When Athletes Play Around Technology – A Sporting Approach to Computing Inquiry

Ashley Quiterio
ashleyquiterio2027@u.northwestern.edu
Northwestern University
Evanston, IL, USA

Vishesh Kumar
vishesh.kumar@northwestern.edu
Northwestern University
Evanston, IL, USA

Marcelo Worsley
marcelo.worsley@northwestern.edu
Northwestern University
Evanston, IL, USA

ABSTRACT

Exploration and play are core components of sports-related computer science learning. This study explores how youth collaborate and compete in an activity with an AI-embedded sports application. The activity design and technology fosters interactions where the youth leverage their bodies, social interactions, and the camera's view to construct knowledge around computational concepts and gaming practices. Through interaction analysis of video recordings, we examine how social and embodied engagement with the technology's live camera feed enables an interplay between collaboration and competition. The study highlights the value of designing sports technologies and experiences for social sensemaking where youth have opportunities to collaboratively make sense of how these technologies work, such that they can use them productively while being aware of possible shortcomings. Designing game-based sports training technologies like this opens up space for shared social sensemaking around complex technologies, and developing computing knowledge while improving athletic skill.

CCS CONCEPTS

• **Social and professional topics** → **K-12 education**; • **Applied computing** → *Education.*

KEYWORDS

Sports; Collaboration; Interaction Analysis; Joint Media Attention

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1 INTRODUCTION

Innovations in computer science (CS) education extend computing experiences across diverse collaborative and interest based learning environments. Our study delves into the intersection of CS and sports, particularly how youth collaborate and compete with HomeCourt.AI [10], which is an artificial intelligence (AI)-embedded sports application. In our activity design, we frame this app as a game, where youth can practice their sports skills and explore and develop new understandings around advanced computing technologies.

By framing the activity as a game, we see the game-based learning processes emerge from the context of the interaction between the youth and the tool. Game-based learning has been used in CS education to support youth learning problem solving, decision making, and computational thinking [12, 22]. The design of the game is not always explicitly built for youth learning, but that does not mean rich learning around these skills cannot emerge. Drawing from video recordings of youth in-game engagement, this paper explores youth's emerging CS learning with a sports technology that is designed explicitly for athletic and sports learning.

Sports contexts offer environments where youth engage in personally and culturally grounded interests. These spaces are recognized for having rich constellations of resources and practices through which youth develop pluralities of identities as athletes and knowledge and expertise around sports [18]. These resources have been described as spanning ideational, relational, and material resources. The relational resources include a spectra of fluid relationships among athletes and coaches (among many others), which span changing ways of engaging collaboratively and competitively – depending on the activity at hand, as long as athletes' dispositions and ongoing relationships.

In the material resources enacted in sports (particularly team sports), there is a widespread usage of objects, tools, and practices that foster learning through joint attention and engagement. The use of learning through joint engagement and attention is also considered foundational and central to early development across skills like language and gestures [14]; as well as a productive design heuristic for games and technology based learning for socially learning across a variety of complex concepts and domains [17]. This suggests sports spaces to be a particularly effective and well fitting space to design and study learning through joint engagement through technologies relevant to athletic contexts.

Our project explores how game-based, sports-training technologies can foster unique social ways of engaging in building athletic skill while developing understandings about computing technologies and systems. We examine design aspects for these games aimed for athletic spaces to see how they can complement athletic play and training with CS learning – especially through natural moments of social play. We analyze this and highlight how young athletes are able to bring interpersonal relationships and athletic ways of social engagement to develop understandings around complex AI-driven tools designed primarily for individualized sports practice. Additionally, we articulate ways how designing such technologies and for such experiences can support more interest-centered learning

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opportunities, and aspects of facilitation to keep in mind for the same.

2 PRIOR WORK

2.1 Joint media engagement

We approach youth learning through a situated and sociocultural lens, where learning occurs through collaborative action between peers with different capabilities and the cultural-historical structures of the environment [31]. The collaboration in this case is mediated by the co-viewing and participation of the game within the physical environment and the live digital recording. Joint media engagement (JME) emerges as multiple youth view, play, and create media within the in-game environment [29] of the AI embedded app. JME provides youth the opportunity to learn about technology and situations together, because it creates a means for learners to bridge their experiences through an external resource they both have access to [27], such that shared understandings emerge from the interaction.

Some design principles for JME include making the design kid-driven, supporting multiple forms of engagement, differentiating roles, scaffolding for co-creation, and fitting existing participation structures [29]. These principles lead to productive joint engagement as co-viewing leads to processes of mutual engagement, dialogic inquiry, co-creation, and boundary crossing [29]. Notably, mutual engagement speaks to the internal motivation of group members to contribute to the activity and conversation based on their individual interests. Similarly, dialogic inquiry is the conversational process of collaborative sense-making taken up by a group [32]. Key to our process, mutual engagement and dialogic inquiry promote conversations between participants and their joint inquiry as to learning about the technology.

