Youth Embodied Communication and Collaboration in Making

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Abstract: Making activities in non-formal learning has the potential to improve the technical and social skills of youth. To unpack those potentials in this empirical study we examine youth collaboration and communication in a making activity via the lens of embodied cognition. We analyzed youth interactions within the group and with the educational robot, *Dash*. Findings reveal three ways of youth embodied communication - Peer-feedback, Group Negotiation, and Developing Shared Meaning - while collaborating on a making activity. Also, youth were found personifying and embodying *Dash* to take its perspective while programming it to perform specific actions. Different modalities (e.g., gestures, bodily actions, speech) within the activity enabled students to collaborate by communicating with each other and *Dash* effectively. These findings suggest that the use of an embodied lens in making activities can provide useful insights to improve youth engagement, communication, collaboration, and conceptual knowledge.

Introduction

A recent explosion of makerspaces across a range of formal and informal learning settings has made *making* a popular form of activity for engaging youth in STEM learning that involves creativity and innovation (Bers et al., 2018; Daugherty, 2013; Halverson et al., 2014). Youth interactions with making tools is critical to the essence of STEM learning and community building (Bers et al., 2018).

*The making environment is a blend of technological tools (such as educational robots) and informal participatory cultures, which made participants report makerspaces feel like a family or a group of friends (Sheridan et al., 2014). Peer-supported making and robotics activities have a positive effect on youth's learning due to the potential for feedback-in-practice (*DiGiacomo & Gutiérrez, 2016). *These learning environments provide youth opportunities to learn by leveraging distributed knowledge, collaborative design processes, and constructionist learning-by-making pedagogies (*Honey & Kanter, 2013; Vossoughi & Bevan, 2014). Limited robotic studies have examined youth participation in robotics activities through the lens of embodied cognition (Kopcha & Ocak, 2019). Particularly, there is a temporal relationship between metacognitive and collaborative talk in group educational settings (Socratous & Ioannou, 2019). However, it remains unclear what this collaborative talk looks like for youth and how it can foster improving collective knowledge building in making activities. To address this, we examine youth experiences in the making activity which involve an educational *robot, Dash.* We examined two research questions: (i) *What does an embodied cognition lens reveal about communication and collaboration within a making activity?* and (ii) *How do youth interact with the robot (Dash) in a making activity?*

Theoretical framing

Educational robotics and physical computing learning environments have proven to be an efficient way of improving students' overall learning interest and motivation (Bocconi et al., 2018; Chin et al., 2014; Seoane-Pardo, 2016). Robots are considered an effective tool for communication and collaboration (Benitti, 2012; Chin et al., 2014). Young children treat social robots as companions and guides (Belpaeme et al., 2012; Kahn et al., 2012) and learn new information by interacting with it (Breazeal et al., 2016). Social robots share physical spaces with humans and leverage our means of communication – e.g., speech, gestures, gaze, and facial expressions (Kennedy et al., 2016). Making environments rich with technologies, tools, resources, and community values can provide makers with opportunities to develop identities as individuals and community members and become uniquely poised to engage with and impact their world (Bers et al., 2018).

According to an embodied cognition perspective, human cognition is deeply intertwined between the body and brain (Kirsh, 2013; Wilson, & Golonka, 2013), i.e., to solve problems, humans use their brain as well as their body. It provides the understanding of people's participation in practices of inquiry that include interactions with others and technological resources present in their environment (Kozma, 2003). Gestures play an integral role in interpersonal communication by containing unique communicative content separate from spoken language (Nathan et al., 2013; Shokeen et al., 2021). An individual's interaction with other people and with resources and materials in the environment influences their cognitive and reasoning processes (Hollan et al., 2000). There is a tight connection between an individual's movement, gestures, manipulation, vision, and haptic feedback (Gibson, 2014). Hence, an embodied perspective within a making activity means that we need to understand how language, gesture, and bodily actions are used and perceived by the group and their roles within social and physical interactions (White & Pea, 2011).

