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Examining Mathematical Questioning during Math Walks

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Abstract: This qualitative study examines the use of math walks with middle grade students and adult facilitators at a local zoo. Drawing on situated learning and participation frameworks, we used interaction and stance analysis to compare two contrasting cases: In the first case, the adult chaperone asked more questions and evaluated student responses. In the second case, the adult chaperone intervened less frequently, leaving more room for student discourse. Findings support efforts to design informal math learning activities which amplify student voices, towards increased mathematical interest and learning.

Introduction

Despite the growing popularity of informal STEM learning environments, there is little research about how students learn mathematics in these spaces (Pattison et al., 2017). Additionally, facilitating mathematics learning in informal STEM environments can be challenging. Many adult facilitators do not have formal pedagogical training (Hmelo-Silver & Barrows, 2008) or may have difficulties with recognizing mathematics in informal settings (Peck et al., 2022). Therefore, we aim to investigate how adult facilitators and students collaborate to recognize and discuss mathematics in informal learning environments. To address this, we analyzed video footage of adults and students participating in math walks (Wang et al., 2021) at the City Zoo (a pseudonym). Our research question was: *What are different dynamics for adult-student interactions during informal math activities and what implications do these dynamics have for student learning?* Drawing on interaction analysis (Jordan & Henderson, 1995) and stance analysis (Goodwin, 2007), we identified and analyzed two contrasting cases (Schwartz & Bransford, 1998) to highlight how context and student-adult dynamics shaped the mathematical discussions.

Theoretical and Analytical Framework

This study is theoretically grounded in situated perspectives on learning, which recognizes that all learning is the development of participation structures specific to the setting, (Greeno, 2006). When considering mathematics, it is important to note that learned participation structures may not be especially useful or appropriate in other settings For example, based on their participation in "school math" students may come to believe that participation in a mathematical activity is constituted by obtaining answers to short, self-contained problems requiring repetitive calculations, with no larger goal or purpose for which the answers have meaning. Authentic participation practices in mathematical activities in real contexts (like designing an animal enclosure for a zoo) may bear little resemblance to how students are used to seeing mathematics in school. We believe the difficulty for students and adults to 'see' mathematics and negotiate mathematical meaning together in informal settings stems from this tension. To analytically map this tension, we draw on Goodwin's (2007) construct of participation frameworks which describe how participants publicly organize conversations through a series of stances. Goodwin describes five stances: instrumental, epistemic, cooperative, affective, and moral. We use Goodwin's stances to trace how adults and students together recognize and discuss mathematical ideas while participating in math walks. Here we only use the first three stances (instrumental, epistemic, and cooperative), because conversations in our dataset rarely involved affective and moral stances.

Table 1
Interactional Sequences

Stance	Definition	Example
Instrumental	Drawing attention to entities (objects, materials, etc.) that are necessary to complete the in-progress activity	Referring to an object (i.e., video) when posing a question
Epistemic	Positioning in a way that promotes the experience through perceiving or understanding the activity	When students discuss mathematical or science content
Cooperative	Organizing one's body in the direction toward others, as well as the environment, to sustain the activity	Involving other members in the group during a discussion

Context, Data Sources, and Analysis

We partnered with informal educators from the City Zoo to design three math walks, in various locations within the zoo. These math walks highlighted the mathematics of animal behavior, enclosure size, and coat patterns. We demoed the math walks with 20 middle grade students enrolled in a three-day City Zoo camp. Students were in six groups and paired with one adult. Students explored the City Zoo, participated in math walks, completed worksheets to summarize their thinking, and created their own math walks. Each small group was video recorded by the adult participant, using a hand-held video recording device. We began analyzing the video recordings by creating content logs (Jordan & Henderson, 1995). This allowed us to explore the data at a high-level to scope out patterns in interactions and mathematical questions. We created minute-by-minute content logs which documented the turn taking patterns between adults and students, the artifacts used or things referenced in the physical space (e.g., the worksheet, animals in the zoo), and the types of mathematical questions being asked and answered. At this point, we discovered the prevalence of some adult-driven small group discussions. We marked the content logs where adult questioning was most pronounced and compared the set of interactional sequences. For this manuscript, we selected two interaction sequences from the first day to transcribe, compare, and further analyze. With the two cases in hand, we turned to Goodwin's participation framework (2007) to describe how adults and students go about engaging in the math walk stops. Working line-by-line, we annotated each turn-at-talk as to whether it was an instrumental, epistemic, or cooperative stance. Our annotations described *how* a particular sequence of talk achieved a particular stance. In many cases, participant's talk functioned as more than one of the interactional stances (ex. a turn at talk could be coded as both instrumental and epistemic). In the sections ahead, we synthesize our annotations in order to 're-tell' these conversations, with an eye towards the contextual and interactional features that made these cases different.

