Constructing Sports Technologies and Understandings: Constructionist Pathways to Enrich Athletic Experiences

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Sports spaces are being increasingly used for enabling a variety of computing education opportunities. This work often aims to support socially and disciplinarily minoritized communities, often children of color with specific cultural practices and identities around sports. In this work, we focus on how these experiences can be extended to support youth in developing lasting long term skills around computational making using athletic interest and participation as a jumping off point. We focus on how such a making process can enhance and augment learners' sports understanding, and by extension sports performance; as well as how their sports interest helps them encounter and make sense of different computing concepts. In this paper, we discuss working with a student athlete, his journey of designing and bringing to life ideas around sports technologies, through physical computing and prototyping technologies. We employed a user-centered design approach for designing the learning experience, and emerging methods for assessing learning in making experiences. We blend data around his making experience with observations and interview data around his sports experiences. We find that the process of making augmented his ability to think more deeply about elements of his practice (e.g., strategies of play, ecosystem, and teamwork) and a deeper appreciation of science and technology in the real world. This work contributes an additional lens on how making can serve as a powerful process to realize new possibilities involving computing education in cultural-sustaining computing learning environments.

CCS Concepts: • **Applied computing** → *Interactive learning environments*; **Collaborative learning**; • **Human-centered computing** → **Empirical studies in HCI**.

Additional Key Words and Phrases: sports, making, microbit, makecode, wearables, physical computing, computing education, basketball, puerto rico, culturally sustaining, identity

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1 INTRODUCTION

Athletics and sports are integral parts in many children's lives. They provide spaces for identity development, individual development, team collaboration, physical wellness, and, in some cases, embodied learning. All of these positive aspects of athletics and sports are not only good for children's development and learning about capabilities as an individual and part of a collective, but also take place in cultural processes that bring communities together. While sports plays a central role in Puerto Rican culture, especially among underprivileged groups, computing learning experiences are rarely available and hardly ever coupled with athletics.

This work centers a student-athlete in Puerto Rico as a case for exploring a culturally responsive-sustaining making learning experience. There is much discontent with the education landscape in Puerto Rico. Recent analyses show that

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46% of schools have closed in the past 5 years. Local organizations have started to explore other learning arrangements. For example, nonprofits have opened over 80 Montessori schools in underprivileged communities. Few of these spaces, however, provide computing learning experiences and even fewer engage youth in activities that align computing education with sports culture. Hence, the work we describe in this paper bridges between research on culturally responsive-sustaining computing education and community motivated innovations in alternative learning spaces to realize a different form of computing education.

Prior work in sports, technology, and learning has touched on the role that tools can play in helping children learn about technology and sports performance as well as how data can data support sports interests in authentic ways (Jones, 2020). While that work gives us a glimpse into technology, this paper explores how making can support student-athletes in gaining agency around designing tools they might want to build and how such processes affects learning about sports. In thinking about the design of the learning experience, we were interested in how this sports-related constructionist learning experience might support development as both a makers and as an athlete. Precisely, we have the following research questions: RQ1) How a constructionist approach to sports training supports different ways to think sports? RQ2) What computing constructs are learned and developed by student athlete in the process of developing sports-technology through such an experience?