An embodied perspective on the nature of communication and collaboration includes attending to how tools and representations are perceived and used, and their roles within rich social and physical interactions (White & Pea, 2011). Gibson (2014) described affordance of a tool as a term to convey the array of potential actions that arise as one perceives and responds to tools in the immediate environment. External representations are important because they transform concepts and processes into symbolic and visual forms that are intended to stand for ideas, objects, and relations (Nathan et al., 2013). Tools and representations can have a strong impact on people's actions, thoughts, and support their creative thinking (Resnick et al., 2005). While solving problems as a group, different modalities such as speech, gesture, and writing are helpful for youth to develop their reasoning strategies (Bjuland et al., 2008). However, there is scant literature investigating youth collaboration and communication practices in non-formal making activities from an embodied cognition perspective. This intrigued us to examine the communication and collaboration practices via embodied cognition lenses in a making activity.

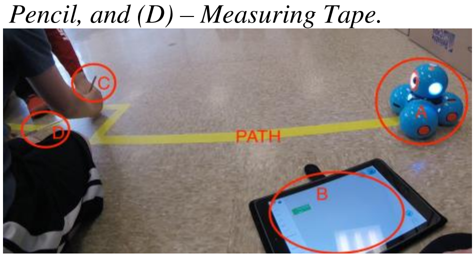
Methodology

Description of making activity

The making activity consisted of two phases. Phase 1 involved making a path for Dash (Figure 1-A) by placing yellow tape on the floor from one side of the room to the other. This path was to be traversed by another group in Phase 2. The goal of Phase 2 was to program Dash (Figure 1-A) to stay on the path (Figure 1-PATH) through composing a series of block codes on the iPad app Blockly (Figure 1-B). In addition, groups were provided with two other tools - a pencil (Figure 1-C) and measuring tape (Figure 1-D). This activity was performed by two groups simultaneously in the peripheral presence of a schoolteacher and a researcher from the research team.

Figure 1

Group using the different tools provided to them for the Making Activity: (A) – an educational robot, Dash, (B) – Blockly app interface on iPad, (C)– Pencil, and (D) – Measuring Tape.



Data collection

For this study, the teacher offered a "free" Tinkerlab period for two 3rd-grade, two 4th-grade, and two 5th-grade classes at different times during the school day. Videos were collected using two Go-Pro™ cameras and a wide-angle camera per group. In total, we collected and analyzed 19 videos (approximately 350 minutes of video data). The utilization of multiple cameras for any one group afforded the research team an opportunity to "see" different perspectives to form a larger possibility space of an event (Simpson et al., 2021). The study included 32 students (13 girls, 19 boys). These students were familiar with *Dash*, diminishing the barriers due to the introduction of a novel educational robotic in the study.

Data analysis

Our research team consists of four members with expertise involved in makerspaces, education, embodied cognition, and human-computer interaction. Using the constructivist grounded theory method (Charmaz, 2006), we analyzed data in five phases - sensitizing, open coding, axial coding, focused coding, and memoing (Polit & Beck, 2006). First, to sensitize ourselves to the data, we randomly chose one video from Grade 4 to be collectively watched by the research team. Watching the collected video consisted of silently watching the video in two-minute increments, followed by a research team discussion on what was observed in that increment (Jordan & Henderson, 1995). Second, each team member individually wrote descriptive and analytical memos for this video data within ~15-sec increments. At least two members of the team focused their memoing through the lens of embodied cognition. Third, our individual memos were then placed in a shared Excel sheet, allowing us to look within and across memos. The entire team of researchers met to discuss how we were each making sense of the similarities and/or differences in our memoing with a particular focus on how youth used gestures, actions, and tools through the activity. Next, a focused code sheet was developed utilizing the foundational scholarship of representational fluency by Moore et al. (2013) and gestures by Alibali and Nathan (2012) (see Table 1). Fourth, two research team members applied those focused codes to all of the video data, while continuing the process of memoing. They began by individually applying the six categories to one video, and then met to discuss similarities and differences, as well issues and concerns that were raised such as how to illustrate the sequence of interactions among group members or clarify the difference between symbolic and language representations or how to categorize a student who uses a strip tape to point in a particular direction as opposed to using their finger. After reaching consensus, the two researchers again watched another video individually and were consistent in their categorical coding of group members actions and behaviors. The remaining videos were divided between the two researchers. Fifth, categorical actions and behaviors, as well as memos, were organized through axial codes, analyzing how students communicate and collaborate with their group (i.e., Research Question 1) and with *Dash* (i.e., Research Question 2) from an embodied perspective. This was done through looking across all the videos for one group (e.g., Grade 3-B), as this provided a more holistic picture of the unfolding events within the making activity of one group, and then considering how the categories and memos presented a pattern across the axial codes from the six groups. This process afforded the research team to account for how communication and collaboration was embodied through their interactions with each other and through their personification and embodied perspective-taking with *Dash*.

