Characterizing Collaboration with Metapragmatics: Using PreK Virtual Manipulatives on a Multi-Touch Tabletop

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Abstract: This paper is a microethnographic comparison between a pair of PreK (ages 4-5) girls and triad of boys working collaboratively on the same mathematical task. The children, matched by gender homogenously, are charged with completing a tangram puzzle on a SMART Table, a multi-touch tabletop that supports virtual manipulatives. Tasks are constrained by specific rules to encourage communication. Normally, collaboration can be investigated in terms of the task: did participants finish the puzzle efficiently? In contrast, we approach collaboration analytically as a way of acting. We define acting collaboratively as consistent alignment as to the focus of talk, and taking turns to complete the task while following the specified rules. We use the notion of metapragmatics to capture how a participant's actions (talk and gesture) are meaningful for the consequences of interaction.

Overview and Purpose

The purpose of this study was to examine the degree to which social constraints placed on PreK students (ages 4-5) working in pairs or triads to solve transformational geometry problems affected the quality of discourse. We applied a multimodal (talk, gesture) analysis technique to characterize a stage in the development of problem-solving and communication skills along with mathematical reasoning. This works extends prior efforts working with grade 2 students (ages 7-8), allowing us to compare findings as we establish a developmental perspective on mathematical reasoning in early childhood mathematics with manipulative technologies.

Impetus

Social Considerations in Education. According to the U.S. National Council of Teachers of Mathematics (NCTM), communication is a highly necessary component of mathematical comprehension (NCTM, 2000). The authors of NCTM's *Principles and Standards for School Mathematics* (2000) write, "Students who are involved in discussions in which they justify solutions – especially in the face of disagreement – will gain better mathematical understanding as they work to convince their peers about differing points of view" (p. 60). This communication-centered framework for understanding, which advocates a learner-centered pedagogy, differs noticeably from "transmission and acquisition" metaphors, is not only gaining attention in the learning sciences, but also in public school systems and teacher education programs. Previous studies have described communication as necessary for facilitating mathematical learning as collaborative, positive, and academically relevant. Researchers define this type interaction in terms of sharing, turn taking, and active talking or gesturing of instructions to peers. In contrast, this study seeks to bring a finer-grained notion of collaborative behavior, taken from linguistic anthropological literature, to bear on children's performance in such mathematical tasks. We examine the structure of their interactions on the whole, in both talk and gesture, looking for cohesive structures of speech and behavior, as an indication of collaboration and interactions that we suspect will facilitate greater learning. Directly related to communication is the idea of social constraint within the classroom. Social constraints are often embedded in instructional technologies, but not always incorporated into designed classroom activities. Implementation of these constraints, however, can foster communication; as the level of constraint increases, communication becomes increasingly necessary amongst the students (Saxe, 2002). As a means to understand how constrains influence communication, and subsequent attempts to collaboratively solve a mathematics problem, we have devised a taxonomy that is also meant to approximate certain constraints and enablers of physical and standard desktop virtual manipulatives. In this study we create an environment where children are each given a subset of the pieces for themselves. While our primary goal is to understand how communication, social constrains, and current technologies support the development of mathematical thinking, we are also interested in deriving requirements for future applications that may be developed for interactive surfaces, including multi-touch tabletops and tablets.

Mathematical Thinking in PreK Geometry. According to NCTM (2000), PreK-2 students should be engaged in learning geometric foundations. More specifically, children at this age should work to use direction, distance, location, and navigation skills to build mental maps through participation in hands on activities such as solving puzzles, individually or in small groups, with manipulatives. Additionally, children should move beyond simple trial and error strategies, and instead begin to develop the visualizing, describing, and justifying skills that will serve them as they progress through their studies of mathematics (van Hiele, 1985). With these mathematical goals in mind, a base-line ability for PreK students can be established.

