Engaging Students through Math Talk and Questioning Techniques

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Action research is an effective tool that allows teachers to reflect about their teaching practices while connecting educational theory and research to classroom instruction. In the present study, I (Dr. Halimun) used two learning tasks and addressed the following research question: Does my classroom discourse show a student-centered pattern? Through this study, I discovered a performance gap between my standards-based intentions and my actual classroom practice.

Introduction

After teaching high school mathematics for twelve years, I unwittingly believed my teaching aligned with the reform vision elaborated in the *Principles and Standards for School Mathematics* (NCTM 2000), hereafter called "the standards." However, discussions and readings in graduate classes about practices of critical reflection unsettled this belief. When a teacher consistently examines his/her practice, reviews problems and makes improvements, it is referred to as reflective teaching (Qing 2013). The call to be reflective compelled me to verify that my standards-based teaching intentions matched my classroom practices. Thus, I launched an action research project to examine the following question: Does my classroom discourse show a student-centered pattern? Focusing on whole-classroom discourse –a type of mathematical discourse that receives extensive attention in the standards– I entered the realm of research necessary to connect educational theory to my classroom practice. Although the study was conducted in my classroom, Dr. Kohler provided valuable resources on teacher reflection to illuminate the new knowledge base in teaching practice.

Theoretical Framework

Having reviewed research studies in the field of mathematical discourse, I knew my action research needed a guiding path to analyze classroom discourse. Thus, I aligned my action research with an established research study: Nathan and Knuth's (2003) theoretical framework implemented in "A Study of Whole Classroom Mathematical Discourse and Teacher Change." I employed this framework as a yardstick to find the level of discourse practice occurring in my classroom because the framework embodies charts that guide teachers to 1) examine discourse traits and 2) classify student responses in a real classroom setting. Within this framework, my study sought to recognize evidence of the specific standards-based teaching intention of whole-classroom discourse – a format in which students become actively involved in making sense of mathematical situations. At the core of this action research, I practice reflective teaching to build a knowledge base which involves the ability to make rational changes and to assume responsibility for those choices. As Suter (2006) proposes, teachers who are reflective practitioners can make significant contributions to instructional improvement. Additionally, teacher efforts to improve mathematical discourse link this action research to other research studies focused on how the teacher promotes students' thinking. I shared the view of Doerr (2006) from "Examining the Task of Teaching When Using Students' Mathematical Thinking," in which she suggested that teachers adopt interpretive and hermeneutic orientations. Doerr describes the interpretive and hermeneutic orientations to clarify the teacher's understanding in shifting role from evaluator to facilitator, whose goal is to make sense of how students are interpreting the learning task.

Methodology and Data Collection

In general, a classroom teacher initiates action research by establishing transparent lines of collaborative communication with colleagues and overseers. Planning my research project, I collaborated with a network of support in drafting a letter to parents, obtaining school district approval and choosing a method to collect data. I decided to use video-recording of whole-classroom discourse in a ninth grade Math Support Class that I taught.

To execute my plan, I arranged student seats to facilitate whole-classroom discussion and assigned seat numbers according to the class roster as shown in Table 1. Next, in correspondence, I drew a seating chart to map flow of information, where each small circle represents a student (see Figure 1). This flow of information chart, when completed, will record vertical and horizontal responses, which will be shown after presenting data from two tasks: Painted Cubes and Triangles Learning Tasks.

Table 1

Female		Male	
Seat Number	Name	Seat Number	Name
1	Dora	3	Fort
2	Mae	4	Todd
5	Kay	8	Troy
6	Tess	10	Ben
7	Nina	12	Ramos
9	Lupe	13	Dan
11	Hope	15	Patel
14	Vera	19	Park
16	Sue	24	Wes
17	Ali	25	Jed
18	Rosa	28	Grant
20	Liz		
21	Jen		
22	Tara		
23	Juana		

26	Beth
27	Novi

Table 1 Class Roster with assigned seat numbers

The circles represent students listed in Table 1. The line thickness represents relative frequency of the expected responses.

Analytical scaffolding from teacher.

Social scaffolding from teacher.

Analytical scaffolding from math-talker (student who responds and participates during a whole-classroom discussion).

Social scaffolding from student.

