An Investigation of Teaching Practices for Facilitating Whole Class and Small Group Discussions in Middle School Mathematics Classrooms

Sukanya Suksak

Department of Mathematics, Faculty of Science, Srinakharinwirot University, Bangkok, Thailand
E-mail: sukanyasuk@g.swu.ac.th

Abstract

This observational and interview study aimed to explore how an experienced middle school teacher, Ms. Watson, from a public school in a small college town in a midwestern state in the United States, used talk moves to elicit students' thinking and facilitate both small group and whole class discussions. The study also examined her perspectives on using talk moves in order to accomplish particular goals. In this study, observations of Ms. Watson's entire instructional unit, which focused on three-dimensional geometry, were conducted. Five teacher interviews were conducted to elicit her perspectives on utilizing the talk moves. To ensure trustworthiness of this study, triangulation was employed by obtaining critiques on the codes and some of the findings from another colleague and Ms. Watson. The findings revealed that Ms. Watson's talk moves for eliciting students' mathematical thinking and facilitating discussions could be categorized into five types: probing a student's thinking, challenging a student's conjecture, gathering students' ideas or observations, asking students to engage with another's reasoning, and asking students to make predictions. Some of these talk moves were similar to those identified in previous studies. However, some of them arose from the data. Ms. Watson also used each of these talk moves for several purposes, including to ensure students' mathematical understanding, to learn students' mathematical thinking, to ensure her interpretations of students' ideas, to orient students' mathematical thinking, and to help her make decisions about the next steps in lessons. Some of Ms. Watson's purposes and findings differed from previous studies.

Keywords: *Discussion, Talk move, Middle School Mathematics, Teacher Perspectives*

1. Introduction

Several well-known contemporary policy documents have recommended teaching practices that support mathematical communication in mathematics classrooms. The National Council of Teachers of Mathematics (NCTM) named communication as a process standard in the *Principles and Standards for School Mathematics* in April 2000 (NCTM, 2000). Indeed, facilitating meaningful mathematical discourse is one of eight recommended mathematics teaching practices in *Principles to Actions* (NCTM, 2014). In this document, NCTM states, "Effective teaching of mathematics facilitates discourse among students to build shared understanding of mathematical ideas by analyzing and comparing student approaches and arguments" (p. 29). The Common Core States Standards Initiative (2010) also highlights developing mathematical proficiency via communication in the third Mathematical Practice, stating that mathematically proficient students are able to "construct viable arguments and critique the reasoning of others" (para. 4). To meet this standard, teachers need to establish mathematics classrooms in which students have opportunities to develop these mathematical skills. In addition, the Core Practice Consortium (CPC) lists leading discussions as one of the core practices of high-quality mathematics instruction (Jacobs & Spangler, 2017).

Although mathematical discussions are recommended by many contemporary policy documents, productive mathematical discussions in classrooms are rare. Studies indicate that creating mathematical discussions in classrooms is one of the most challenging tasks in teaching (Cengiz, Kline, & Grant, 2011). Bennett (2010) found that the task of creating mathematical discussions was even more difficult for new teachers. Fortunately, Bennett (2010) found that first-year mathematics teachers were able to improve their ability to conduct whole class discussions in their mathematics classrooms with support, guidance, and feedback on their teaching practices from a mentor.

One way to support teachers in establishing mathematical discussions is to introduce teachers to specific talk moves for facilitating those discussions and eliciting students' mathematical thinking, along with the purposes of using these moves. Researchers have examined several of these talk moves, such as revoicing (e.g., Herbel-Eisenmann, Drake & Cirillo, 2009), creating opportunities to engage with another's reasoning (Franke, Turrou, Webb, Ing, Wong, Shin, & Fernandez, 2015; Herbel-Eisenmann, Steele, & Cirillo, 2013), and teacher questioning strategies (e.g., Cengiz et al., 2011) that teachers can learn to prepare them to facilitate discussions and to use students' responses effectively in mathematical discussions.

Moreover, several frameworks for supporting teachers in leading discussions in mathematics classrooms were proposed. One of them was the *Teacher Discourse Moves Framework* developed by Herbel-Eisenmann and colleagues (Herbel-Eisenmann et al., 2013). It affords more flexibility for utilizing during mathematical discussions within different lesson structures. The authors claim that when teachers use these talk moves purposefully, they can be beneficial for students' participation and development of their mathematical thinking and reasoning (Herbel-Eisenmann et al., 2013). Herbel-Eisenmann and colleagues proposed six talk moves, which include (1) *waiting*, (2) *inviting student participation*, (3) *revoicing*, (4) *asking students to revoice*, (5) *probing a student's thinking*, and (6) *creating opportunities to engage with another's reasoning* (Herbel-Eisenmann et al., 2013). However, for the purpose of this study, I chose to discuss only three of them that mainly are used to elicit students' mathematical thinking.