Use of Manipulatives in Early Childhood Mathematics Education. As previously stated, NCTM (2000) recommends the use of manipulatives as PreK-2 students learn the basics of geometry. Furthermore, Tapper (2007) points out "…manipulatives, like tangrams, help students build on prior knowledge and expand both their math content knowledge and their problem solving skills" (p. 11). Given that young children have limited abilities to mentally transform shapes, activities allowing them to experience and perform such transformations on physical and virtual objects can contribute to development and refinement of this ability. Additionally, virtual tangram puzzle activities provide learners with the opportunity to create and share artifacts socially, and thus, by their very nature, create the opportunity for communication. Given the importance of communication,, we find it pertinent to advance how learning scientists characterize *collaboration* as socially-oriented, rather than task-oriented. In the following, we suggest that metapragmatic speech may prove fruitful, leveraging this construct to analyze data from a study on PreK-2 virtual manipulatives developed for an multi-touch tabletop.

Characterizing Collaboration via Metapragmatic Speech

Metapragmatic speech refers to speech about the occurring discourse. Metapragmatic speech may be more or less explicit such as markers of reported speech (explicit), performative verbs like say, opine, or yell (explicit), or metrical structures like pair-part turn-taking and repetition of poetic form (implicit). In the implicit case, the particular way speech is structured as opposed to all other possibilities comments on what sort of speech is occurring. Metapragmatic speech functions to characterize the present interaction as an interpretable sort of action. For example, the way speech is reported characterizes the interaction in which it originally occurred. When someone says, "Sally reported that she ran into a wall with her car," a listener has an idea of the interaction in which Sally did so as a presentation of "an informational account of some event, especially one that some listener awaited or was entitled to" (taken from Lucy, 1993, p.96). We understand this as such because the explicit metapragmatic 'reported' entails that which Sally said had the socially understood features of a report. Growing out of the sum of previous characterizations in that interaction's relevant past, the metapragmatic elements of an utterance "regiment" the references and predications of the pragmatic aspects of speech with respect to the future course of the interaction. They function in a dialectic among the history of what has been achieved in an interaction, the immediate description of the interaction, and what has now been done by describing the interaction in such a way (Silverstein, 1993). Consequently, collaborative interactions should not be called so simply because multiple participants are engaged in the same object task. Interactions are collaborative because participants act in a mode socially understood as collaborative, a fact that is analytically describable only with metapragmatics. Collaboration emerges when participants explicitly describe themselves as collaborating, or implicitly fit themselves into the structures we associate with collaboration as a way of interacting such as turn-taking structures marked by time and repeating poetic structures from turn to turn. Metapragmatic speech that functions to make an interaction coherently collaborative is a co-referential string (McNeill et. al., 2010). Such an interaction is composed of parallel structures across orderly turns that establish the same referential goal. A metapragmatic structure is maintained by repeated instantiations in talk and gesture. Because collaboration operates on a scale larger than a moment, an emergent collaborative character of 'what we are talking doing now' depends on the chain linkages of collaborative metapragmatics throughout an interaction.

Methods

Participants. For this study, participants consisted of three PreK girls and three PreK boys from a child development center for learning and research located on the campus of a large research university in the mid-Atlantic United States. During the virtual manipulative phase of the study, only two of the three girls were present due to fluctuations in summer attendance. *Location.* The child development center describes its mission as "to provide a model preschool program and leadership for local, state, and national early childhood communities in teaching, learning and research as well as to address the service missions of the university." Although a separate room was used when conducting research, the overall setting remained within the PreK classroom atmosphere. Students were not removed from the center, but instead led by a teacher to an adjacent classroom dedicated to participation in this project. *Setup.* Video equipment, consisting of two cameras, was set up to capture the students' faces and hands. Next, a SMART Table was placed in the corner of the room, with students being arranged around it. Finally, windows were covered with paper and a screen was placed behind the researchers to reduce distractions. *Task*. The task imposed social constraints on participants in three stages. This study focuses on the "divided ownership" stage, where each student has control over a subset of puzzle pieces only. This mode is meant to mimic a policy-heavy constraint that can be reproduced with physical or virtual manipulatives.