2 RELATED WORK

2.1 Cultural Sustaining CS Pedagogies

Cultural-sustaining approaches to learning and teaching computing center's children's identities and agency, community problems, and local cultural processes [4]. There are a few important goals of this line of work that are relevant to this study. First, providing identity supportive and expanding learning experiences. Second, epistemological pluralism, that is identifying and characterizing learning in many ways that reflect the learnings of the children. Lastly, relevancy for local community. Sports as an identity supportive space dates back to Nasir's work on dynamics of identity and learning in sports as a community of practice and mathematics. She found that sports provide access to certain elements for support and expansion of children's identities [16]. Previous work has explored physical activity and sports affordances as a cultural sustaining space with various approaches and age groups. In terms of identity, Jones et al. [11] found that physical activity and sports can be an identity supportive space for these groups by centering their athletics and sports interests. In addition, sports are generally seen as healthy learning spaces due to embodiment, apprenticeship, access to domain, and practices with opportunities for self expression [14]. Thus physical activity and sports are a fertile, productive and healthy space to study learning and interactions across those dimensions. Relevant to this work is research at the intersection of sports, technology, and learning. Such work has explored opportunities for embodied cognition, sociocultural participation, and disciplinary knowledge within the context of computing and technology. Examples include: shifts in perceptions about STEM with computing tools oriented on sports performance [6]; how engaging with machine learning modeling helps with training among youth practicing physical activity and sports [22]; and personal expression through a platform for dancing that leverages embodied data among youth females [18]. All these are productive angles to starting to understand what are the opportunities that sports and physical activity represent as cultural sustaining learning experiences. Much of this work, however, shows promising possibilities with technology as a supportive tool for enhancing training and increasing performance. We, however, are interested in the possibilities that a constructionist approach to technology in sports spaces would represent for youth athletes. Examining sports, technology, and learning in Puerto Rico is needed due to its importance for children in the community and its long history of supporting identity-building opportunities, and sociocultural context. Athletics and sports participation among children and youth is at an all time high in Puerto Rico [8]. Such participation has a history dating back to colonial beginnings. It has played an ever increasing importance in Puerto Rican society as a way to reinforce cultural traditions, construct and expand local identity, and as a vehicle to fight narratives of inferiority imposed by others [9]. To put into perspective the relevancy of sports to the local community, we bring about Juan Garcia Passalacqua, a local political analyst, reflection on the matter: "Sport has become the most important single issue at the level of the masses with respect to national identity, more important than language" [9].

2.2 Constructionism and Computational Literacies

We draw from constructionists as a theoretical backbone to design the learning experience, and identify and reflect learning happening in the making learning space. Some of the key ideas from the constructionist community include children learning better by manipulating and creating physical objects [17], the emancipatory benefits of bringing ideas to life [2], and different ways of knowing [1, 21]. We leverage such themes in designing the learning experience. This in conjunction with culturally-sustaining pedagogies supports our goal of employing activities, tools, and pedagogical practices that support the creation of personally and culturally authentic artifacts. This draws computing fluency away from being understood as a set of abstract skills that can be learned from courses and used across contexts, towards a constellation of practices that develop across different kinds of exposures and uses. Research on ways of knowing and teaching computing has historically focused on specific tools, languages, and use cases for technology, and puts strong emphasis on developing and measuring individual cognitive abilities [12]. This is believed to cause marginalization in who gets to participate in computing at multiple levels. This surfaces the need for supporting and identifying different ways of thinking and knowing [21]. Due to the cultural-sustaining nature of this study, we sought to build and expand in progressive theories and ideas of computational literacies. One of the ways to assess fluency in computing is through computational thinking (CT) frameworks. While there are different approaches and frameworks to assess CT in out-of-school learning experiences such as computational action [20] and computational empowerment [10], we are using Brennan and Resnick's CT framework [3]. We make this choice due to their focus on process rather than output, which we believe is appropriate for communities with no previous making or computing background. Furthermore such processes-oriented lenses enable us to think of computing competency as being composed of concepts, practices, and perspectives – complex elements that are learned and used in applied contexts. While there are many unknowns in assessing CT [7], Brennan's focus on process and involving practices and perspectives makes the connection on the things of focus for the exploratory nature of this study -identity in relation to cultural processes and how making supports sports learning in this space. Essentially, we believe framing this study within these two bodies of literature, we would be able to to reinforce existing identities and cultural practices, instead of instilling a set of values and beliefs associated with a particular identity (e.g., technology).

3 PROGRAM DESIGN: PARTICIPANT, SETTINGS, ACTIVITIES, TOOLS, AND FACILITATOR

This year-long (Sep 2021 - Sep 2022) non-formal program facilitates making experiences with physical computing prototyping for a student athlete with no previous experience making computing-related artifacts. Due to the COVID-19 pandemic, sessions were hybrid and lasted between 1 to 2 hours. There were 8 sessions in total (four in person and four online) equalling 12 hours of synchronous work.