Designing for learning through JME, especially through games, is often conducted in informal learning venues that can enable diverse and dynamic roles across different participants. A complimentary design and analytical framework is offered in Hornecker et al's work on describing shareability in interfaces – through the description of access and entry points in interfaces [9]. Their work highlights which aspects of interfaces and experiences support gradual entry of participation from newcomers, which can transition to the ability to access and play. Our work here builds on this work highlighting how player uncovered novel forms of engaging with limited access points can enable unexpected learning opportunities.

2.2 Learning in Sports – Social and Embodied

The situated learning of many group social practices often exist within a community of practice such that they are socially constructed by the group and taught to new members [8, 13]. This all applies to sports learning which has core embodied actions within the community of practice that determine how new members become participants. That is to say, players learn how to move their body in the context of their sport across individual and group scales of interaction.

Sports are often competitive in the goal of many specific activities, but engender a collaborative endeavor at a macro scale as well as numerous collaborative learning moments and configurations. The community of practice in most sports spaces fosters this hybrid social configuration – where players are friends, training and learning with each other, while often competing with each other and aiming to be the best.

This social collaborative experience is mediated by embodiment. The embodied learning of human movement is achieved through practice as seen within actions from walking to dribbling a ball. Such practice requires embodied cognition where a body's interactions with their environment contribute to sense making [24], while also building relationships among athletes along axes of ability, strengths, and weakness.

The focal app in our study emulates the contextually authentic social configuration of competition as well as relevant training drills – where players work on improving their agility and reaction skills, with increasing complexity and constraints over time. Engaging this through the app provides a unique opportunity to reflect on their actions when they can see their actions in real-time through external media. This new view can support the development of a disciplined perception, where learners can perform and critique practices of interest [26]. The exploration of embodied pathways can also happen as a group where players receive assistance from peers in ways that impact their future interactions [30]. Thus, the tool and group practice enable collaborative learning about embodied actions, while negotiating with the affordances and limitations of the technology at hand.

We hope to explore the transfer of knowledge between these game-based environments (soccer practice and soccer reaction time drills) as active processes youth are constructing [28].

2.3 Embodied and Athletic Computing

Embodied learning has been explored in a variety of STEM domains, most often math and science, to engage with and learn complex concepts through games. Embodiment often plays a role in different inquiry processes taking place in such environments [25]. We believe embodiment can be extended to learning computing concepts, given the body is an always present resource for understanding joint action.

We choose to explore computing in sports contexts in pursuit of creating and studying culturally relevant-sustaining computing education experiences [4, 23]. Technology and computing is highly authentic to athletic practice across all levels of training, practice, and even spectator-ship. This offers a uniquely organic connection between embodied learning and computing learning opportunities.

Bringing a culturally sustaining pedagogy approach to such contexts needs to prioritize making space for linguistic and cultural pluralism – such that the dialects embedded in sports are recognized and elevated as disciplinary practices – instead of aiming learners to assimilate into dominant forms of (CS) disciplinary engagement [21].

This necessitates fostering athletes' participation with technology and computing in ways that empower them. There is building work on recognizing how their regular participation enabled them to develop complex understandings around data science and practices [5], as well as social ramifications around how technologies intersect with boundaries of privacy [2].

Our work aims to build on this by recognizing and elevating the activity-embedded embodied practices of young athletes around technology as authentic forms of computing practice. We also aim for this to be a starting point for creating analytical and design strategies on how to expand the forms of participation recognized as valuable computing learning.

3 DESIGN OF ACTIVITY

Within an after school space for middle schoolers, we designed a sports and CS program composed of multiple challenges that introduced youth to a series of sports technologies such as wearables, sensor-enabled balls, and sports applications. For this analysis, we examine our week four activity with an AI-embedded sports app around soccer. The app was created to support sports learning for professional and young athletes by utilizing computer vision to guide and check players as they complete timed drills. The drills help players practice their coordination, speed, and agility. The app relies on computer vision to estimate the body, floor, and ball position with a live camera feed. It is designed for one person to do a drill at a time. It automatically generates markers for the user to interact with as they continue to play. The users coordinate their actions on the app screen with the markers to earn points. The app encourages players to repeat the exercise and assigns points based on the quality of their performance. A record of the high scores is kept in the app and called upon as they approach the previous high score. The live video recording is saved within the app for future review.

Although the app was not designed for learning computer science, we included it in our program for youth to view technologies that apply CS concepts and are designed for sports learning. Within the gym of the after school program, we provided one tablet for each small group and they spread out throughout the space. Youth took turns doing the same drill, where they could compete with each other's high scores. The group members would orient themselves around the tablet and watch their play between the screen and their peer's movement. The app was framed as a game that the group was collectively playing and their joint attention was an artifact of the activity structure. Youth inquiry about the technology emerged from their interactions with the app, and these interactions were mediated by the group's forms of social engagement that moved between competition and collaboration. We reflect on these interactions as a case of what may emerge when designing for CS learning with technologies that are not explicitly designed for such learning.