Metapragmatic Speech in Two Groups

Here we present two groups (depicted in Figures 1 and 2) showing significant differences in the way that they negotiated the task at hand. These differences can be located in the relative frequency of object co-references

and task co-references, and also in the function of metapragmatic speech, either to assert one's presence and correctness or to co-create a coherent structure for the interaction. Accordingly, Group 1 (girls) and Group 2 (boys) also differed in the way that they involved the teacher in their interaction. Group 1 made few object references in speech, none of which were negative. Gwen used object references only on one occasion to suggest where the other girl could put her piece next. Direct references to the task occurred rarely. Furthermore, most of their object references were non-verbal: gestural indications to objects or spaces, or uses of a point handshape to pull the piece around the tabletop. By contrast, Group 2 made frequent object references, as they pointed out where pieces are and where they should go, to themselves or their teacher, rather than to each other. These object references were not co-references as they were not chains of repeated reference to the same spaces or objects across turns and participants, but instead were disconnected. Most of their object references were verbal, and often used to undermine each other's actions. In a rare co-reference, one participant may convey that a piece should go "here," rather than "there," to which another replies "that does go there," ignoring the previous suggestion and continuing to move the piece in the intended direction, whether it fit there or not. Group 2 primarily discusses the objects in front of them, while Group 1 references them only infrequently.

Group 1_Stage2 00:00:43:00 – 00:01:02:00

Time	Name	Talk	Gesture
0:43-0:46	Emily	Hey can you move your stinky head?	Emily touches red piece
0:47	Ms. Lisa	That's not nice.	
0:49-0:50	Ms. Lisa	Is she teasing you Gwen? (both girls giggle)	Emily moves hands to green piece, moves it to the puzzle
0:54	Emily	Yeah.	Gwen touches blue piece, moves it to waiting space, and orients it to the puzzle
0:54-0:55	Ms. Lisa	You guys are a big tease.	
0:56-0:58	Emily	We are. We always tease each other.	Emily moves green piece on puzzle, trying to get it exactly right.
0:59-1:02	Ms. Lisa	Hey, there you go. Good job!	Emily and Gwen's pieces switch (computer error)

(0:54) Gwen moving the blue piece to waiting space from her corner

(0:55) Gwen holding the blue piece in waiting space

Figure 1. Transcript excerpt for Group 1 (Gwen and Emma) working with "teapot" puzzle.

Group 1 makes mostly explicit metapragmatic references to their interaction as being collaborative. Emily remarks "we always tease each other" and "we always know where it goes." These characterizations of their relationship have two functions: the first allows them to address each other throughout the interaction as "butthead," "stinky butt," "stinky head" and allows for these terms of address to not be considered offensive; the second describes their interaction as a collaborative one, at a time when there has been a break in their cooperation. When they hold two pieces too close together, the computer switches them and they jump apart. This gives Emily Gwen's piece and Gwen Emily's piece. Emily says "we always know where it goes" right after this break in their cooperative pair-part structure. By predicating both in the first person plural, Emily reaffirms that they are collaborating and are correct in how to do it. Group 1 only referred to the rules of the task at the very beginning of the interaction, when Emily asks "why is no one sharing the green?" The girls used explicit metapragmatics to describe themselves as in alignment. Group 2 (boys) however, predominantly made references to the task, reinforcing the rules imposed by the teacher in a competing manner. The few instances when they do speak about things other than the pieces in front of them are when a participant accidentally touches another's piece. Even though he may already have recognized his mistake in touching the wrong piece, the other boy reinforces the rule by saying "You can never touch any of these." While these instances are still metapragmatic, members of Group 2 use the rules of the task to assert their rights over the rights of the others. Only one boy uses 'we' once, to say "I know we turn it this way," after an open-ended "I know" by another boy, apparently describing how he is turning the piece to fit it in the puzzle. They do not talk about themselves as part of a group.