Our recruitment criteria included looking for youth who are currently student-athletes, had no previous experience making computing artifacts, and that would be available throughout the duration of the program. We reached out to and considered recruiting from a basketball team of 12 players that had participated in one of our sports and technology camp programs in the summer of 2021 [add citation(?)]. Importantly, during that camp, participants did not gained experience making artifacts. They used off the shelf and custom tools provided by the research team. Two participants started the study, but only one finished the program. The data and narrative presented in this work is solely that of the participant that started and finished the program. The participant was 16 year old Latino male, and he is currently a high school student-athlete in southern Puerto Rico. Sessions were conducted in a public basketball court, and in a community center in the same municipality. None of the spaces had an internet connection. The participant' first language is Spanish. All sessions and data collected were in Spanish. Due to space constraints, we share memorable data snippets translated to English by us. The research team got approval from the institutional IRB and the parent signed a consent form. The name of participant was changed to Roberto for this submission.

Selection of activities focused on iterative processes and encouraging the participants to center his own experiences in playing sports, which responds to cultural sustaining computing education [4]. Specifically the participant was asked to think about skills of sports, how he would go about improving such skills with artifacts, and lastly to implement his ideas with prototyping tools. We used a combination of non-computing and computing artifacts for this program. Non-computing materials included T-shirts, paper, pencils, glasses, and duct tape. The primary computational tool for prototyping was Makecode and Micro:bits. Makecode and Micro:bit were chosen because they integrate a a web-based programming platform that supports block-based programming and their integration of various sensors. Lastly we used iPads and cellphones for the makecode environment. During the first session, the participant was introduced to Makecode, and the Micro:bit.

Lead author served as facilitator. The facilitator grew up in this community, played in same leagues as the participant, and has coached basketball in the area. He shares identity with the participants both as having been a student-athlete, and also demographically in terms of gender, language, and ethnicity, but had not coached the participant in the past. His discursive practices emphasis supporting sports performance, and the possibilities of making. For example, providing examples of how data can support his training by providing ways to collect data overtime. And highlighting how making artifacts can better serve his particular sports needs.

4 METHODS

4.1 Data Collection and Analysis

Data collection and analysis focused on ethnography (i.e., observations, initial and exit interviews, journal entries, and recordings of making sessions, and artifact interviews), and on artifacts (i.e., sketches, physical, and digital) [13]. Which addresses RQ1: different ways to think about sports through making, and RQ2: computing constructs learned through making. Such methodological choices follow from constructionist and computational literacies literature which seeks to identify and characterize learning with different methodological tools [3].

For the artifact interviews, we adapted the artifact-based interview protocol in Brennan and Resnick's framework for assessing computational thinking [3]. The framework was chosen because of its focus on processes when making artifacts rather than on final designs. Additionally, recordings of the making sessions were done with iPads. In analyzing such recordings, we follow a deductive approach to content analysis [15], analyzing participants' experiences with making and learning through the lens of Concepts, Practices, and Perspectives [3].

The three authors analyzed the data individually and then discussed their collective analyses. Such analysis involved reflectively looking at the artifacts and recordings, identified significant actions, and writing notes about those moments.

Key moments included when participants get stuck, and what they did, engagement in different parts of the making process such aspects as coding, testing, and arranging physical objects. We present findings from this analysis through a case study describing his evolution as a player and as a maker.

5 FINDINGS

[VK: idk that this is a narrative anymore...] We present a chronological narrative [19] that synthesize our different data sources to highlight the different ways making supported Roberto's sports understandings, corresponding to our research questions on how making supports different ways of thinking sports, and what computing constructs can be learned through the process. The narrative is divided in three sections (beginning, midway, and final), which we believe better surface his progression making.

