.

5.3 Coding teacher gets the high score??!!

In addition to shifting perceptions of themselves and computing, some student actions indicated shifts in their perceptions of their teachers. In the case of coding, teachers would occasionally participate in testing some of the student-created games and other sports technologies. In a few of these situations, the teacher, a woman, produced the highest score among everyone in the class. This was particularly startling to some of the boys who expressed disbelief at being beaten in an athletic activity by their coding teacher. Within PE class, students started to engage their teachers in conversations about technology and coding. While some initially expressed surprise that a PE teacher had created the juggling game, for example, the experiences facilitated students engaging with their PE teachers in new ways. This is something that the team is particularly keen to explore further while also looking at changes in teacher self-perceptions.

It is difficult to capture and describe the full extent of shifts the students displayed. This is an area of ongoing analysis. As one final indication that the program is being well received by students and teachers, the district plans to incorporate SportSense activities across the fifth-grade curriculum in the coming year.

6 DISCUSSION

Individually and collectively, the four iterations of learning activities described above point to some important implications, opportunities, and challenges. First, looking at the initial adaptation of the 'Take off That Silly Watch' activity, and its subsequent simplified version, is a good reminder of the need for differentiation. This is especially important as we think about bringing computer science into a space that normally falls outside of the broader STEM domain. Some students may view physical education class as a chance to detach from the traditional academic language and activities present in mathematics, science, and history classes, for example. For some students, trying to build the initial version of the Scratch game was overwhelming, but by quickly adapting the experience we were able to maintain the goal of having them develop familiarity and awareness of computer vision technology. Notwithstanding, after completing the shorter version, some students became interested in returning to the longer version. Planning for this tension is important to consider.

The Juggling Game is a strong example of how to authentically integrate coding into the existing physical education curriculum. Moreover, it offered a prime example of how ingenuity on the part of a physical education teacher can support meaningful and engaging coding experiences among youth. Hence, the model of building on PE teacher knowledge and experience is one that can be generative for advancing novel activities that bridge CS and PE.

Finally, the warm-up activities highlight the potential for youth to use coding to design of their own learning environments. Instead of using recorded, non-interactive, web-based content for their warm-up activities in PE, they can use appropriately designed tools, like Scratch, together with some basic computer vision, to develop more engaging and locally relevant warm-up activities.

These implications, however, were not without their challenges. First, the amount of time needed to train physical education teachers in introductory coding and computational thinking is a significant undertaking. The summer intensive provided an entry point into the space, but is not sufficient, in and of itself, to prepare the PE teachers to lead this work. Instead, both the evolution of the experiences and the ongoing support that they receive is a clear indication that embarking on this approach requires a considerable time investment. One way to reduce the need for this level of in-service training is to incorporate computational thinking and coding experiences within teacher pre-service training.

Relatedly, enacting relevant assessments can also be difficult within combined computer science and physical education contexts. Throughout this research-practice partnership, we are exploring the different academic standards used within each of the respective areas. We are in the process of developing a combined set of standards each group of teachers can use to document the computer science learning that students might exhibit in PE and the PE competencies that students might exhibit in their coding classroom. The research team's ongoing analysis will assist with this.

Finally, conducting this type of work can introduce physical and technological infrastructure challenges. Physical education classes often take place within a gymnasium, and teachers seldom have more traditional classroom spaces in which to lead the types of instruction frequently found in coding classes. For PE teachers in our group, this meant not having access to appropriate seating for students to use while coding and limited access to digital whiteboards or projectors for collective viewing of student-generated content. These did not serve as significant impediments to the current project because students could do their coding activities in coding class, and a mobile whiteboard was often available for the teachers to borrow. Nonetheless, this can be a notable challenge to implementing some of the existing activities.

7 LIMITATIONS

First, this work is in a district that has established coding classes in its elementary schools. Given the expertise and creativity of the coding teachers, they were easily able to take the materials from the original SportSense modules and translate them for an in-school experience. Without the presence of these coding teachers, adaptation, and re-imagination of the SportSense modules would have required several more cycles of iteration. Second, the district has a one-to-one student to technology program. This means that all students have access to a device at any point during the school day. This can simplify the process of having students engage in coding experiences in PE classes. However, we recognize that this is not the case for all school districts and would therefore require some level of coordination to ensure that youth have access to the appropriate devices when needed. Finally, because of the COVID-19 pandemic, many of the observations and interactions that the research team hoped to have directly with learners were simply unfeasible. Our partner schools significantly limited in-person participation from non-school personnel. As a result, many of the observations are based on teacher noticing and the artifacts that they shared with the research team.

8 FUTURE WORK

Moving forward, we will continue to study the challenges and affordances of these types of activities. This will include the data from the activities described in this paper and others that use sports wearables. Across these ongoing cycles of iteration, we will foreground both curricular and pedagogical best practices for supporting this work.

9 CONCLUSION

Computer science has found its way into many core academic disciplines. This paper describes ways that a research-practice partnership team has been productively designing in-school learning experiences that bridge computer science and physical education. Within this work we are excited about the opportunity for students and teachers to see new possibilities for computer science within physical activities. Toward this end, we described our work to take an initial set of modules designed for an out-of-school, middle school program, and grow them into an expanded set of experiences for elementary school students. The structure of this collaboration, and the resultant activities are contributions that we believe can be beneficial to other researchers and practitioners. We also touched on some preliminary findings that highlight ways the activities supported new and different forms of engagement and facilitated shifts in student perceptions of themselves, coding, and their teachers. In short, we see this work as supporting broadening participation and awareness of computer science in ways that meaningfully contribute to one's physical health and well-being. It also serves to rethink where and how the field might aim to teach computer science, and who is invited to teach it.

10 SELECTION AND PARTICIPATION OF CHILDREN

All the data for this project is from teachers or is otherwise teacher provided. Teachers shared the quotations about students and their behaviors.

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