Discussion

Group 1 developed a distinction within the tabletop between their space, the waiting space, and the puzzle. Their metapragmatic strings of co-references created the turn taking structure that they used to divide labor in their virtual tangram puzzle. They developed a spatial regimentation of the board, where each participant had her own corner of the board, and an area between the puzzle outline and the corners served as waiting space. When Gwen or Emily moved a piece from their personal space to the puzzle they took control of the turn, the other would then move a piece from their space to the waiting space. This continued in turns. They also used their teasing words as ways of enforcing their turn taking. Early in the interaction, Emily uses the formula 'move your ___' as she is beginning her turn of moving a piece. Later, Gwen says "move your poop head" to which Emily responds "move your butthead" and "move your stinky butt." These happen when she is taking a particularly long time to orient a piece perfectly in the white background. This is not immediately effective, and Gwen finally ends this with a "move your hand" and grabbing Emily's hand out of the way. After the first iteration of this formula, Emily describes it dismissively as typical of their friendly interactions, making it non-insulting. By using it as she takes her turn with the puzzle, the parallel structure of this formula functions as an implicit metapragmatic indication that they are taking turns, not simply talking. When Emily takes too long on her turn later in the interaction, she and Gwen use this formula with neat parallelism to determine whether her turn with the puzzle is over. Gwen ends by breaking slightly with the structure and talking about Emily's hand, not addressing her with a silly name. Group 1creates a turn taking structure by continuing to act it out non-verbally throughout the interaction, which is mirrored in the parallelism in their speech. This metapragmatic chain of co-references in action and speech instantiates their explicit metapragmatics of collaboration.

Group 2_Stage2 00:01:02:000 - 00:01:15:000

Time	Name	Talk	Gesture
1:02-1:03	Jason	How do I do this?	Jason looks at his piece and starts moving it toward the puzzle.
1:04-1:05	Rico	Hey how did this happen?	Rico attempts to move triangle piece with index finger.
1:06-1:07	Jason	How did this happen?	Notices piece to be upside down.
1:07-1:08	Charlie	Rrrrr	Moves piece rigorously.
1:09-1:11	Jason	Hey move, silly.	Uses index and middle finger at first in an attempt to rotate piece, then rigorously attempts move it with the index finger.
1:12-1:13	Rico	Hey move, silly.	Attempts to move piece into place, now using index and middle finger.
1:13-1:15	Charlie	Move the right way, silly.	Still moves piece rigorously, attempting to rotate it.

(1:09) Each of the boys is struggling with the technical aspects of the puzzle. While their speech and gesture show a degree of parallelism, reflected in the repetition of similar words and gestures, it is directed at each of their puzzle pieces, rather than each other.

Figure 2. Transcript excerpt for Group 2 (Jason, Rico, Charlie) working on "teapot" puzzle.

Group 2 also makes an exchange with parallel structure, but we cannot call it a chain of co-references. They are not participating in a turn taking structure; rather each mimics the speech of the other while performing their own task. As they all struggle with the technical aspects of the puzzle, one of the group members utters in frustration "move silly," which triggers a chain reaction of the other two members repeating the same or a similar utterance. Comparable scenarios occur frequently throughout that group's interaction, most of which related to their inability to solve the puzzle, rather than indicating attempts at solving the puzzle in a cooperative manner. While their speech and gesture suggest a form of parallelism, it is directed at each of their puzzle pieces, rather than at each other and can therefore not be characterized as the sort of cooperation we find productive. They are not taking turns at the time, and because their gaze and focus of action continues to be on their pieces on the board, this parallelism is not part of a chain of co-references to the same puzzle piece and cannot be seen as metapragmatically instantiating cooperation. Groups 1 and 2 also interacted differently with the teacher present in the elicitations. Group 1 seemed to be interacting with each other into the structure of which the teacher would interject. The teacher's comments were often giggled at and not responded to directly. The individual participants in roup 2 however, used the teacher as their interlocutor, rather than each other. The teacher frequently had to encourage and remind them to help each other, which created an artificial sense of cooperation in certain instances. Most importantly, group 2 actively sought recognition from their teacher for accomplishing tasks. If one boy moved the piece into the right place, the teacher would praise his efforts, which in turn seemed to motivate the other boys to put pieces into the right place as well, in order to be praised and