[Beginning] Firstly, Roberto overall experience with the program was positive. During the final exit interview, Roberto mentioned feeling proud of gaining new understandings about sports and other aspects of his life, perceived a strong growth in his own computing skills, and an excitement to participate in such a program again. The final projects that Roberto worked on included a shooting wearable made from a combination of available product and adding new materials; a T-Shirt for defense made from scratch; decision making glasses made with available materials; and a wristband for space and time made from re-purposing an existing product. Roberto first started working on a vest that would integrate various capabilities back in September 2021. From September through October we met 4 times, and he worked on the vest and decision making glasses. He experienced difficulties balancing school, team practices, and this additional learning experience. Thus we did not meet between November 2021 and April 2022. From April to September 2022, Roberto found more time to re-engage in making with us. In those months he created the T-Shirt, shooting wearable, wrist band, and re-imagined the decision making glasses.

5.1 Diverse Thinking In Sport

To get a sense of Roberto's existing practices, he was asked, in the initial interview, in what ways he improves his sports skills. He shared: "I practice at home and through the different teams I play throughout the year". He also asked in what ways he uses technology to support his skill development routines. He shared: "I search videos and stuff online. Like how to improve jumping and stuff like that". With that idea in mind, we thought sketching in paper would support Roberto's thinking about his sports performance and technology artifacts.

When he first drew about what skill to improve and what artifact to build, he made three sketches 1. They were all related to shooting the basketball. His ideas about improving as a player were directly tied to his ability to improve his shooting skills, and he wanted to make artifacts to improve that skill. He provided the following descriptions for such sketches. First, "I would like to build a glove with sensors that help us rotate the ball. When you release the ball the glove makes a noise when it detects that you give the rotation, and it does not sound when you are not giving the ball rotation." Second, "I'd make a smart backboard that would tell you the angles for making shots off the board. Have like micro:bits LED displays. It would be for kids. To learn how to shoot". Lastly, he added: "I'd make a phosphorescent ball with a chip. If it rotates well, it turns green, and if it rotates poorly, it turns red."

Prompted by, and in collaboration with, the facilitator, Roberto came up with a set of two additional sketches. One sketch was a vest that could help him and his friends in playing defense, and managing space and time. In part due to the excitement of the form factor, Roberto decided to make the vest first. [add imagine of vest].

Roberto was unsure how to start implementing his idea. Facilitator suggested thinking in paper how such a vest could work. Roberto started imagining the functionality as written steps, in particular thinking about the distance

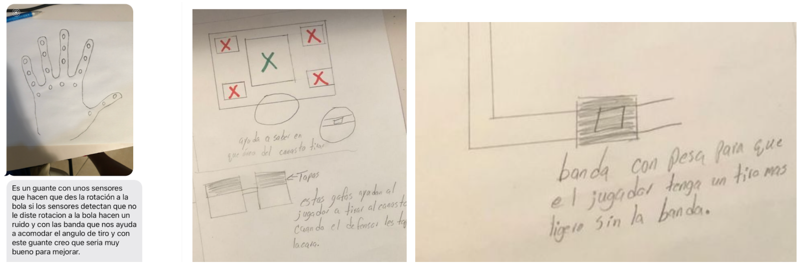

Fig. 1. Original idea of glove

between two players provided that each player would be wearing a vest. This required programming more than one micro:bit to tell how far and for how long each micro:bit was from each other. Roberto wrote the following steps for his code (akin to pseudocode): "When the chip detects that the other chip is getting closer, it starts to light up and the one that is getting closer starts to sound. All this is activated when the player is 6 feet away, if he is one foot away the chips will detect that it is a pick or a handoff and will stop ringing and turn on for 3 seconds. When the 3 seconds are up, the chips will be activated again."

Writing steps down was relatively quick, but moving to Makecode and selecting specific blocks was difficult. After demos provided by facilitator and a YouTube tutorial, we decided to find a tutorial on the Makecode platform that is about a similar project. We ended up choosing the "Proximity Beacon" tutorial. After seeing the tutorial on proximity beacon and trying different versions of the code, Roberto was still unsure how to make it work. Since he had access to the tutorial, he tried to work on it at home, but did not make much progress (Appendix A.3). During the next session, Roberto shared being unsure of how to keep the radio communication between the two micro:bits and still have them do sound and LEDs. Besides being able to tell how far each player was from each other, Roberto thought about the amount of time that players should be near each other. This conversation brought up how Roberto started actively thinking about other time and space based basketball rules like not being in specific zones for spans of time (Appendix A.4).