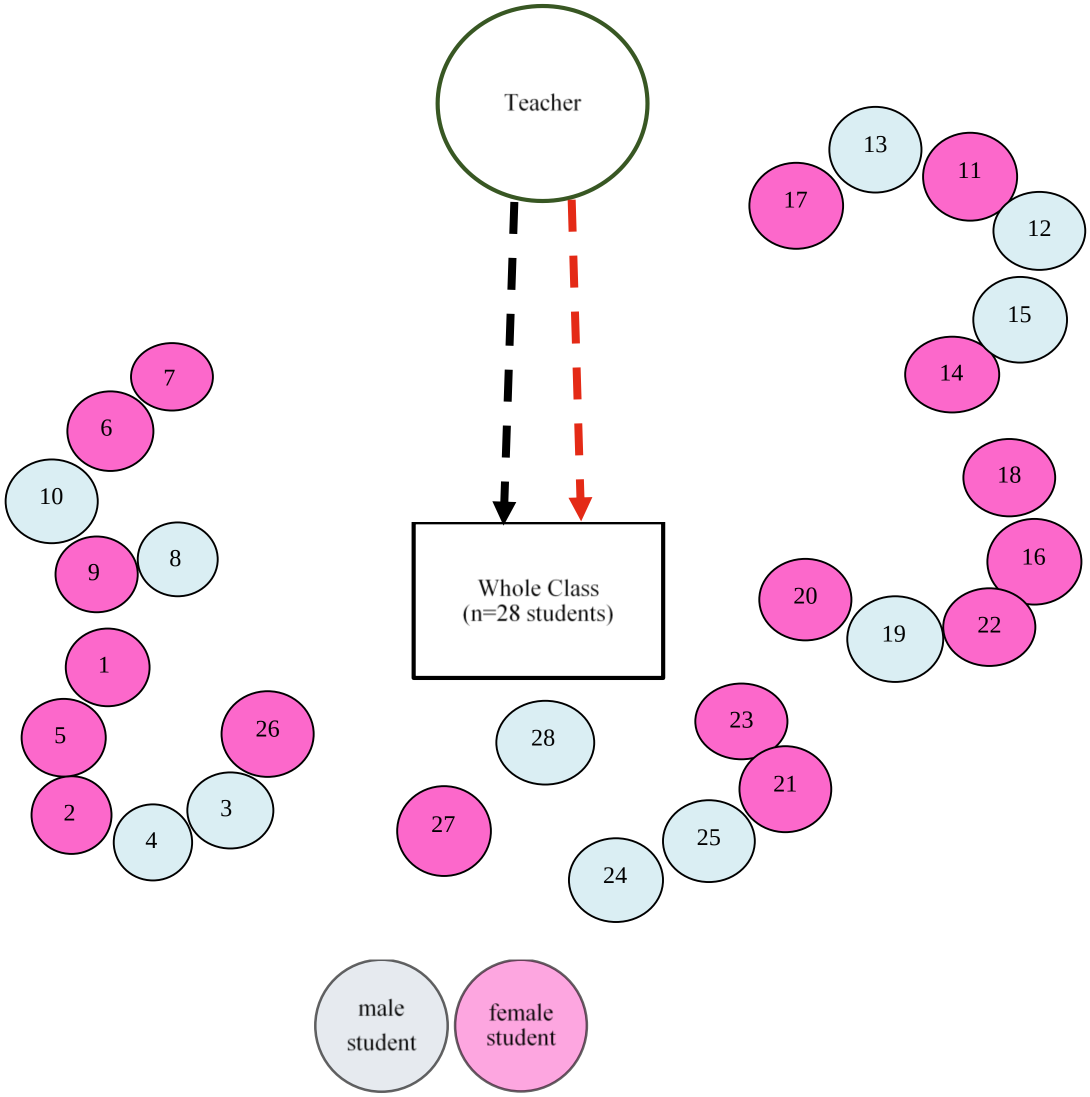

Figure 1. The Flow of Information Chart adopted from Nathan and Knuth (2003)

The Painted Cubes and Triangles Learning Tasks include activities suitable for small group interactions and whole-classroom discussions in ninth grade mathematics classes. The Painted Cubes Learning Task can be found online at https://www.georgiastandards.org/Frameworks/GSO%20Frameworks/9-12%20Math%20I%20Student%20Edition%20Unit%201%20Function%20Families.pdf (page 55).