Three of them include *inviting student participation*, *probing a student's thinking*, and *creating opportunities to engage with another's reasoning*. The first talk move is *inviting student participation*. Teachers may use this talk move to gather students' multiple solutions or strategies that they use to solve a problem (Herbel-Eisenmann et al., 2013). Some examples of *inviting student participation* are "Would someone like to add something more to this?" and "Any other ideas?" A Goal of *inviting students' participation* is to include more students in discussions (Herbel-Eisenmann et al., 2013).

The second talk move is *probing a student's thinking*, which can be used to support students to justify their solutions (Herbel-Eisenmann et al., 2013). Brodie's (2010) term "pressing" appears to refer to a similar talk move as probing a student's thinking. That is, pressing on students' ideas is a talk move that the teacher takes to "ask the learner to elaborate her ideas—to clarify, justify, or explain more clearly" (Brodie, 2010, p. 32). Some examples of probing a student's thinking can range from "Can you say more?", to "Why did you choose *x*?" (Herbel-Eisenmann et al., 2013). Different teachers use *probing a student's thinking* in different ways for different purposes. Rickard (2014) studied the work of an experienced sixth-grade mathematics teacher as she facilitated classroom discussions about perimeter of rectangles. Findings revealed that when students only provided answers, both correct answers and misconceptions, without justification of their answers, the teacher usually asked students to explain how and why they got their answers to unpack their mathematical reasoning (Rickard, 2014). Brodie (2010) examined two experienced reform-based teachers, who taught the grade 10 classes at schools in different socio-economic settings in Johannesburg, South Africa. While one of the teachers chose to get several students' ideas into the public domain first before he pressed further on some of these students' ideas that he was not clear about, another teacher chose to press on a pair of students who provided their idea without explanation.

The last talk move in the *Teacher Discourse Move Framework* is *creating opportunities to engage with another's reasoning*, which can be done in multiple forms such as asking students to use a particular student's strategy to solve a problem, asking students to revise another student's explanation or conjecture, and asking students whether they agree or disagree with a particular student's idea (Herbel-Eisenmann et al., 2013). By using this talk move, teachers support students in developing an important ability to apply their own reasoning to another student's reasoning. Moreover, this talk move also helps encourage students to engage with each other's ideas (Franke et al., 2015).

These studies have extensively investigated talk moves and the purposes of each move. However, in a review of this literature Jacobs and Spangler (2017) pointed out that teachers' perspectives on using talk moves and leading mathematical discussions are missing from this research. In order to understand more about how to support teachers to use talk moves to elicit students' mathematical thinking and to lead productive discussions, mathematics educators need to know more about teachers' understanding of this practice and their learning of it. Therefore, including teacher voice in the research on leading discussions is crucial. The purpose of the study is to explore how an experienced middle school teacher used talk moves to elicit students' mathematical thinking and establish mathematical discussions during both small group and whole class discussions in order to accomplish particular goals. In addition, to address the gap in research on leading discussions, I explored the teacher' perspectives on utilizing these talk moves as well.

2. Objectives

1) To identify talk moves that a middle school teacher used to elicit students' mathematical thinking and establish mathematical discussions during both small group and whole class discussions and how she used them

2) To identify the teacher' perspectives on utilizing talk moves

3. Materials and Methods

3.1 Participants and Context

At the beginning of the selection process, a colleague at the university where the researcher worked, which was located in one of the Midwestern states in the United States, suggested some teachers from local middle schools. The researcher observed these teachers' mathematics classes. Following preliminary observations, a female teacher was purposefully selected based on her richness of mathematical discussions in her class. Therefore, the main participant in this study was an experienced middle school teacher called with a pseudonym, Ms. Watson. She had 11 years of teaching experience: 4 years in a primary school and 7 years in a middle school. Data was collected during the spring of 2019, her seventh year at this middle school.

For the study, the researcher purposefully chose to observe one of Ms. Watson's advanced mathematics classes because the students in this class appeared to have a wide range of participation levels. Moreover, Ms. Watson suggested that students in this class were usually willing to be engaged in productive struggle. These two criteria would likely make this class an interesting case to observe. There were 14 female students and 15 male students in this class. They were all seventh-grade students; whose ages were 12 - 13 years old.

This class mainly focused on eighth-grade materials and some seventh-grade materials from the *Connected Mathematics Project* 3 (CMP 3), which is a problem-centered curriculum promoting an inquiry-based teaching and learning classroom environment created at Michigan State University with financial support from the National Science Foundation (Connected Mathematics Project, 2014). In this study, data was collected from Ms. Watson's Filling and Wrapping unit, which focused on surface areas and volumes of three-dimensional figures.