Table 1
Our updated Translation Model containing six categories of representation with their definitions and examples from this study that was used for focused coding of the data.

Category	Definitions and Study example
Concrete (CR)	Representation with concrete and physical models and tools to convey any mathematical idea, formal or informal. Phase 1: Added a small strip of tape to the path. Student held it one way and then turned the piece of tape about 90 degrees before laying it at the end of the path.
Pictorial (PT)	Pictorial representations, such as graphs, 2-D representations of physical models, diagrams, and digital representations (e.g., virtual protractor). Phase 2: Students used a virtual protractor to determine an appropriate angle for Dash to travel along a taped path.
Symbolic (SB)	Mathematical notation in written or oral forms of communication (e.g., degree); algorithms (e.g., code) is symbolic. Phase 2: Peter stated, “Forward, 10 centimeters.”
Gesture (G)	Representational gesture included iconic and metaphoric gestures, such as shows angle via handshape or motion. Phase 2: Adele stood along the tape path and moved her right arm out-in-out-in, indicating that Dash should turn right.
Language (LG)	Representation of spoken expression/communication, including language representations that did not include mathematical notion (e.g., “Forward ten.”) Phase 1: Beth said, “Let me make this line longer.”
Realistic (RL)	Representation through realistic, real-world, experienced contexts, or metaphors. Phase 1: Ryan noted, “It [tape path] is like one of the crazy roads that you see in movies.”

Results

Ways of embodied communication and collaboration

In response to our RQ1, we found collaboration within the groups was happening through embodied communication in three ways - 1) *Peer-feedback* - group members giving feedback to other; 2) *Group Negotiation* - deciding what to do next for each micro-goal; and 3) *Developing Shared Meaning* – developing a shared understanding of words in the situated action. These are discussed below with corresponding illustrative example.