4 METHODS

Data collection of youth interactions took place over 10 weeks, and we focus on one day of video recordings conducted during an activity with an AI embedded sports app called Homecourt [10]. Homecourt is designed to support sports performance improvement through a variety of training exercises. We highlight the Soccer Dribbling Reaction Time game inside Homecourt which features a countdown clock, points, and a high score record. The game lasts about one minute per round. As part of the game, participants dribble the ball between their feet while maintaining control of the ball. While they dribble, randomly placed targets appear on the screen. Participants must dribble the ball into the targets to score points. The app's camera faces the player and allows them to interact with their full body in the frame of the camera. The AI component of the app adds a layer of annotations (such as interactive shapes and point pop-ups) to the live video, which can be referenced by individuals in real-time as well as later through in-app recordings (Figure 1).

Searching how young athletes develop computing understandings in this sports context, we looked through Homecourt's video recordings of playthroughs for instances of youth talking about how the game works. We found one round of gameplay which highlighted youth being surprised by how multiple balls also reward points in the game, surfacing a noticing about how the underlying algorithms do not reliably look at one specific ball hitting required targets. In this paper, we couple that round of gameplay with previous plays which offered key contrasting interactions and stage-setting for the interpersonal dynamics that develop and play through in the sensemaking round of gameplay. We present these segments of play as three vignettes, highlighting the impact of the activity's design on forms of participation, the flow between participation forms for sense-making, and computational sense-making.

A group of 3 youths played the soccer dribbling activity multiple times and we will see their interactions with the technology as a group. They are all in fifth or sixth grade. We draw on interaction analysis [11] to answer our research question – how can such youth playing AI-embedded training games in sports contexts bring their athletic practices and relationships towards playing with and understanding complex technologies and computing concepts. We generated a transcript of moment to moment interactions that encapsulated the relevant talk, gesture, coordination between participants, and use of camera view [7]. Our analysis contextualizes the behavior of youth, so that we can make sense of their concerted positionings as they make sense with one another [15]. We chose interaction analysis to explore the interplay between youth and technology to provide an initial lens into what we present as examples of athletic practices in computing use and inquiry.

5 FINDINGS

In the following section, we reference all youth through pseudonyms. The analysis follows rounds 3 and 4 of the soccer dribbling activity as key moments to demonstrate the social athletic practices and relationships of the youth in engaging with the technology. We supplement this part of the analysis with brief mentions from other clips of the same activity on the same day. We break our analysis into three parts to describe how the youth played the game, how the game was a competitive and collaborative process, and what we conclude from the interactions about their learning.

5.1 Overview of game-play

Two of the focal youth conceptualize the game in contrasting styles in terms of attention, persistence, and development. Both were present at the start of the session, and demonstrated different trajectories over time. Adrian was a motivated participant based on his consistent viewing and playing of the soccer dribbling game. He played nine out of the sixteen times, and he watched six of the other games for which he was not the central player. In comparison,

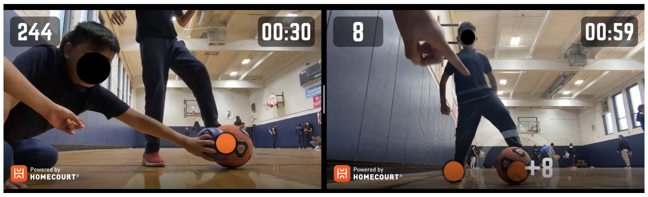

Figure 1: Varying levels of embodied presence and participation by Carlos (left) and Adrian (right) as peripheral players during others' play.

Turn	Discourse
1	Carlos: Let's see him
2	Carlos moves arm in front of camera
3	Adrian: Carlooosss!
4	Carlos moves arm in front of camera again
5	Carlos: You sound mean
6	Adrian: Heeeyyy!
7	Carlos stops and watches Adrian move the ball between his feet a few times.
8	Carlos turns around and picks up a stray ball.

Table 1: A Competitive Setup

Carlos was the central player once, and he watches and interacts as a peripheral player during another five game rounds where others are playing as the central/scoring player.

The nature of Carlos and Adrian's interactions as peripheral players varies significantly. Adrian's interactions are mainly verbal or display only part of his body in camera, such as a pointing arm (Figure 1). His participation highlights the notion that this game is meant to be played by one person, but they may receive external support or advice that does not physically impact their turn. Carlos's participation as a non-central player took up more space, wherein he would enter the camera view with the central player (see left image in Figure 1). The app can not distinguish who is the central player nor the ball with which they are playing. By entering the camera's view, he becomes a peripheral player that can interact with the game even if it is not his turn. The multiplayer interactions that emerge from Carlos's insertion of himself into his peer's game and the verbal advice given by Adrian presents an initial example of these athletes engaging in a common teamwork practice – where they often give feedback to each other during different kinds of practice including emotional (support, discouragement, etc.) and knowledge-based (corrections or questions on technique, goals, etc.) remarks.