Although the dynamic of trying to get the code to work and thinking about rules was engaging, there was a sense of frustration on getting stuck, and Roberto wanted to continue with other designs. He engaged in iteration by reimagining how he would support players' space, time, and defense by splitting up the vest into two artifacts. Through this progress, he decomposed the overall vest idea into two designs, a vest that would only work for defense, and ended up looking as a T-shirt, and a wristband for the space and time management experience.

[Mid way] As a way to support Roberto's sense making about the purpose of making artifacts (i.e., to help his sports practice), half way through the program, he was asked to make sketches of the different aspects of the game he had previously imagined. This time not focusing on how the technology would look or making functional code work, but more so parting from the specific basketball-related skills. While he was asked to make sketches, for some of the skills he only used written notes since it was a better way to express himself. This time around, Roberto starts to consider numerous components of the different skills. For example, in terms of improving shooting. For this construct, he includes the angle of the arm, and the spin rate of the ball. Furthermore, he expressed a sequential progression around this skill development surfacing. He shared, "Good Posture > Good balance > Perfect shot".

During artifacts interviews, Roberto was asked where these shooting constructs originated from.

Facilitator: How did these concepts of shooting originate? For example, any person like parents, coaches, friends?

Roberto: No, no, it was a combination of all the coaches, all the coaches from all the teams. They always said the same things, "bend the knees", "rotate the ball", "good posture". Like I had to fix my shot, when I first started shooting I'd take out the ball from my chest, and they laid me on the floor, and made me shoot in the air. And that's how I started to improve my shooting. And that's how my idea came."

While Roberto was able to express his constructs of shooting and defense through sketches, constructs related to making decisions, and space and time were completely textual, and articulated concepts with effects on the game. [not so much from a principles-based approach] For example, one of his notes said, "right decision > point for the team". Such a representation articulates the results of taking different decisions. He had similar notes around space and time, for instance, "Coach > Game Control > Space > Game points". A key difference is the mention of the coach, who Roberto often refers to as the "leader". Furthermore he then mentioned the leader controls the clock on the court. He wrote "Good leader > Patient > Controls the clock". When asked where these constructs of time, space, and decision making came from, he hesitated for a few seconds, and then said, "From the coaches too, but it wasn't long ago. It's like making decisions that are very important".

After deciding to rethink the original multipurpose vest idea, Roberto focused on making a T-Shirt that would support his defense skills by providing sound and LED feedback. In this instance, Roberto was quick to make the physical aspects of the T-Shirt, but he was still not certain how to get started with the behavior/programming of the artifact. The facilitator reminded him of the previous attempted approaches for the vest. Although Roberto had done such a process for the distance program above, he was not confident about how to get started. He first wrote his overall idea on paper. This time, however, the steps were not as sequential, and leaned towards a more general description of what the artifact for defense should do. With the facilitator's assistance, he decided to find a tutorial that was similar to his idea of what defense should look like. In the process of looking for a tutorial we discussed what defense is about. In searching available tutorials, we found re-purposing a clap tutorial could assist him in being attentive and remind him to give effort when defending another player. We went through the tutorial together. To figure out how to extend the code, we both engaged in reading the code. Then the facilitator encouraged Roberto in thinking about what needed to be changed or added, such encouragement was grounded in the sports (i.e., rules of play and expectations as a player). Roberto added time to original tutorial code, connected the Micro:bit to the iPad, downloaded the code on the Micro:bit, and then reset the Micro:bit, but the Micro:bit would not work as expected. We re-read the code, and Roberto identified that he had done a change to the LED block. He was excited to find the bug and fix it. Roberto got very excited to get it to work, and gave the facilitator a fist bump while smiling.