The Triangles Learning Task can be found online at https://www.georgiastandards.org/Frameworks/GSO%20Frameworks/9-12%20Math%20I%20Student%20Edition%20Unit%203%20Geometry.pdf (page 14). It took five days to present both learning tasks. The class produced a set of rules and a corresponding poster (see Figure 2) called "Math-Talk Norms" in order to create an environment of respect. Aligned with this effort, I encouraged students to be math-talkers who are willing to respond and participate during our whole-classroom discussions.

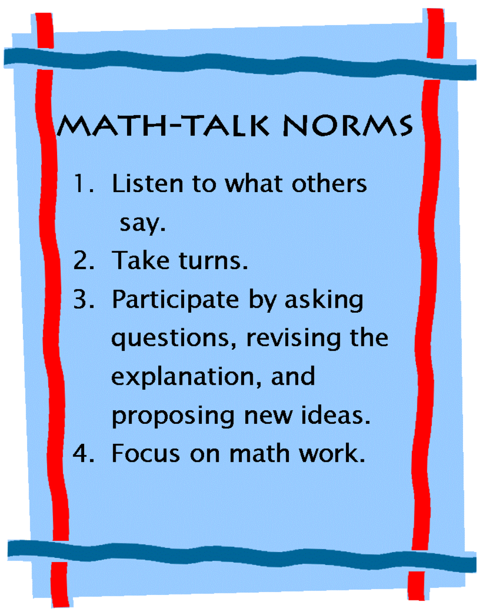

Figure 2. Poster of Math-Talk Norms

The Painted Cubes

In the Painted Cubes Learning Task, students worked in small groups to build a large cube out of smaller cubes as an initial investigation (Problem Number 1, part a). In Problem Number 2, the task presents a table and asks students to fill in the number of painted faces that they observed from building a large cube with edge lengths of 3, 4, 5, 6, and 7 centimeters. Since there were not enough small cubes to build a large cube, students needed to recognize the pattern of numbers and predict the number of painted faces all the way to a cube with an edge length of 7 centimeters. Students used the values table where the edge length of the large cube is the input and the number of painted faces is the output.

The process to find the pattern from the input and output values was not flowing successfully. Students gave up investigating in their small groups. Thus, I began a whole-classroom discussion. During the discussion Todd said, “Each output is divisible by twelve.” Trying to extend Todd’s idea, I probed, “Guys, we’re almost there. This is twelve times what? What is the output when you have twenty? Twelve times what?” These questions focused on the answer, rather than on the strategy, which resulted in students responding with one word or brief descriptions of their thinking. I reviewed the video recording several times, transcribed the spoken words of the whole-classroom discourse, and charted the flow of information.

Flow of Information

The application of the analytical and social scaffolding framework involved classifying each sentence to examine the flow of information and type of scaffolding. For the flow of information, Nathan and Knuth (2003) coded each sentence with a “From/To” label. For example, *TS* indicates a sentence directed from the teacher to a student in vertical interaction. For each sentence (or group of sentences that are related to one line of thought), an additional code labeling A (analytical scaffolding) or S (social scaffolding) was given for the type of scaffolding it represented. The application of Nathan and Knuth’s (2003) coding scheme is presented below:

> Todd: “Each output is divisible by twelve.” ST – A – V (Student-to- teacher; analytical scaffolding; vertical)
>
> Teacher: “Guys, we’re almost there.” TS – S – V (Teacher-to-student; social scaffolding; vertical).

