SPONTANEOUS MATHEMATICAL MOMENTS BETWEEN CAREGIVER AND CHILD DURING AN ENGINEERING DESIGN PROJECT

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Research studies support caregiver's involvement in their child's mathematical journey as foundational to their cognitive development and academic success as mathematical learners (e.g., Sheldon & Epstein, 2005). The purpose of this intrinsic case study was to understand how a caregiver initiated and/or continually engaged their child in spontaneous mathematical moments during the engineering design process. Through the analysis of approximately 13.5 hours of video data, we noted several ways in which Tonya guided, supported, and challenged Cindy through a shared endeavor of designing a remote-controlled delivery robot – questioning that promoted reflection and advanced Cindy's mathematical understanding, affording Cindy opportunities for decision making, and providing Cindy with the mathematical language to describe her approaches within the engineering design process.

Keywords: Caregiver as Educator, Informal Education, Mathematical Moments

Objective

Previous research suggests that interest and engagement in science, technology, engineering, and mathematics (STEM) can be triggered at a young age, and caregivers are considered to be one of the most significant influences in this development (e.g., Maltese & Tai, 2011). Additionally, the benefits of out-of-school learning experiences for youth is well documented and include positive dispositions toward STEM, greater likelihood of pursuing a STEM-degree and career, and development of interest and confidence in STEM (e.g., Bell et al., 2009; Denson et al., 2015). Engaging in teaching and learning of mathematics within home environments and other out-of-school contexts are framed as shared family experiences and tend to include budgeting, home improvement projects, games, proportions of ingredients when using recipes, and verbal exchanges during mealtime (e.g., Esmonde et al., 2012; Pea & Martin, 2010). As such, caregivers, regardless of their own experiences, are able to act as mathematics educators in engaging their child(ren) in mathematical moments (Sheldon & Epstein, 2005). In this study, these mathematical moments are defined as a spontaneous experience to engage with and/or explore mathematical ideas and concepts (Cunningham, 2015), and situated within a project aimed at developing, implementing, and refining a program for integrating engineering design practices with an emphasis on emerging technologies (i.e., making, DIY electronics) into home environments of families. Research has shown that participating in engineering design principles support students' application of mathematical concepts (e.g., Berland et al., 2014). Yet, we know very little of how such mathematical moments in the engineering design process arise in out-of-school learning contexts between caregiver and child. We address this gap in the literature by addressing the following research question – How does a caregiver initiate and/or continually engage their child in spontaneous mathematical moments during the engineering design process? We contend that caregivers and other family members should be recognized for their ability to enhance school mathematics within out-of-school learning contexts.

Perspective

In this study, we utilized a socio-cultural perspective, which views learning as active participation and engagement in cultural and social activities (Rogoff et al., 1993). More specifically, we employed Rogoff and colleagues' (1993) guided participation in which participation is guided, supported, and challenged from another in a shared endeavor; in this study, this other referred to the caregiver and the shared endeavor is the development of a robot (see below). As such, Rogoff (2008) defined participation as an interpersonal process in which individuals are actively observing and/or communicating with their words and hands. It builds upon the notion of zone or proximal development as it involves "not only the face-to-face interaction, which has been the subject of much research, but also the side-by-side, joint participation that is frequent in everyday life" (Rogoff, 2008, p. 60). Similar to Vedder-Wiess (2017), we contend that the caregiver's role within in the process of guided participation is through modeling and engaging in spontaneous mathematical moments with their child. Collectively, the caregiver and child are employing their knowledge and understanding of mathematics.

Methods

The larger research project was conducted between January to May. We met with caregiver-child dyads once a month for approximately 3 hours in length. This particular study is an intrinsic case study of a caregiver-child dyad (Tanya and Cindy) engaging in mathematical moments during an engineering design project developed and designed by the dyad (Stake, 1995). As stated by Cindy, "My project is a remote-controlled delivery robot to help people who can't get out of bed or are sick…I was thinking about someone in a nursing home." At the time of the study, Cindy was a third-grade student who aspired to be an artist.

Data Collection

The main source of data was video recordings of each monthly session and home video recordings of Tonya and Cindy working alongside a member of the team. Cameras were stationed as to capture the interactions between Tonya and Cindy, as well as interactions with facilitators and engineers who volunteered their time to assist the dyad. This amounted to approximately 11 hours of video data from the monthly sessions and approximately 2.5 hours of video data from the home visits.

Data Analysis

The analysis was conducted in two phases. During the first phase, both authors watched all the videos, individually looking for mathematical moments. We each noted the time range and provided a brief overview of the interaction in terms of engagement with mathematical ideas and/or concepts. Our goal was not to establish inter-rater reliability, but to capture identifiable mathematical moments, or ethnographic chunks, for further analysis (Jordan & Henderson, 1995). We met five times to discuss our observations as we acknowledged these identifiable moments to be influenced by our cultural understandings of and experiences with mathematics as a mathematics teacher educator and STEM education researcher, and science education doctoral student respectively. The final meeting focused on identifying specific moments that addressed the research question, which were transcribed verbatim and included non-verbal acts of communication. During the second phase, we individually read through the transcripts and noted the ways Tonya initiated and continually engaged Cindy in spontaneous mathematical moments. When we met to discuss, we were similar in our understanding of these spontaneous moments such as the manner in which Tonya posed questions to both initiate and advance Cindy's engagement as a mathematician. We also developed a shared language (i.e., agency).