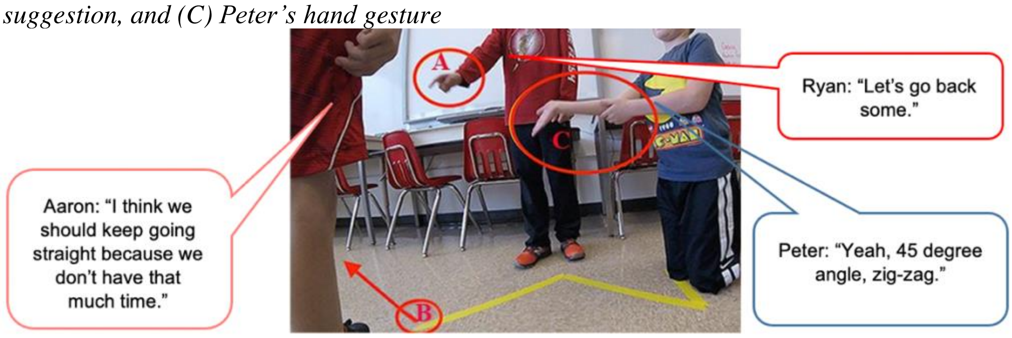
Peer-feedback

The main goal in Phase 1 of the activity was to make a masking tape path from one end of the room to another for another team, which encouraged groups to make a path that was challenging but doable to program Dash to travel that path. Micro-goals within Phase 1 of the activity involved groups making decisions such as how long the next piece of tape should be, the overall shape of the path, and the angle between two pieces of tape. For instance (Example 1): when Group 4-B were beginning to make a path, Ryan offered to make a 10-degree angle between the second and third section of the path. However, Fawn suggested him to expand the angle between two sections of the tape, "I think it has to be a little bit more like that". Fawn collaborated with Ryan in the action of laying the strip of type to demonstrate her suggestion. Fawn's verbal and non-verbal actions helped Ryan to follow her suggestion in the activity. This example illustrates how group members collaborated with each other by taking a suggestion via verbal and non-verbal action clues to achieve the goal of the activity.

Use of gestures during group negotiation

During group negotiations around how to lay the path, participants were often using gestures in addition to their speech. For instance (Example 2), within Group 4-B while making the path Ryan suggested "let's go back some" by using the pointing gesture to convey the direction he was referring (see Figure 2-A). Peter denied Ryan's suggestion by saying "No". Then Aaron suggested, "I think we should keep going straight because we don't have that much time" by using his leg gesture to convey the direction of the connection of next segment of the tape (see Figure 2-B). To which Peter responded, "Yeah, 45-degree angle, zig-zag" using his hand gestures to demonstrate his suggestion (see Figure 2– C). Peter's comprehension of Aaron's suggestion was based on considering both his words and gestures, because Aaron only mentioned straight via his speech, but his gestures mentioned the specific direction.

Figure 2
(A) Ryan using his finger pointing to the direction, (B) Aaron using his feet to demonstrate his suggestion, and (C) Peter's hand gesture



Developing shared meaning

We found that group members developed a shared meaning of terms (such as zigzag, tight angle, etc.) within their group. While communicating about angle between two adjacent sections of tape, participants were found to be struggling to communicate their suggestion due to lack of a shared understanding of words used to refer to angle. For instance (Example 3), in Grade 5-A, Olivia struggled to communicate her ideas about rays and an angle, and began by saying "Make it jagged. That's way too long." To explain what she meant and perceived, she performed an action of pulling up the last tape section from the floor, ripping it into two parts and laying one piece of the ripped tape back down. She then stated, "keep doing that pattern," and pointed toward a specific angle on the path. Later, Robert responding to Olivia by proposing to the group, "We have to make really tight angles." Continuing, Sam added, "Make it a tight angle." Next Ben added, "Make it zig-zag." Ben repeating the term 'zig-zag' demonstrated that he had now aligned with Olivia's perception of desirable angles and rays and was able to follow the meaning of zig-zag. This example illustrates the development of their shared meaning of 'zig-zag' in reference to a concrete representation (i.e., tape path) and the use of other words such as 'tight angle'.

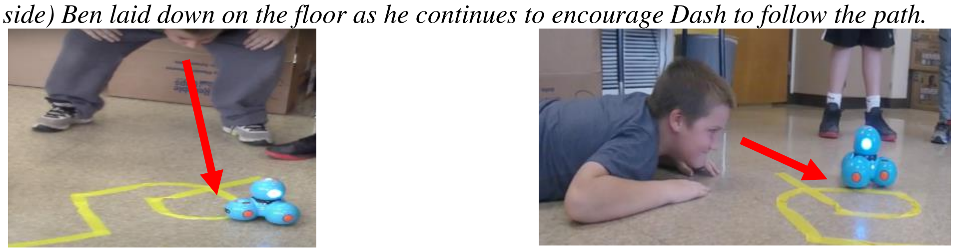
Children-robot interaction

In response to RQ2, we found two ways that the group members interacted with Dash: 1) *Personification* - talking to/about the Dash like an individual; and 2) *Perspective Taking* – considering the abilities of the Dash to perform a certain action. These are discussed below with corresponding illustrative example.