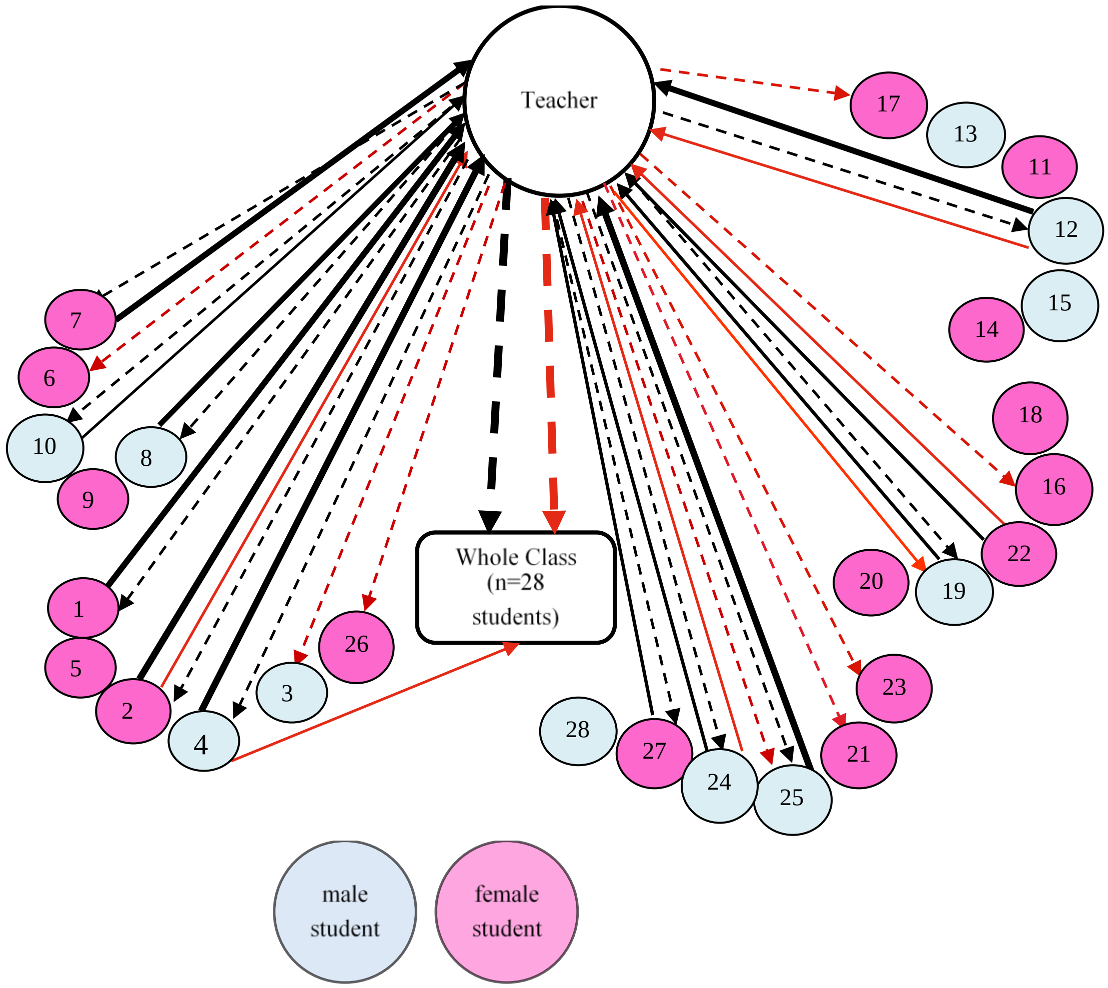

Figure 3. The Painted Cubes Flow of Information adopted from Nathan and Knuth (2003)

Figure 3 presents the flow of vertical and horizontal information that occurred during the Painted Cubes Learning Task. Separate nodes represent each student, the teacher, and the class as a unit participant. The frequency of interactions for each math-talker was measured by the tallied number of sentences spoken and received by that node. The flow of information indicates Nina (7), Troy (8), Dora (1), Mae (2), Todd (4), and Ramos (12) became the prime math-talkers of their groups. Jed (25) participated equally as a math-talker in his group. Jed's participation indicated personal growth and the usefulness of the exercise because he usually does not try to solve math problems. He historically lacks confidence and work ethic, which is most likely due to the fact that he failed his freshmen math class. The activity helped break this patterned behavior.

The examination of the Painted Cubes Task indicated the barrier between my standards-based teaching intention, and the actual classroom practices where I maintained the practice of a traditional teacher-centered classroom. This finding is an important *performance gap* in teaching practice as described by Herbel-Eisenmann and Cirillo (2009). In reflection, I recognized my need to develop more discourse strategies by asking myself, "How can I improve the whole-classroom discussion?" I need to facilitate small group discussions where students can share their ideas and support each other before taking the role of math-talker in the whole-classroom discussion. As a facilitator, I need to listen to my students and pose more questions that focus on their thinking. I need to constantly remind myself that my goal is to slow down the process of getting an answer in a whole-classroom discussion. Discourse is about eliciting multiple strategies from different students.