Case A: Exploring Animal Walking Patterns

Our first case demonstrates how adults and students reproduced canonical mathematical classroom dynamics. This case involved three students and one adult. All three students were middle grade girls, two of the students were Latina (112 and 111) and one of the students was African American (116). The group of students was led by an adult member of the research team (RR) who was a South Asian man. At the start of the recording, the group was seated in a circle on the floor. The group had just watched a short video which explained the walking pattern of all quadrupedal mammals. The video recording began with RR asking the students what they found interesting about the video. Students 116 and 112 briefly mentioned "the walking patterns" and recalled the numerical code '3-1-4-2' which described the order in which legs strike the ground. RR prompted 116 - who was holding the clipboard - to record her group mates' answers. After a short silence from the group, RR began questioning the students to clarify what was interesting about animal walking patterns (below).

Table 2
Transcript from Case A

Line	Participant	Talk
A.1	RR	So for this one you could - like how else would you describe what's being answered though? The video is about walking patterns but
A.2	116	Like how the walking patterns work
A.3	RR	But we're trying to find a pattern between which animals
A.4	112	All of them?
A.5	RR	or not all animals, but what type of animals?
A.6	112/111	(simultaneously) mammals
A.7	RR	Mammals, but
A.8	112	It's called something I remember at the beginning.
A.9	RR	So, I know it's a complicated word.
A.10	112	(It is)
A.11	RR	(But) what is it? What's like a dumb like definition of that word?
A.12	111	Animals that walk on four legs
A.13	RR	Yeah, yeah, there you go. four legged animals.
A.14	116	Quad - quad - quadra
A.15	RR	quadrupeds

RR breaks the silence by asking the students "how else would you describe what's being answered though" (line A.1). Instrumentally, he drew students' attention back to the video. Cooperatively he faced the entire group, panning the camera back and forth to see all the students. Epistemically he signaled that students' initial interest in 'animal walking patterns' was not enough. Then, RR and the students engaged in a series of back-and-forth questions and responses until they had reached the correct answer - one that RR determined was sufficient. Student 116 took up RR's cooperative and epistemic stance, responded first, and said "like how the walking patterns *work*" (Line A.2). RR ignored her epistemic clarification (work), and instead posed a new question: "but we're trying to find a pattern between which animals?" (Line A.3). We interpreted this new question as both an epistemic stance (redirecting what types of mathematical questions should be asked) and a new cooperative stance (continuing to ask students to provide him answers - just not the one 116 had provided). RR led the students, through iterative questioning, to the scientific term 'quadruped.' The discussion ended when RR made two final statements. First, he made an epistemic stance by summarizing their conversation: "So it's trying to find a walking pattern between quadrupeds right - and then we we figured out that they all walked the same across - every single animal." Then, he made an instrumental stance by instructing student 111 to complete the worksheet: "you can - you can just write that - what are walking patterns? Or how do you - how do four legged animals walk - right?"

We interpreted this sequence as a reproduction of canonical mathematical classroom dynamics. The mathematical discussion was epistemically and cooperatively led by RR. Students participated only by taking up RR's cooperative stance and attempting to provide correct answers. When students did not provide correct answers, they were either ignored (as with 116) or redirected with a new question (as with A.10). Furthermore, instrumental stances were limited to references to either the worksheet or the video.

Case B: Exploring Giraffe Coat Patterns

Our second case demonstrated how adults and students engage in a more distributed dynamics relations and student-led talk. This case involved three students and one adult. All three students were middle grade boys, two of the students identified as multi-racial (117 and 118) and one identified as Latino (120). The group was led by an adult member of the research team (AM) who was a white man. The students watched a short video about giraffe's coat patterns. The recording began with the AM asking the students to recall the mathematical content from the video. Student 118 mentions that "you can measure the patterns of a giraffe." From there, Student 117 poses a question after observing the giraffe's behavior (Table 3).