5.2 Collaboration and Competition across Segments

Extending our view to interactions by all central and peripheral players, we see that the youth take up different embodied actions to make sense of how the app works. As mentioned above, the live camera view of the environment and players opens up youth's exploration of movement in relation to the technology. The different types of actions include making silly faces at the camera, kicking feet in the camera's view up close without a ball, moving a ball within their arms or hands, and changing the pace where they move the ball between their feet. Through these embodied explorations, the youth were watching themselves in camera as they did moves that could not be classified as soccer dribbling. There was not a clear answer before their exploration about what random or non-expected movements might award points. Each of these moves came from the youth's engagement with the app and each other, and were not part of the original activity design. We frame these actions as moments where youth are individually tinkering to see what the technology acknowledges and how it reacts to their movement.

Through a detailed examination of the example visualized in the left image of Figure 1, we can see how youth move between moments of collaboration and competition as they explore how the technology works. In this scene, it is Adrian's second turn with Benny, Carlos, and the instructor on the sidelines. We have broken the analysis into three segments presented in succession, initiated with a transcript and followed by surfacing a description of the phenomenon of interest in the same episode.

In this segment, Adrian is the central player and Carlos is challenging him to beat his high score from the last round (turn 1). Immediately in succession, Carlos also starts disrupting Adrian's progress by blocking the screen with his arm (turn 2). Adrian responds by calling out Carlos's name (turn 3), as a request for him to stop interrupting his play. This happens once more and Carlos decides to stop after Adrian reprimands him a second time (turns 4-6).

While competitive challenges are universally found in sports and gameplay, the act of overt interference is distinctive given the single player nature of the Reaction Time game, and the space limitation created in the game's presentation on a small tablet screen. Seen through the lens of soccer play, interfering is an authentic form of engaging in competition, though its inappropriateness for the individualized practice nature of the Reaction Time game stands out as important to Adrian.

In the second segment, as Carlos returns to interrupt with an extra ball, a technical limitation in the functioning of the reaction time game sparks a tangent of interest, inquiry, and changes the nature of competitive interference that Carlos was engaged in. Hector, an educator facilitator in the space as well as Benny are additional observers and (off-camera) peripheral participants who remark on the following gameplay.

Carlos moves out of the screen and re-enters a few seconds later with a ball in his left hand, which he lines up with the orange dots that pop up on screen. Over the course of five seconds, Carlos shakes his ball with his wrist over the dots one at a time. He then starts shaking his arm left and right between the two orange dots. The game counts Carlos's movement as valid and gives the action points, such that the score nearly doubles from 77 to 143. This leads to laughing from Carlos and Benny. Adrian and the instructor comment on the fact that Carlos "helped" him by giving him more points (turns 9-12). Benny encourages Carlos to repeat his action ("again, again", turn 12). Carlos tries to repeat his movement from before, and does so for 9 seconds total. The dots appear further apart than before, and it requires Carlos to lean further in front

Turn	Discourse
1	Adrian: Hey now I can do better than you
2	Hector: Ooh technique
3	Game: Great job
4	Carlos moves ball in front of camera
5	Hector: Nooo
6	Carlos shakes arm at the wrist in front of the camera and interacts with orange dots for 5 seconds.
7	The game recognizes the ball and movement earns points.
8	Carlos: Oh[ohoho
9	Benny: [Heheheh
10	Adrian: You just helped me
11	Hector: Yeah you actually helped him
12	Benny: Again again
13	Carlos moves ball in front side to side on screen (for 9 seconds)
14	Benny: Estamos mehi-meditando (?)
15	Carlos reaches further across the screen to reach for the orange dot
16	Adrian: Heeyy
17	Hector: Nooo

Table 2: Competition transforming into investigative collaboration on discovering gaps in understanding of technology

of the screen. This time Adrian is reaching the dots before Carlos when they appear on the opposite side of the screen. Carlos tries a few more times with a slower pace, until Adrian and the instructor call for him to stop.

We see a shift in Carlos's orientation with respect to interruption and competition when his movement with the ball led to Adrian scoring more points. Carlos and Benny had an uproar in excitement with laughter reflecting their surprise from the outcome. Carlos became a supporter of Adrian's play, and was engrossed in the discovery enough that his interest in winning a contest of higher score was quickly forgotten. This action is perceived positively by Benny when he calls Carlos to repeat his action (turn 12). Also, it is interpreted as helpful by Adrian and Hector ("You just helped me", turns 10-11).

This reorientation is facilitated through a mix of the youth's joint attention, unexpected events in the game, and a consequential interest in understanding how the game and the technology works. Instead of the earlier resistance against Carlos's interruptions, Benny invites Carlos to enter Adrian's turn, and Adrian and Hector do not immediately shut down this idea. Carlos is able to retry his movement for a longer period of time than his initial attempt. Benny even enters the screen with his arm reaching into the screen alongside Carlos's half body (see Figure 1). Despite the way this move helped Adrian score more, he did soon express annoyance at the interference nature of Carlos's participation ("heeyy", turns 16-17).