The Triangles

In the Triangles Learning Task, students worked in groups of three to construct triangles and appropriately justify their conclusions. The class decided to use two sides and one angle. They chose side lengths of 5 and 7 inches with an angle of 40°. While working in groups students explore three cases: 1) angle between the two given sides, 2) angle opposite the 5 inches side, 3) angle opposite the 7 inches side.

Figure- 4 is an example of student work from Case 2, which shows a student's participation and completion of the learning task in her group prior to a whole-classroom discussion. Dora constructed an angle of 40° opposite the five inch side to compare with a larger triangle that also had a 40° angle opposite the five inch side. She used the same endpoint for the five inch side to show these two triangles are not congruent. Dora explained, "They are not congruent even though they give you 5 in- 7 in- 40º the same measurements but produce different shapes."

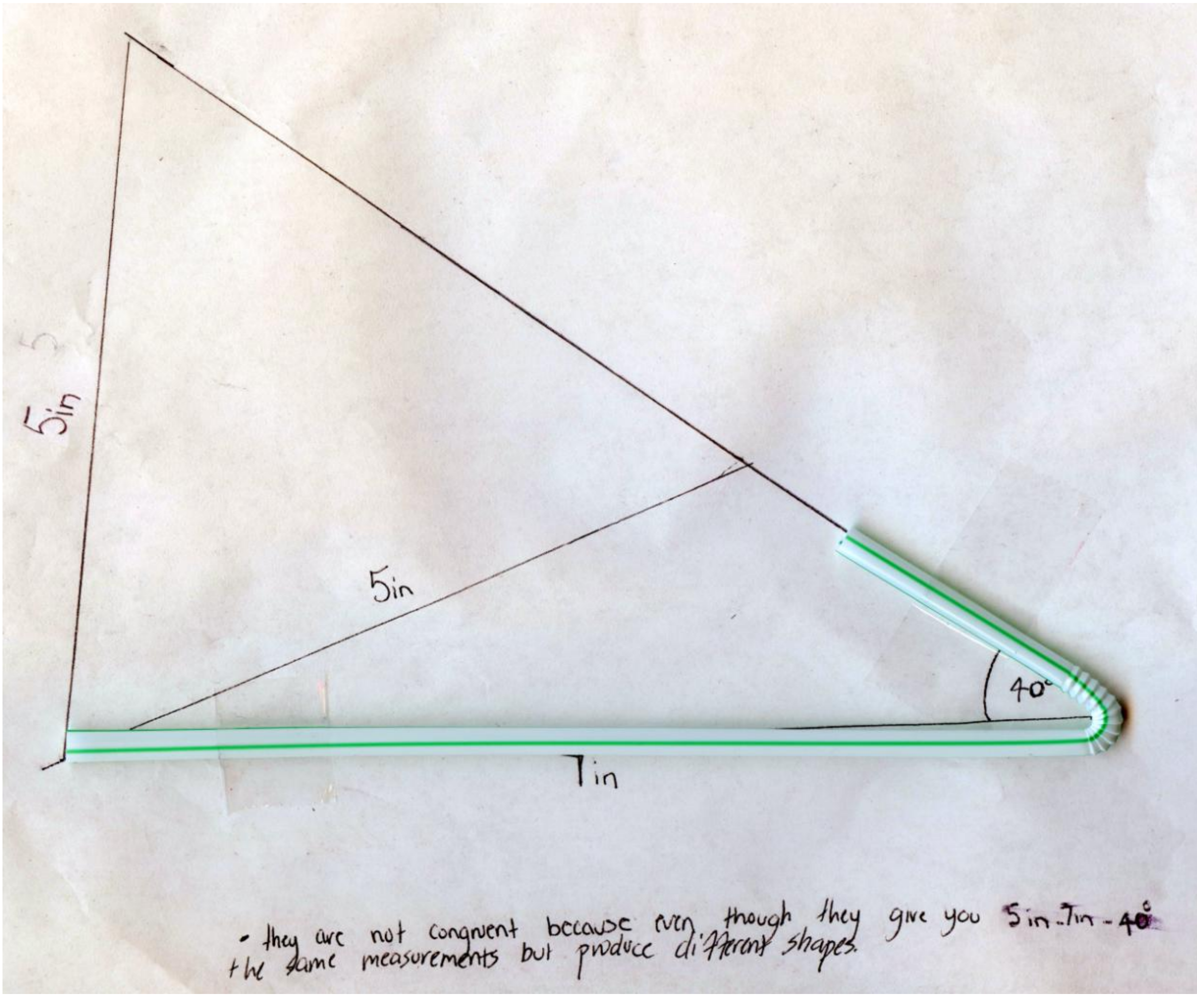

Figure 4. Dora constructed 2 triangles, each with angle 40° opposite the 5 inches side