recognized by the teacher. Consequently, group 2 mostly addressed the teacher, and not each other. Overall, group 1 used speech and gesture to create a turn taking structure integrated with the space on the board, through which they collaborated on their task. They both used implicit and explicit metapragmatics in the same way, to achieve alignment. Group 2 in contrast, worked mainly individually, in occasional dialogue with the teacher or competitively with each other. They accomplished the task; however, it took them 3:52 min. to complete their puzzle, whereas it took Group 1 2:15. Even though Group 1 was composed of girls, and Group 2 of boys, we do not intend to use these data from only two elicitations to draw comparisons along gender lines. It is suggestive that the two groups behaved so differently in these cases, but there are other factors that may condition this. There were only two girls in Group 1, while Group 2 had three boys. It may have been easier to maintain turn taking and negotiate space on the table with only two participants. Either way, these two groups exemplify different types of metapragmatic behavior that have different functional consequences in their interactions. Group 1 co-created a coherent poetic and metrical structure that puts them in alignment (even when they 'tease' each other), whereas Group 2 competed for praise and the floor. With reference to mathematical learning, we believe that the coincidence of a coherent interactional structure characterized by a metapragmatics of collaboration and relative ease with completing a task are not coincidental. The group that collaborated implicitly negotiated the task through the structure of their talk and action. The group that did not collaborate explicitly discussed the task, but their talk seemed to be for themselves or the teacher, and got in the way of attention to the accuracy of their movements with relation to the mathematical goal of the task. We believe that collaboration in this sort of task can then be seen as an indicator of attention and mathematical ability.

Conclusion

In this paper, we present a rationale for investigating PreK mathematics education, focusing on the social, cognitive, and technological priorities as advocated by national standards organization. This study is significant in that it may serve learning scientists interested in characterizing collaboration and early childhood educators intending to enhance communication as a pedagogical value (Ares et al., 2009; Clements et al., 2004). Additionally, this study involves extending our framework for multimodal analysis of nonverbal and verbal deixis to apply to the PreK age range. In addition to generating findings about which virtual and physical modalities are most successful for different types and levels of PreK learners, we are also generating more general information about communication habits of students in this age range and their potential for distributed cognition. Given a larger goal of developing additional software for multi-touch and interactive surfaces, these results begin to lead to new requirements for instructional strategies and technologies. Additionally, the system of coding we are continuing to develop for this data may be useful to other researchers seeking to find complex patterns in multimodal data, especially in work pertaining to early childhood education.

References

Ares, N., Stroup, W., & Schademan, A. (2009). The power of mediating artifacts in group-level development of mathematical discourse. Cognition and Instruction, 27(1), 1-24.

Clements, D., Wilson, D., & Sarama, J. (2004). Young children's composition of geometric figures: A learning trajectory. *Mathematical Thinking and Learning*, 6(2), 163-184.

Lucy, J. (1993). Metapragmatic presentationals: reporting speech with quotatives in Yucatec Maya. In John Lucy (ed.) *Reflexive Language: Reported Speech and Metapragmatics. 91-125*. Cambridge: Cambridge University Press.

McNeill, D, Duncan, S., Franklin, A., Goss, J. Kimbara, I. Parrill, F. Welji, H., Chen, L. Harper, M. Quek, F. Rose, T. & Tuttle, R. "Mind-Merging". In a Festschrift for Robert Krauss, Ezequiel Morsella (ed.), *Expressing oneself / expressing one's self: Communication, language, cognition, and identity*. London: Taylor and Francis. 2010

National Council of Teachers of Mathematics (2000). *Principles and standards for school mathematics.* Reston, VA: National Council of Teachers of Mathematics.

Saxe, G. (2002). Children's developing mathematics in collective practices: A framework for analysis. *The Journal of Learning Sciences*, *11*(2&3), 275-300.

Silverstein, M. (1993). Metapragmatic discourse and metapragmatic function. In John Lucy (ed.) *Reflexive Language: Reported Speech and Metapragmatics.* 33-58. Cambridge: Cambridge University Press.

Tapper, J. (2007). Tangrams and geometry concepts. *Connect Magazine, 20*(4), 7-11.

van Hiele, P.M. (1985). *Structure and insight: a theory of mathematics education.* Orlando, FL: Academic Press.

Acknowledgments

National Science Foundation (Awards 0736151, 0832479); SMART™ Technologies