This highlights an exemplary instance of a social way of playing sports and games among friends – in the presence of incompletely

Turn	Discourse
1	Game: Push it a little
2	Carlos: Push it faster
3	Carlos fixes his hair in camera
4	Benny: Dang he told you he was going to beat it
5	Hector: He did?
6	Benny: No so close
7	Hector: Oh you got 15 seconds
8	Carlos: Nah!
9	Carlos: Nah get out
10	Carlos starts to hit the ball in Adrian's feet (to protect score)
11	Hector: Stop
12	Benny: Oh he beat it
13	Benny: No way!
14	Benny: Four hundred!
15	Carlos: Four hundred?
16	Benny: And you can get better than that!

Table 3: A return to competition

understood technologies – creates moments for collective computing inquiry and discoveries. Specifically, the singular screen and limited camera range of the tablet fosters a narrow form of joint engagement – where even as a peripheral participant, Carlos is able to take over control and significantly impact Adrian's game experience. Carlos's interruptions keep diversifying up to the point of introducing a second ball on screen surfacing a line of questioning about the technology: what happens when there are multiple balls in front of the app? This helps the youth expand their understanding of how the technology works and seeing how it responds to any balls without having the ability to track a specific ball. Another question is what movements the device registers? Carlos demonstrates multiple movements from his slow shaking of the ball with his wrist to the shaking of the ball with his whole arm, and finally the slow stretching over more of the screen. Each of these moves represent a form of computational tinkering [3], illuminating how the kinds of movements recognized and scored by the game. By tinkering with the use of his ball and body on the screen, Carlos expands the group's shared understanding of how the game works. The conclusions appear in the subsequent statements made by youth in later iterations of play, where they mention "there can only be one ball" during the game. This inquiry approach centered on embodied investigations to draw conclusions.

In the final segment of round 4, the game audio says, "push it a little faster", which Carlos imitates. He stops his reaching and places the extra ball he was using in his tinkering away. Adrian picks up the pace of his dribbling. Carlos stays to the side of the camera and starts fixing his hair as he checks himself on the tablet, not engaging in interrupting any more. Benny comments, "he told you he was gonna beat it". Here, we see Benny take on a supportive role cheering on both Adrian's following success as well as Carlos who seems to lose interest after being discouraged from his role as an interruptive competitor. This segment highlights the underlying emotional connection between the youth as they are invested in the game even if they are not all actively participating. Benny's statement offers some of the excitement from the moment before to this moment, where he is supporting his peers by cheering them on when they are going to beat the previous high score. Hector asks for clarification, and Benny repairs his statement. Hector adds that Adrian has 15 seconds where he can try to beat the score. Carlos registers that Adrian is close to beating his high score and tries to push the ball away from Adrian's feet. In this way, Carlos returns to his competitive mindset and does not want to lose his position with the high score. Adrian catches the ball between his legs and gets the new high score a second later to which Benny erupts cheering "Ah he beat it! No way! 400!". Similar to a cheerleader, Benny's excitement supports the group. Carlos responds with a softer, almost questioning version of "400". To which Benny replies, "and you can get better than that", to Carlos as to encourage him for this next turn that he can do it. Benny presents a contrasting role of an emotionally positive supporter – an integral lubricant in the continued sustenance of this group playing with each other.

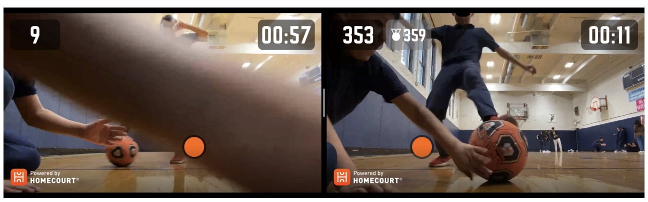

Figure 2: Varying forms of competition between youth in table 1 (left) and table 3 (right).

6 DISCUSSION

6.1 Limited Screens – Central Play and Peripheral Roles

Centering the play around a joint and central screen created a spectrum of roles for the other players. Role taking is an emerging process of JME as a result of the mutual engagement during gameplay [29]. Carlos was engaged in the gameplay as a competitor and a peripheral player eventually helping Adrian's score. His coverage of the screen offers an overt portrayal of how he was often at the edges and occasionally taking over Adrian's visibility completely (Figures 1 and 2). Benny never appears on the screens, but offers a consistent support role (Table 3, turns 4 and 12). Hector, the facilitator, offers a complimentary role of offering moments of guidance while we see the youth develop these roles and dynamics among each other.

This constrained space for interaction provides specific entry and access points [9], originally intended largely for speciation of others' gameplay to learn how to play, and then being able to jump in and play. But through the vignettes we present, we show how a sports gameplay context among youth can reinterpret and expand the different ways to interact with these limitations. This sets the stage to consider how different gameplay mechanics, different screen configurations, camera ranges, and other features would foster different or similar role differentiations among youth, and what they could learn through the same. Moverover, the access points provided by role taking allow group members to participate in a variety of forms and tailor their participation within the community, which directly shapes the group member's process of becoming within the community of practice [19].