[final] Towards the end of the program, Roberto was asked once again to share on paper how he would improve his skills as a player. This time more open ended. He was not explicitly told made only sketches or written explanations. He drew sketches related to shooting, decision making, space, and time as well. In his last sketches for shooting, he connected several important factors that contribute to making shoots including full body engagement, and angle of arm. In terms of decision making, he presents the environment, his brain, his actions, and how he can improve it through studying and reflecting. In terms of space and time, he still used more phrases and connected it to decision making. Some of these realizations came about in conjunction with the vest idea, which were discussed above.

Towards the end of the learning experience, his sketches became more specific and holistic of the factors involved in improving his shooting. In addition to gaining more depth when thinking about this skill, he also gained breadth of higher level basketball constructs. In his final journal entry, Roberto shared, "Programming has helped me think deeper about basketball. It has helped me to think beyond and not in the basics. What do I mean? I mean that I think that I have to think before acting, not like before you did a crossover and penetrate, but I have to think that I have to open space to attack, think about the next move, the extra pass or better said team play."

Furthermore, when asked his thoughts on the making experience, he provided expansive knowledge about the possibilities of technology and science in the outside world. He shared: "Since I started in the program, it has helped me a lot in knowing how things work, how they are done, what the procedure is like, and it has also helped me understand that everything around us has science and computers have helped us a lot to keep improving in daily life!! Seriously, the program has helped me to understand a lot and I feel proud to have remained in it."

6 DISCUSSION

This paper presents and reflects on the design and affordances of a making learning experience with Roberto, a 16 year old student-athlete. It is an exploration of how a culturally-responsive learning experience can enable student-athletes to construct new sports knowledge, and enhance their relationship with their sports practice. We discuss how sports learning took place throughout the learning experience and computing concepts were developed as a part of this making experiences.

6.1 Sports Learning

As he started engaging in the activities, he began to see his sport practice differently, more deeply and broadly. He first gained a deeper understanding on what factors contribute to shooting better. He then constructed a greater sense of awareness about the complexity of the basketball game – more than just shooting the basketball.

We see how manipulating physical objects and digital representations helps youth think more deeply about their sports practice and strategies for play, and also reflect on their broader performance. This is a unique form of reflection in contrast with prior work [5, 22] which keep the reflection to sports practice more central and direct relative to the computing and data practices youth engage in. Roberto is able to engage with a multifaceted and qualitative view of his athletic and ecological possibilities through our making and computing curriculum – reflecting on foundational skills such as shooting, as well as in-game decision-making processes. The activities prompted Roberto to start his journey of reflection by considering concrete basketball specifics – for example, rules of the game, and his position within the team. This corroborates Nasir's description [16] of how sports enables identity construction and rich manners – especially how deeper practice and reflection expands athletes' identity by illuminating new aspects of their access to understanding their sport, afford theme a greater sense of agency around their role, and often enables them to transform the scope of their participation in their journey of self expression. For instance, when thinking about space and time, Roberto initially thought it was the coach's and point-guard's responsibility to manage those aspects, but the making experiences around the vest affected how he approached these in future play sessions.

Roberto shifted away from considering his role and ideal behavior as an obedient follower of instructions to a more reflective, and agentic athlete, actively considerate of how his play and moves respond to and affect other players. This emerged most overtly in his description about how programming helped him think deeper about basketball [...]. Finally, a possibility involving this type of design is the access to constructing new knowledge about sports with other, new community learning places. Roberto thought of shooting as his strategy to be effective playing basketball. However his final representations were not only about shooting. They were broad, encompassing a much larger space of what constitutes a basketball player.

One limitation with gaining access to knowledge about the game from one authority (e.g., coaches) is resource constraints. In a team sport, usually a coach directs a team of 12-15 players. In such setting it is difficult for a coach to provide individualized feedback. At the same time, Roberto did credit even his complex ideas around shooting, and decision making as coming from his interactions with coaches. For instance, when we asked him where his concepts of shooting originated from, he said "it was a combination of all the coaches. All the coaches from all the teams…" Furthermore, while coaches share what they believe are important foundations to know, they still have limited time to teach more advanced concepts to the players. We believe that broader reflection at different community levels – from coaches, friends, and other experiences like this making program that encourage thinking about his sport, help deepen his thoughts and understanding around it in productive ways. Since youth are often committed to sports for long periods of time, and there are thoughts about institutionalizing participation in this community [8], making sports theme artifacts in different contexts can be a beneficial pursuit for the community.