Table 3
Transcript from Case B

Line	Participant	Talk
B.1	AM	okay, we can make a question or that hold that thought okay, let's think about that. So, what else from the video part?
B.2	118	Um that oh that you can make pattern that you can make pattern that well that you can **measure** the patterns of a giraffe
B.3	117	Why are their tongues so long?
B.4	AM	Why do you think so
B.5	118	to get the grass from the trees to get from the high trees (jump)
B.6	AM	What did you? What can you summarize what the video is saying?
B.7	117	Basically, that giraffes' patterns are math mathematical that you can solve them
B.8	120	They have different types of patterns.
B.9	117	Yeah, they have big patterns and small patterns
B.10	120	and different types of shapes
B.11	AM	OK
B.12	117	like squares, triangles, circles.
B.13	AM	Yeah
B.14	117	they can come in different sizes and different shapes.
B.15	AM	OK
B.16	117	Like that one has a lighter in different colors. There's a lighter one and that one has a darker one
B.17	AM	Yeah,
B.18	117	and she has hers a little bit more space a little bit more smaller. Like we're closing, like closer, like not so far away.
B.19	AM	Yeah, that's a good observation

The sequence this case follows is the progression of the conversation related to math patterns. AM begins the discussion in line B.1 by taking an instrumental stance by referring back to the video, epistemic stance by indirectly considering the mathematical concepts from the video, and a cooperative stance by encouraging all of the students to consider the question. Unlike in the first case, the adult facilitator allows the students to pose their own questions based on their observations from the giraffe exhibit and responds in an open-ended manner. In line B.3, student 117 notices the giraffes eating a lettuce leaf from zoo patrons, and poses the epistemic question, "why are their tongues so long?". Immediately, AM answers using a question, which instrumentally indicates that AM took up the students' idea, and epistemically places the agency and ownership on the student. However, AM also took a cooperative stance, based on his positioning toward all of the group members, which led another student (118) to take an epistemic stance and provide an answer to the group (B.5). After allowing the space for the students to consider their observations, AM again, takes instrumental, epistemic, and cooperative stances to have the students recall and summarize the video (B.6). The remaining conversation within this sequence is guided by the students. The students take an epistemic and cooperative stance by building on each other's responses. AM only contributes to the conversation using an instrumental stance, to affirm each students' contribution to the discussion around giraffe's coat patterns. This interaction sequence ends with student 117 taking an instrumental, epistemic, and cooperative stance, by facing and pointing to the giraffes and describing the pattern differences between the giraffes within the exhibit (B.16 and B.18). Finally, it concludes with AM taking an instrumental stance by saying, "Yeah, that's a good observation" (B.19) by acknowledging 117's epistemic stances. We interpreted this sequence as a more equal distribution of power between the adult facilitator and the students. The majority of the discussion was epistemically and cooperatively led by the students. AM's participation during the discussion was taking an instrumental stance to affirm each students' contribution.

Discussion

Our analysis traced the importance of adult facilitators in mediating student mathematical discussions in informal settings. In case A, we found that mathematical discussions were epistemically and cooperatively led by the adult facilitator, thus limiting the students' contributions. In case B, we found that mathematical discussions were epistemically and cooperatively driven by the students, thus enhancing the variety of mathematical questions which were posed. Furthermore, the environmental context differed greatly between the two cases. In case A, the adult facilitator and students were seated in a room away from the rest of the zoo exhibits. This provided a narrower field of possibilities for the students to reference when ideating possible mathematical questions. In contrast, in case B the adult facilitator and students were standing along the giraffe exhibit as they watched associated videos and discussed possible mathematical questions. This provided a broader range of possibilities for the students to explore their natural curiosities through observations, as well as from the videos. Implications for this initial analysis, suggest supporting the adult facilitators so they can better prompt open-ended and student-led mathematical discussions to connect the mathematical content to the present sites. It also suggests that the physical location in which informal mathematics learning discussions take place has important implications for the mathematical discussions that ensue. Finally, it highlights how tensions between academic and everyday mathematics can arise for facilitators in informal learning environments, and suggests that strategies should be developed to explicitly address these differenting participation structures.

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