While outside the scope of this study to describe in depth, the range of roles that Adrian, Carlos, and Benny enact has notable similarities and differences with those who play central and peripheral roles in their broader sport practice at this venue. More pertinently, this spread of roles, and the collective understanding developed through their play also sets the stage for a Homecourt-specific "community of practice", described summarily at the ending of the findings section – where Adrian becomes an authority and guides newer players with guidelines on how the system works, and "how to play".

6.2 Competition and Collaboration – Interference and Discovery

The game-based design of the app emphasizes points through each dribble of the soccer ball between the players feet and gives more points when this is done quickly. The app recordings provides an external resource of score sharing as a site of joint media engagement (JME) [29], which the group members co-view and access to make sense of their participation in the activity. While they are competing with each other to see who can get the most points, they are also learning together. Throughout the games, the youth use language such as "I can do better", "Imma beat it", and "You can't beat my score", which reflects the competitive nature of playing this game. Adrian was especially fixated on points since he mentions points in four different instances. The longest discussion being in game 7, where Adrian talks to Benny as he is playing. Adrian states, "You can't beat my high score... 515. No. It used to be 168, and then they beat it, and then I got 450". By calling attention to scores, Adrian demonstrates that his focus during the activity is the desire to maintain or beat the high score.

One tension that arises from this joint play is the interfering nature that Carlos exhibits in joining Adrian's play. It is noticeable how this stressed Adrian (Table 1, lines 3-6 'Adrian: "Carloooos"; Carlos: "You sound mean"; Adrian: "Heeeyyy"). Carlos was participating in a way that was not intended by the original design of Reaction Time, and affecting Adrian in a way that could easily have made him give up or leave. This curtailing of participatory opportunities carries significant potential in gatekeeping who is able to avail different experiences in such spaces, and feels comfortable experimenting, playing, and feeling a sense of belonging.

The tension of controlling turn taking and who plays and takes up more space is a recurrent challenge in shared participation and play spaces which do not impose specific roles for each participant [1]. At the same time, interfering is an authentic move or action across a variety of competitive sports – in basketball, it is often used to describe blocking a successful shot right at the hoop; and in soccer it refers to one of a variety of infractions for which the player at fault is often substituted and play restarts. This surfaces the need to make space for forms of social engagement that are organic to a context. To facilitate learning through technological supplements like HomeCourt's reaction time in culturally sustaining ways, we need to be conscious of not curtailing such contextually authentic participatory pluralism [21]. We need to cautiously balance the call to enable youth and learners to engage with new tools in ways that are authentic to their practices and proclivities, and the need to consider the equity effects of whose participation is limited due to prior and recurring practices.

Lastly, we can also notice how Carlos's competitiveness, and his choice to enact it through embodied interference, was unique in surfacing technical features and limitations of the game. When Adrian became the "expert" for future plays, he focused on facilitating gameplay that reduced interruptions and worked with the limitations of the system, but functionally circumscribed the inquiry opportunities to uncover the system's working from other players. This highlights the tension of designing and facilitating play tools and spaces which support youth and learners in self-organized play dynamics – following the rules imposed by a technological system can often enable smoother individual experiences, but interruption and "deviation" from imposed rules offer a critical and productive pathway to uncover insights around the workings and limitations of such systems.

6.3 Athletic Computing

Carlos's interference enabled the whole group (i.e. the focal triad of Carlos, Adrian, and Benny) to learn more about how the game's computer vision is not able to differentiate between different balls, and does not even reliably track feet. This opened the space for them to reflect on how technological algorithms differ from the visual sense-making we intuitively engage in. This sense-making occurred in conversation as well as embodied in their gameplay, as the group collectively acknowledged the positive value of Carlos's interferences.

The development of this understanding is embedded in the actions of introducing a new ball, and exclaiming that this helped increase the score for Adrian to win. This highlights an activity-linked athletic form of computing – where their understanding is embedded in and surfaced through how they move and engage with the system, to attain their goals. The vignettes presented here, specifically, are powerful examples of how this is not a passive understanding of how a system works and following pre-designed rules, but a sequence of interactions that lead to uncovering limitations of these advanced technologies and playing at these margins. Testing systems to understand how they work is an extremely common practice in all kinds of games [20], an authentic way to learn computer science formally [6], and a contemporary relevant way to learn AI/ML concepts, especially around AI ethics [16]. This is a critical example of the kind of participatory and linguistic pluralism culturally sustaining implementations for computing education need to highlight and elevate – where disciplinary practices can take significantly different forms when situated in a different context, but still reflect relevant rich learning [21].

7 CONCLUSION

7.1 What is being learned in these interactions?

Across their interactions with each other and the technology, the youth learn how to play the game through inquiry based processes that utilize their existing knowledge of embodied practices. They construct and learn new methods for participating in this space as a collaborative and competitive environment. Overall, social sense-making through joint attention to screen and physical room play are supporting youth understanding of the technology. Their social engagement seems like it can take multiple forms which range from collaborative to competitive. Their learning is situated in the developing practices of how to play the game and subsequently shared with new members through Adrian's assertions about how he understands the technology and how he positions himself as supporting from the sidelines [8, 13]. We saw this in Adrian's and Carlos's methods for collaborating. Carlos was quick to enter the game space as his peers were playing, and Adrian was quicker to offer verbal claims and advice about how the technology works. The youth, especially Adrian, also got embodied practice learning how to dribble a soccer ball. Adrian lost the ball six times during his first playing with the app and only lost it once in his final iteration. The ball leaving his feet less often indicates a possibility that Adrian constructed new ways to dribble the ball in the game environment through his repeated practice [8].