Findings

We present two specific instances in which Tonya initiated and/or continually guided Cindy in spontaneous mathematical moments during the engineering design process. Both examples occurred during the last workshop when Tonya and Cindy are brainstorming how to construct the tray with the materials on hand. The first transcript begins as they are discussing the appropriate height for the tray once mounted on top of the rumba, which served as the base of the robot.

T: Okay. And so you were talking about the height of your stands and what you, you had said that- oh, well maybe you'll do it a certain way.
C: Yeah, in the middle of the three beds.
T: Okay. So what would that measurement be here? How would you figure out that measurement?
C: That would, wait…it would be all the beds to get all of it? No, it'd be the biggest height and then split that in half. So 32 in half is…
T: Are you trying to find the average?
C: Yeah.
T: So if you are going to take an average, you would take the three numbers. You would add them together and then you would divide them by three, if you're trying to get the average. Is that what you want? Or are you trying to do it one particular height to get to the person that…it's kind of your choice here.
C: No. I want it to be the average. So then it could get to anything. And it would either be a little too tall or a little too short. They [people in bed] would have to reach down a little bit or reach up, or like sit up.
T: Okay. So you think we should do the measurement or do you want to figure out the actual height?
C: I want to figure out the average.

The transcript highlights several things. One, Tonya provided Cindy with an opportunity to decide whether the average of the height of the three beds or the height of one bed was preferred (e.g., "It's kind of your choice here."). While Tonya more than likely knew the most appropriate approach within this context, she allowed Cindy to make her own decision (i.e., agency; Norén, 2015). Further, Cindy revealed her reasoning of why the average was appropriate in that the person in bed would have to reach down or up to gain access to food on the tray. Two, Tonya provided Cindy with the definition and language to describe the approach, which Cindy adopted as part of her language throughout the transcript (e.g., last line). Three, this example illustrates how Tonya was "with" Cindy in these moments as she gathered evidence of Cindy's thinking and made in-the-moment and intentional decisions regarding the project and Cindy's process and progress. This was often done through questioning.

In the next transcript, Tonya encouraged Cindy to find an alternative to converting inches to centimeters, which would be needed for her code.

C: *(Speaking into a tablet.)* Centimeters to inches.
T: *(Reaches across the table to grab a tape measure.)* Instead of using that, there's a way that you can figure it out using this. What do you think it is?
C: *(Grabs tape measure and pulls the tape from the housing. Smiles.)*
T: Yeah, you don't always need that. You can figure it out without just trying to get the quick answer.
C: Eight and a half. *(Let's go of the end of the tape and it retracts.)* I mean, no. *(Pulls the tape out again and seems to examine.)*
T: Yeah, that doesn't… Does that make sense to you? [Asking - How can 27 inches equal 8 centimeters?]
C: It said eight. *(Continues looking at the tape.)* Oh no, I get it. I get it. Sixty…sixty…sixty-eight and a half.
T: *(Takes the tape measure.)* These are decimals, so it actually would be 68 and six-tenths. When you're doing measurements, sometimes that tenth of a centimeter is going to make a big difference.

This mathematical moment was sparked through Tonya's question that pushed Cindy to think of another conversion strategy, namely, reading the tape measure. We also observed Tonya questioning the reasonableness of Cindy's first response of eight, indicating that 27 inches was the same as 8 centimeters. This question, as noted in the previous example, was intentional; it served a purpose as Cindy was encouraged to reflect upon her response (NCTM, 2014). Lastly, Tonya explained to Cindy the importance of accuracy and precision appropriate to this particular context (i.e., Mathematical Practice 6; CCSO, 2010).

Significance

The two examples presented here illustrated how one caregiver initiated and engaged their child in mathematical ideas and concepts that spontaneously arose within and throughout a self-identified engineering design problem. Tonya guided, supported, and challenged Cindy through a shared endeavor, designing a remote-controlled delivery robot (Rogoff, 1993). These spontaneous mathematical moments afforded authentic sense making between caregiver and child, which may be harder to attain in structured learning environments and other out-of-school contexts such as STEM-focused afterschool programs and summer camps (e.g., Vedder-Weis, 2017). For example, Cindy gained a different perspective and strategy of how to convert centimeters to inches; a strategy that was authentic and spontaneous to the design of the tray in this instance. Such mathematical moments were often initiated through questions for Cindy to explore within the design of the robot. These questions were not always answered orally, but addressed through physically engaging in mathematical ideas and concepts. Tonya further provided Cindy with a sense of agency in that Cindy was allowed to make mathematical decisions regarding the project. As such, we contend that this case highlighted how children can engage in mathematics in out-of-school learning contexts through the support and encouragement of caregivers. As a field, we should continue to think about ways to engage caregivers as mathematical partners, both within mathematics and STEM fields more broadly (e.g., engineering projects). As mathematical partners, researchers and educators should consider what is required for caregivers to actively and productively engage their children in spontaneous mathematical moments. Archer and colleagues (2015) made a similar argument in respects to science capital or the "level of scientific literacy and access to plentiful, high quality science-related cultural and social resources" (p. 15).

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