In a whole-classroom discussion, I began to probe questions that prompted students to explain their mathematical thinking. “Does it matter what order the two known sides and the known angle are in?” Todd immediately responded, “Yes.” I followed his answer with, “Why does it matter, Todd?” Shortly after, Dan answered, “The triangle would be different.” I used Dan’s idea and probed, “The triangle would be different. And different how? Can anybody comment?” This time Tess volunteered, “Because it’s not in order.” I pressed further, “It’s not in order. Please explain.” Tess described, “Like, if it’s side-side-angle, the angle would be moved, like, over.” (Tess moved her left hand up into the air).

While exploring the above cases, students responded with brief descriptions of their thinking. I noted (from the field notes) that Nina, Todd, Ben, and Troy responded in sequence or almost at the same time as Troy or Nina gave the answer. This phenomenon showed that students responding to each other's ideas may intrigue other students to join a whole-classroom discussion.

Repeating the process of collecting data as I did in the Painted Cubes, I applied the analytical and social scaffolding from Nathan and Knuth (2003) to transcribe the whole-classroom discussion and chart the flow of information for the Triangle Learning Task. Figure 5 presents the flow of vertical and horizontal information that occurred during the Triangles Learning Task. The nodes include new math-talkers Tess, Dan, and Grant (indicated by stars). The overall pattern of the flow of information still indicates the teacher's role as the center of discussion