Personification

The "Personification of Dash" theme emerged when we found evidence of the group members talking to Dash and talking about Dash as an individual itself. For example (Example 4), while the group Grade 3-B tested their program, Dash does not travel on the path. As illustrated in Figure 7, Chris walked up to Dash and asked, "What are you doing? You are supposed to be on the line. Do you see a line over there? Hey c'mon." He picked up Dash using his hands and put it back on the beginning of the path. In Group 3-A, while Dash was moving in an opposite direction from the path (Example 5), Khaki said "Turn" and moved his finger quickly in a circular pattern above Dash's head to suggest in which direction it should move. Khaki's response suggests that he was treating Dash like a person and expected it to respond as per his suggestion through speech and gesture. Lastly, while Grade 5-A was programming Dash, there was much chatter and noise among group members (Example 6). Sam said, "Shut up. Especially, you Dash" as he tried to position Dash at the beginning of the path, but the code was running so that Dash was making a sound. Here Sam was speaking to Dash as a person. Moreover, in the final run, Ben laid down completely to check whether Dash was touching the tape or not. He said, "He is touching it." Looking into the eyes of Dash, Ben tried to encourage Dash by saying "You got this." He even used his gesture of tapping fingers on ground to encourage Dash as if it was looking at him (Figure 3).

Figure 3
Personification Illustration: (Left side) - Ben talking to Dash by looking into its eye, and (B) (Right side) Ben laid down on the floor as he continues to encourage Dash to follow the path.



Perspective taking

The "Perspective Taking" theme emerged when we found patterns of youth replacing their body in for Dash to consider its perspective, particularly while programming Dash to perform certain actions. For example, in Grade 4-B (Example 7), while programming Dash, Peter and Aaron discussed the angle size and direction in which Dash should be programmed. To consider the perspective of Dash, Aaron sat right behind Dash and used his hand to estimate what should be the measure of input for Dash to travel that section of the path (gesture representation; see Figure 4).

Figure 4
Taking Perspective of Dash to estimate the input in the code

Moreover, in Grade 5-A, (Example 8), While testing program for Dash to travel the given path, pointing towards Dash, Omar said, "What are you [Dash] doing there?" and then looking at his group members he added, "I don't know what he [Dash] is doing." To his comment Robert laid down to make sure Dash was rightly placed at the beginning as he responded, "His wheels were not set up right. Make sure his wheels are right." Omar personified Dash, and Robert used Dash's perspective by focusing on how Dash's wheels were positioned on the path.

Discussion

Our first aim of the study was to answer: What does an embodied cognition lens reveal about communication and collaboration within a making activity? We found that groups engaged in three main types of communication while collaboratively working on the activity: 1) *Peer-feedback* - group members gave feedback on an action/suggestion given by other members for each micro-goal; 2) *Group Negotiation* - deciding what to do next for each micro-goal; and 3) *Developing Shared Meaning* – developing a shared meaning of certain words with situated concrete examples within the group. These categorization of youths' patterns of communication and collaboration within the making activity expand on Bevan et al.'s (2018) claim that young makers develop their confidence through active participation while collaborating with others. Additionally, we found our participants giving feedback to each other's suggestions and actions. These findings support that peer-supported making activities have the potential for feedback-in-practice, which contributes to collaborative learning (DiGiacomo & Gutiérrez, 2016). Moreover, our findings echo prior claims that group making activities provide youth opportunities to learn by leveraging distributed knowledge, collaborative design processes, and constructionist learning-by-making pedagogies (Honey & Kanter, 2013; Vossoughi & Bevan, 2014). Furthermore, we found that youth, via embodied communication, developed a shared understanding of multiple representations to engage in meaningfully grounded actions. In both phases of the activity, we found youth actively rely on their bodies to better communicate their thinking while collaborating in the group. These findings emphasize how the use of gestures, accompanied by corresponding actions and verbal language, helped the groups collaborate effectively by developing a shared perceptual understanding. Importantly, our findings illustrate that the lens of embodied cognition can reveal important insights into group collaboration and communication skills, which also reinforces prior research claims that participation in group making activity enhances youth social skills such as collaboration and communication (Lanz et al., 2019; Shokeen et al., 2020).