7.2 Design Considerations

The original design of the app is for individual players to train their sports skills independently. However, the screen and group structure of our learning environment led to specific instances of joint media engagement, where the youth on the sidelines took up various peripheral roles, and manifested unique learning opportunities. The frameworks of JME and entry and access points highlight numerous potential directions to explore with this work – such as using multiple cameras, designing for multiple players simultaneously, and using multiple or larger screens. The central highlight we notice from these vignettes is in the value of not over designing for individualized experiences – youth were able to engage in unique social configurations significantly because of the limitations of input and output in this system.

Additionally, a key aspect of the inquiry was enabled through the presence of extra soccer balls for Carlos to interfere with Adrian's gameplay, which incidentally led to their discoveries around the technology. This highlights the value of having an abundance of contextually relevant tools, and fairly limited access to technology. This enables more entry points into participating with the technology in culturally grounded forms, and increases the chances of those participations being social.

We also notice a key value in minimizing how much facilitation is engaged in such play. While greater facilitation can enable more standardized learning outcomes, it circumscribes surfacing novel forms of participation that lie at the intersection of these disciplines and concepts. At the same time, this engages with the tension of the forms of facilitation required to pay attention to how prior practices of a context limit the participation of groups of or specific learners, and find productive strategies in enabling their sustained participation and learning as well.

7.3 Implications

We considered how the youth collaboratively made sense of an AI-embedded sports application and how that changes interactions with the app over time. Their collaborations were embodied as they initially interacted with the technology in a process of jointly viewing the in-game media [27, 29]. By tinkering with different types of movements, they developed a sense of what the technology registered and ignored. They shared knowledge amongst themselves and with peers as they entered the space. As a group, they established norms about how to collaborate and participate in the game [13]. This is most seen through Carlos's involvement in Adrian's turn.

From this project, the mix of verbal and embodied experimentation with the technology is increasingly relevant for designing learning environments for learning CS in context. We showed how youth co-develop embodied pathways for their learning through their bodies and voices that established valid collaboration processes and relations [30]. Moreover, this project's learning environment builds on inquiry based learning literature. We provide another case of what inquiry can look like in this context outside of a classroom setting, and highlighting how it shows up in moment to moment interactions between youth. We frame the inquiry process as a concerted collaboration amongst youth wherein they make sense of technology together, and embodiment is one of the primary forms of their engagement [15].

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REFERENCES

[1] Sue Allen and Joshua Gutwill. 2004. Designing with multiple interactives: Five common pitfalls. *Curator: The Museum Journal* 47, 2 (2004), 199–212.

[2] Jason F Arnold and Robert M Sade. 2017. Wearable technologies in collegiate sports: the ethics of collecting biometric data from student-athletes. *The American Journal of Bioethics* 17, 1 (2017), 67–70.

[3] Matthew Berland. 2016. Making, tinkering, and computational literacy. In *Makeology*. Routledge, 196–205.

[4] Kapor Center. 2021. Culturally Responsive-Sustaining Computer Science Education: A FRAMEWORK. https://www.kaporcenter.org/wp-content/uploads/2021/07/KC21004_ECS-Framework-Report_final.pdf

[5] Tamara L Clegg, Keaunna Cleveland, Erianne Weight, Daniel Greene, and Niklas Elmqvist. 2023. Data everyday as community-driven science: Athletes' critical data literacy practices in collegiate sports contexts. *Journal of Research in Science Teaching* 60, 8 (2023), 1786–1816.

[6] Stephen H Edwards. 2003. Rethinking computer science education from a test-first perspective. In *Companion of the 18th annual ACM SIGPLAN conference on Object-oriented programming, systems, languages, and applications*. 148–155.

[7] Frederick Erickson. 2006. Definition and Analysis of Data from Videotape: Some Research Procedures and Their Rationales. In *Handbook of Complementary Methods in Education Research* (3 ed.). Routledge. Num Pages: 15.

[8] Charles Goodwin. 1997. The Blackness of Black: Color Categories as Situated Practice. In *Discourse, Tools and Reasoning: Essays on Situated Cognition*, Lauren B. Resnick and Säljö (Eds.). Springer, 111–140. https://doi.org/10.1007/978-3-662-03362-3_6

[9] Eva Hornecker, Paul Marshall, and Yvonne Rogers. 2007. From entry to access: how shareability comes about. In *Proceedings of the 2007 conference on Designing pleasurable products and interfaces*. 328–342.

[10] NEX Team Inc. 2022. HomeCourt: Basketball Training (Version 3.34)[Mobile app]. App Store.