6.2 Making and Computing Learning

In relation to concrete learning about making and computing, Roberto made specific additions to his knowledge about computing concepts and practices. These specifically included increasing detail in design and code plans, thinking expansively of objects (objective, inner workings, and appearance), manipulation of physical objects, and exercising computational thinking' practices and concepts. Although several of the ideas that Roberto tried did not result in a finished object, the attempts enacted numerous valuable concepts, practices, and perspectives. Importantly, we want to highlight the ways Roberto learned within the broader community of assessing CT. Roberto experienced shifts in passively searching online for ways to improve his game, to imagining artifacts that integrated many features, into smaller, more manageable artifacts that he learned to execute, and finally becoming more comfortable with failure and interacting.

His vest idea posed an initial challenge in terms of complexity – making progress necessitated Roberto to be *incremental and iterative* since trying to have the vest do all things at the same time was not feasible, and trying to manage groups of features also surfaced as practicing *abstraction and modularization*. The modularization emerged in the start itself, in the form of asking Roberto to organize his code plan in text (Appendix A.2). Roberto started imagining the functionality as written steps, in particular programming the distance between two players. This required programming more than one micro:bit to tell how far and for how long each micro:bit was from each other. Roberto wrote the following steps for his code (akin to pseudocode): "When the chip detects that the other chip is getting closer, it starts to light up and the one that is getting closer starts to sound. All this is activated when the player is 6 feet away, if he is one foot away the chips will detect that it is a pick or a handoff and will stop ringing and turn on for 3 seconds. When the 3 seconds are up, the chips will be activated again."

A key expansion of perspective is expressed in his found awareness of seeing greater possibilities involving science and computing not only inside the court but outside in the real world as well: "Since I started in the program, it has helped me a lot in knowing how things work, how they are done, what the procedure is like, and it has also helped me understand that everything around us has science and computers have helped us a lot to keep improving in daily life!! Seriously, the program has helped me to understand a lot and I feel proud to have remained in it." Brennan & Resnick [3] discusses the difficulty of realizing this broader awareness in relation to the world. Roberto was likely able to do so thanks to the dynamics between thinking about the sports' rules and practices and how they could assist their design goals.

Through the making of the wrist band and T-shirt, Roberto learned that there is not a lot of time to execute plays in the offensive and defensive side of the game. He reasoned how being too close to his teammates on the offensive side would not use their time well. For defensive plays, he learned that it is not about staring at the ball for the whole play, but about containing the adversary player for a handful of seconds, so they are forced to make a poor decision. Over time he developed this understanding of the implications of the limited space on the court, and the scarce time to make good decisions for the team. Attempting to program tools for this, surfaced a unique conception of *time* and *space* as *computing concepts*. These are not typically taught as introductory concepts and left for more complex contexts enacted through the combination of many other simpler programming concepts. The sport context afforded and necessitated Roberto (and us) to think through these lenses, which indicates critical value in designing programming blocks that enable interacting with time and space management in simpler ways for such sports technology makers. We see powerful potential in exploring and explicating this further through future work to understand and describe what can comprise effective *athletic computing concepts*.

7 LIMITATIONS, FUTURE WORK, AND CONCLUSIONS

The study identified several challenges that young athlete Roberto faced while adopting online communities for progressing in his designs. These challenges included the lack of good resources in his native language, a lack of familiarity with how to interact with open creative communities, and a lack of awareness around the potential and specifics of programming terms to search with. Additionally, Roberto had to transition from being command by an authoritative figure to a collaborative facilitation learning experience, which was a notable attitudinal transition period for him. Lastly, grasping the limitations of prototypes having only seen commercial finished products also led to a management of expectations in aims of avoiding feeling disappointed or a sense of failure.