Our second aim of the study was to answer: How do youth interact with the robot (Dash) in a making activity? We found that while programming Dash, youth demonstrated two types of interaction with Dash: 1) *Personification* – talking to Dash as a person; and 2) *Perspective Taking* – embodying the robot to consider its perspective. Also, we found that participants were exploring the affordances of tools (such as Dash and the Blockly app) that were provided to them during the activity. Our findings extend claims that a making context encourages learners to inquire about tool properties and learn about fabrication tools (Meehan et al., 2014; Lindsey et al., 2018). Our findings suggest that youth interaction with Dash encourage them to inquire, question, and test their code, and that testing helped them to improve their code. This strengthens the argument that the use of educational robots helps youth to learn programming and engineering skills (Anwar et al., 2019). An embodied cognition lens revealed that youth's communication and youth's interaction with Dash were deeply intertwined with their gestures and bodily actions while manipulating it. These findings reinforce the radical hypothesis that human cognition relies on their brain as well as body to solve problems (Kirsh, 2013; Wilson & Golonka, 2013). Moreover, in our making activity environment youth were found to be using STEM concepts and refer to concepts such as angle and length measurement in both phases of the activity, which are critical in STEM education. These findings imply that participation in making activities engages youth with STEM concepts. This reinforces the claim that making environment enhance youth competency in STEM education (Vossoughi & Bevan, 2014).

These findings have laid the groundwork for further research into the role of gestures and actions in making activity. These findings are limited to students' participation in only one making activity with a particular educational robot, Dash. Generalizing these finding across different making activities and/or with the use of different educational robots is beyond the scope of this study.

Implications

Design of making activity

In this activity, there were visible structures (iPad, the Blockly app, Dash, tape, floor, group members) and invisible structures (such as the pre-existing relationships between the students, the passage of time, and external goals set by teachers). These structures directly influenced the nature of youths' collaboration and communication. This implies that the making design structures in the activity directly influence the nature of communication and collaboration within the group, Thus, educators designing making activities should be aware of both visible and invisible structures in their design process.

Peer-feedback in making

Peer-feedback was found to be prevalent in our data, as group members gave feedback to each other about their suggestions and actions in the activity. While giving feedback, youth were observed to be relying on gestures and bodily actions to complement their speech while speaking with each other to provide unique information to their communication. This implies that youth should be encouraged to use gestures and actions as it helps them better communicate ideas and feedback to their peers. In summary, educators should encourage youth participants to give such multimodal feedback to each other to communicate and collaborate more effectively.

Embodying to consider perspective

We found youth moving their body in the direction *Dash* needed to go was useful for them to identify what input was needed in the code. This implies that youth benefit from moving their bodies to embody and estimate the code input while programing educational robots like *Dash*, Thus, educators should consider providing appropriate space and opportunities for youth to move their bodies while engaging in programming a robot.

Conceptual communication in making

We found youth referring regularly to mathematical concepts while communicating with their group (e.g., angle, length, measurement). These findings extend prior findings that making activities help youth to recognize and maintain common conceptual threads of mathematical play (Shokeen et al., 2020). Such conceptual threads provide opportunities for students to build cohesion across STEM disciplines mediated by the learning environments (Nathan et al., 2013). This implies the power of making activities in building conceptual understanding across various disciplines using different symbols, tools, and in different social interactions. Educational robots such as Dash support computational practices, complex cognitive interactions, and the use of scientific and mathematical concepts that are particularly observable through the embodied cognition lens.

To conclude, analyzing multiple groups' interactions within making activity using embodied cognition is a challenging process, but its findings are useful at multiple levels. Youth's communication involves gestures and bodily action to collaborate effectively in making activities. The use of educational robots (e.g., Dash) serves as a tool for affective and embodied interactions for youth. Thus, we argue that more educational contexts should include these types of activities for youth. The examination of making contexts in which participants communicate and learn requires attending to the embodied nature of their communication within the group and their interaction with the technical tools. So, we argue attending to embodied gestures and action can reveal crucial insights into youth development of social skills such as communication and collaboration in making activities.

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