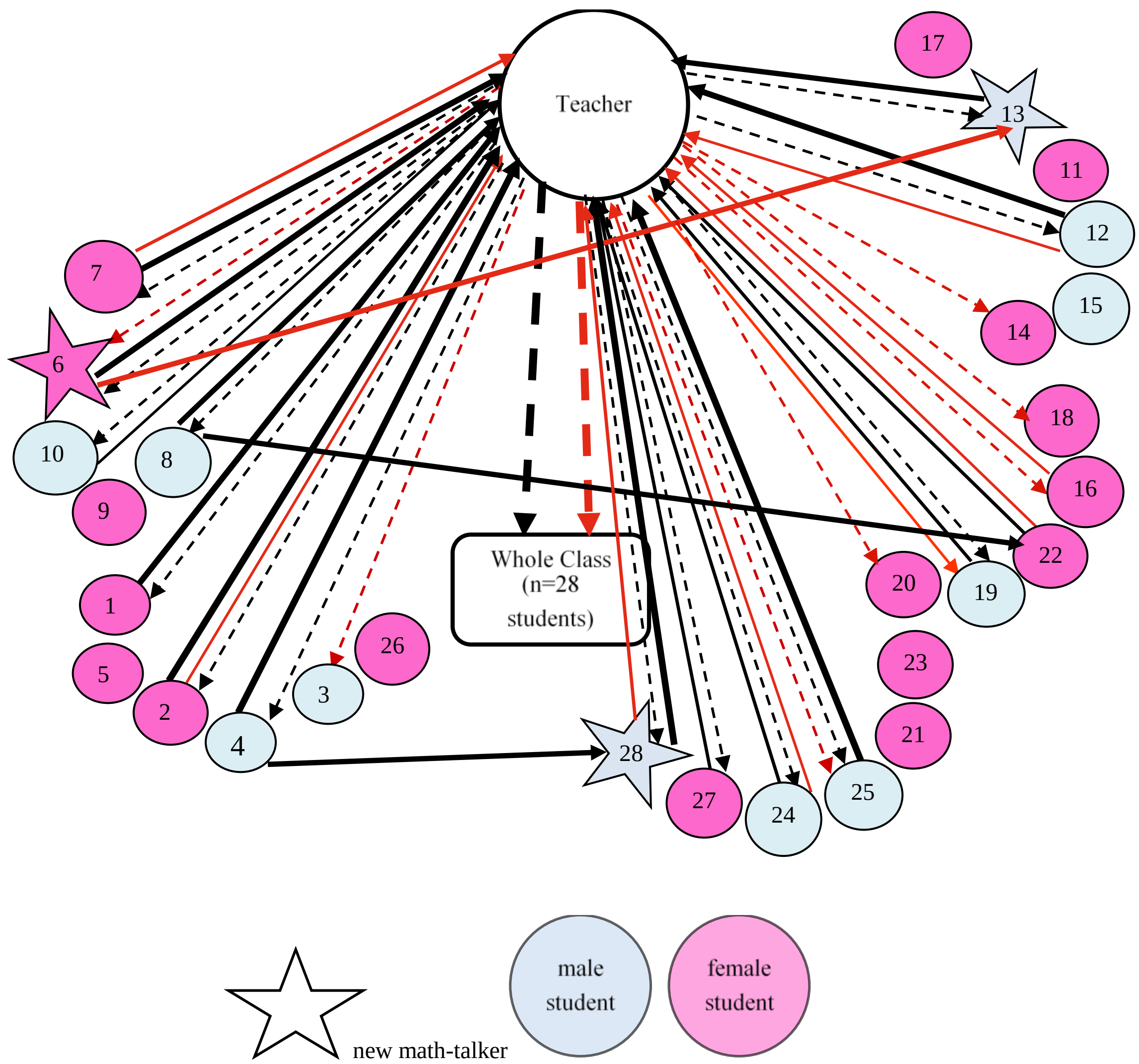

Figure 5. The Triangles Flow of Information adopted from Nathan and Knuth (2003)

Discussion and Conclusions

The examination of classroom discourse revealed several important aspects of discourse practice. First, the transcript of a whole-classroom discussion during Painted Cube indicated that the goal of my questioning is to identify and lead students' thinking in the way of how I would approach the problem. The new awareness I gained motivated me to change my discourse behavior to reflect the multiple ways of student thinking emerged during a whole-classroom discussion. Alternately, I need to adopt the interpretive and hermeneutic orientations suggested by Doerr (2006). Teachers employ interpretive orientation by listening to their students' ideas with the aim to access students' understanding and asking for elaborate responses, demonstration, and explanation. A teacher with hermeneutic orientation interacts with their students and engages them in a negotiation of meaning and understanding.

During the whole-classroom discussion in the Painted Cubes, the absence of the teacher's listening and probing skill consequently increased students' dependence on the teacher rather than other students for mathematical ideas. This reflection encouraged me to improve my questioning strategy with the goal to make sense of students' thinking and to help them describe their thinking. This perspective motivates me to practice an interpretive orientation while orchestrating a whole-classroom discussion as an ongoing process of upgrading my teaching skills.

Second, the experience in Painted Cubes became a self-study to construct a new way of supporting students to become math-talkers in a whole-classroom discussion. I focused on being a better facilitator in small group discussion by asking probing questions and helping students to describe their thinking. The questioning in small group discussion related to the teacher's role as a facilitator who created an environment of negotiation to access students' thinking. It also helped students to practice their problem solving skills (hermeneutic orientation). As a result, in the Triangles learning task students participated in listening and responding to each other's comments. The dialogue carried over into the whole-classroom discussion. Students demonstrated progress by taking roles as math-talkers and began to respond to one another. Therefore, this finding suggests that the absence of small group discussion impedes students' contributions to whole-classroom discussion.

The analytical and social scaffolding framework presented in this study provides a practical tool for evaluating mathematical discourse in a classroom setting. In particular, my experience in evaluating classroom discourse provided an example of using reflective action through two learning tasks. After gaining insight into my own teaching practice, my new reflection prompted me to ask myself whether I posed questions that probed students thinking, guided students to refine their answers, and elicited more insightful responses among math-talkers. The flow of information chart was a useful tool for reflective teaching that allowed me to find the answers related to these questions.

Updating knowledge on how to improve my own discourse behaviors, I feel encouraged to share my findings to other mathematics teachers in my school and the entire mathematical community. Helping students explain their mathematical thinking paired with good questioning strategies leads to a great student-centered classroom. Furthermore, classroom discourse can also be improved across the grade level. These efforts include teachers who collaborate with each other through planning, practicing discourse strategies, and reflecting about their classroom discourse as a team in order to enhance student mathematical growth.

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