In future work, the authors aim to explore fuller trajectories of making with computational tools in the context of young student-athletes, potentially through the high school period. The primary contribution of this work is to show how making digital and physical computing artifacts enhances young athletes' abilities to think about sports-related constructs. The authors suggest that integrating making in spaces that have sports is a promising approach to better design learning experiences that integrate more play time and making time. Additionally, assessing computational literacies in sports environments could focus on specific skills and strategies that children have within the sport, which could lead to more context and children-relevant assessments [3].

Overall, making enables self-evaluation and constructions of possibilities within and outside the practice, and following the learning experience design process can better empower children's voices by integrating their needs.

8 SELECTION AND PARTICIPATION OF CHILDREN

We reached out to and considered recruiting from a basketball team of 12 players that had participated in one of our sports and technology camp programs in the summer of 2021. Our recruitment criteria included looking for youth who are currently student-athletes, had no previous experience making computing artifacts, and that would be available throughout the duration of the program. The research team got approval from the institutional IRB and the parent signed a consent form.

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A INTERVIEW EXCERPTS

A.1 Final Interview

Facilitator: What skills, beliefs, and dispositions do you have about computer science after participating in the program? what you think more or less. in your own words.

Roberto: Since I started in the program, it has helped me a lot in knowing how things work, how they are done, what the procedure is like, and it has also helped me understand that everything around us has science and computers have helped us a lot to keep improving in daily life!! Seriously, the program has helped me to understand a lot and I feel proud to have remained in it.

Facilitator: How do you think your computer skills have changed since last year?

Roberto: My computer skills from last year to this year went from 3 to 5.5, on a scale of 10.

Facilitator: How does that make you feel?

Roberto: Good! Proud! A complete change from where I started.

Facilitator: Would you participate again?

Roberto: Yes! I would participate again, but I would change other things. I liked the camp better. In the part of creating I liked it better with another player, and also if makecode lets us collaborate on the code from different computers.

Facilitator: Why is collaboration better?

Roberto: It helps to progress faster. If I have doubts, talking to others I can improve and do things faster. It's just harder alone.

Facilitator: Do you have other feedback for us?

Roberto: Not during the year. During the summer would have been better.

A.2 Code Plan Prompt

Roberto: I don't know how to make the vest. How do I get started?

Facilitator: Try to think step by step, how it would look? One approach is to write on a piece of paper how the code would do one instruction at a time.

Roberto: Got it. It is not complicated per se but more so we need time to get familiar with the tool, and what each family of codes does. (Here he talks about aboth the pseudocode and Makecode as well. Our interpretation is that he is thinking of how his natural language can be expressed through blocks.)

A.3 Text Exchange about Coding at Home

Facilitator: How is the code on space and time coming along?

Roberto: I have worked on it.

Facilitator: How is it going?

Roberto: A mess

Roberto: I haven't done much after this. Hahaha (Referring to adding music)

Roberto: I gotta keep trying and try that one micro:bit plays sounds and the other one shows the screen

Facilitator: It is looking better! What have you tried?

Roberto: Well I was trying how the micro:bit would look with the sound and light on it

Facilitator: Nice! Have you tried searching for more tutorials? Or some other instructions online?

Roberto did not respond again.

A.4 Time and Space Rules and Programming

Facilitator: Okay, in terms of time, what are you thinking?

Roberto: Oh yeah, time.

Facilitator: Should it be a non changing time? Like the 3 seconds you have right now.

Roberto: Remember we have exceptions depending on the area. Like if you are in the paint, you can only be there for 3 or 5 seconds.

Facilitator: How does that affect your program?

Roberto: Because if it is more timing than what our program is doing.

Facilitator: Remember what the goal of your program is though. Is your program about how much time you spend in an area? Or how much time you are too close to your teammate?

Roberto: Oh yeah, never mind.

Facilitator: But that's a good way of thinking! you are taking into consideration many aspects of the game that matter.