[11] Brigitte Jordan and Austin Henderson. 1995-01-01. Interaction Analysis: Foundations and Practice. 4, 1 (1995-01-01), 39–103. https://doi.org/10.1207/s15327809jls0401_2 Publisher: Routledge _eprint: https://doi.org/10.1207/s15327809jls0401_2.

[12] John Kirriemuir and Angela McFarlane. 2004. Literature Review in Games and Learning. (2004).

[13] Jean Lave and Etienne Wenger. 1991. *Situated learning: Legitimate peripheral participation*. Cambridge University Press. https://doi.org/10.1017/CBO9780511815355 Pages: 138.

[14] AN Leontyev. 1981. Problems of the development of the mind (M. Kopylova, Trans.). *Moscow: Progress.(Original work published 1981)* (1981).

[15] R. P. McDermott, Kenneth Gospodinoff, and Jeffrey Aron. 1978-01-01. Criteria for an Ethnographically Adequate Description of Concerted Activities and their Contexts. 24, 3 (1978-01-01), 245–276. https://doi.org/10.1515/semi.1978.24.3-4.245 Publisher: De Gruyter Mouton Section: Semiotica.

[16] Luis Morales-Navarro, Meghan Shah, and Yasmin B Kafai. 2024. Not Just Training, Also Testing: High School Youths' Perspective-Taking through Peer Testing Machine Learning-Powered Applications. In *Proceedings of the 55th ACM Technical Symposium on Computer Science Education V. 1*. 881–887.

[17] Catalina Naranjo-Bock and Jennie Ito. 2017. Playing together: The importance of joint engagement in the design of technology for children. In *Proceedings of the 2017 Conference on Interaction Design and Children*. 749–752.

[18] Na'ilah Suad Nasir and Jamal Cooks. 2009. Becoming a hurdler: How learning settings afford identities. *Anthropology & Education Quarterly* 40, 1 (2009), 41–61.

[19] Na'ilah Suad Nasir and Victoria Hand. 2008. From the Court to the Classroom: Opportunities for Engagement, Learning, and Identity in Basketball and Classroom Mathematics. 17, 2 (2008), 143–179. https://doi.org/10.1080/10508400801986108 Publisher: Routledge _eprint: https://doi.org/10.1080/10508400801986108.

[20] V Elizabeth Owen, Gabriella Anton, and Ryan Baker. 2016. Modeling user exploration and boundary testing in digital learning games. In *Proceedings of the 2016 conference on user modeling adaptation and personalization*. 301–302.

[21] Django Paris and H Samy Alim. 2014. What are we seeking to sustain through culturally sustaining pedagogy? A loving critique forward. *Harvard educational review* 84, 1 (2014), 85–100.

[22] Birgit Schmitz, André Czauderna, R. Klemke, and M. Specht. 2011. Game based learning for computer science education. https://www.semanticscholar.org/paper/Game-based-learning-for-computer-science-education-Schmitz-Czauderna/e7be9de7521c8b0c26976af07acb4d36f2ce6cf2

[23] Kimberly A Scott, Kimberly M Sheridan, and Kevin Clark. 2015. Culturally responsive computing: A theory revisited. *Learning, media and technology* 40, 4 (2015), 412–436.

[24] Lawrence Shapiro and Shannon Spaulding. 2021. Embodied Cognition. In *The Stanford Encyclopedia of Philosophy* (winter 2021 ed.), Edward N. Zalta (Ed.). Metaphysics Research Lab, Stanford University. https://plato.stanford.edu/archives/win2021/entries/embodied-cognition/

[25] Reed Stevens. 2012. The Missing Bodies of Mathematical Thinking and Learning Have Been Found on JSTOR. (2012). https://www.jstor.org/stable/23266409

[26] Reed Stevens and Rogers Hall. 1998. Disciplined perception: Learning to see in technoscience. *Talking mathematics in school: Studies of teaching and learning* (1998), 107–149.

[27] Reed Stevens and William R Penuel. 2010. Studying and fostering learning through joint media engagement. (2010).

[28] Reed Stevens, Tom Satwicz, and Laurie McCarthy. 2007. In-Game, In-Room, In-World: Reconnecting Video Game Play to the Rest of Kids' Lives. (2007).

[29] Lori Takeuchi and Reed Stevens. 2011. The New Coviewing: Designing for Learning through Joint Media Engagement. (2011).

[30] Shirin Vossoughi, Ava Jackson, Suzanne Chen, Wendy Roldan, and Meg Escudé. 2020. Embodied pathways and ethical trails: Studying learning in and through relational histories. 29, 2 (2020), 183–223. https://doi.org/10.1080/10508406.2019.1693380 Place: United Kingdom Publisher: Taylor & Francis.

[31] L. S. Vygotsky. 1978. *Mind in Society: Development of Higher Psychological Processes*. Harvard University Press. https://doi.org/10.2307/j.ctvjf9vz4

[32] Gordon Wells. 1999. *Dialogic Inquiry: Towards a Socio-cultural Practice and Theory of Education* (1 ed.). Cambridge University Press. https://doi.org/10.1017/CBO9780511605895