3.2 Data Collection

To explore how Ms. Watson facilitated mathematical discussions in her classroom, her instructional unit on Filling and Wrapping was observed. This instructional unit consisted of 15 class periods. Each period lasted from 40 to 50 minutes. Since her class met three times a week, the observations of the entire instructional unit lasted five weeks in the spring of 2019. During classroom observations, all class meetings were videotaped using two stationary video cameras and a roaming video camera. The stationary video cameras were set at the front and the back of the classroom to capture the entire classroom. The roaming video camera was operated to focus on the teacher and her interactions with students during both whole class and small group discussions. To better capture sound during small group discussions, an audio recorder was also placed at each small group in Ms. Watson's classroom.

During five weeks in the spring 2019, three teacher interviews, which included an initial interview, periodic interviews, and a follow-up interview, were conducted at the beginning of the instructional unit, after possibly important classes, and at the end of the unit, respectively. During the initial interview, Ms. Watson was asked about her instructional plans for the unit and other relevant questions about her teaching practice. After some important classes in which a discussion seemed to go well or did not seem to go well, short, periodic interviews with Ms. Watson were conducted to capture her thoughts and perspectives right after the discussions occurred. Each periodic interview lasted anywhere from 5 to 20 minutes. These interviews were audio-recorded. At the end of the unit, a follow-up interview with Ms. Watson was conducted. The researcher watched some video clips selected from Ms. Watson's class with her and asked her to share her perspectives on utilizing the talk moves shown on the video clips. The follow-up interview aimed to assess more details about her view of accomplishment in leading discussions in the unit, as well as her self-reflection on teaching the unit. This interview lasted approximately 60 minutes. Two additional follow-up interviews with Ms. Watson were conducted in the Spring 2020 because it was found that the teacher's perspectives on using some talk moves were needed after the data was further analyzed. Each of the additional follow-up interviews lasted about 45-60 minutes. The interviews with the teacher were video-and audio-recorded.

In this study, considering herself as a novice mathematics teacher, the researcher then played a role of quiet observer in the classroom. Prior to this study, she had taught seventh- and eighth-grade mathematics in a middle school for only one academic year. During that year, although the researcher wanted to establish productive mathematical discussions in class, she did not know how to achieve them. Thus, the researcher decided to take on a quiet observer during data collection and tried not to interrupt the teacher and the students during teaching by avoiding coming too close to students or the teacher or asking them too many questions.

3.3 Data Analysis

To analyze data, the researcher repeatedly watched the video records of classroom observations and identified all segments of classroom video files in which the whole class and the small group discussions occurred. These portions of classroom video files, the audio and video files of teacher interviews were transcribed. Then, the researcher watched the video files to understand` classroom events while using transcripts to write both data summaries and analytic notes (Saldana, 2013). Once the researcher had transcripts, an initial coding was performed to produce a set of codes to capture talk moves and other ways that the teacher led discussions to elicit students' mathematical thinking. During the first cycle coding, the researcher coded the transcripts from classroom observations following talk moves that help elicit students' mathematical thinking from the *Teacher Discourse Moves Framework* (Herbel-Eisenmann et al., 2013). Also, the teacher used talk moves that did not fit into these categories. Therefore, the researcher used grounded theory methods of open coding to develop new codes to describe the moves (Saldana, 2013). Then a second coding was performed on the transcripts using MAXQDA. After this second cycle coding, five talk moves, including *probing a student's thinking*, *challenging a student's conjecture*, *gathering students' ideas or observations*, *asking students to engage with another's reasoning*, and *asking students to make predictions*, were identified.

To code the teacher' perspectives on using talk moves, the researcher performed an initial coding of the teacher' interviews to produce a set of codes to capture the teacher's perspectives on her talk moves. The research goal was to develop codes to describe Ms. Watson's perspectives on using her talk moves. Thus, the researcher used the In Vivo Coding method (Saldana, 2013) in the first coding cycle because she wanted to highlight the teacher's voice rather than the researcher's interpretations or suggestions from previous literature. Then, a second coding was performed on the transcripts of the teacher' interviews using MAXQDA again. In this second cycle coding the researcher grouped codes that appeared to suggest similar purposes of using talk moves into themes.

Throughout the process of data analysis, the researcher followed Cobb's (2000) suggestion to obtain critiques on the codes to capture talk moves, the codes to capture the teacher's perspectives on using talk moves and parts of findings from another colleague and Ms. Watson to help triangulate the data interpretation.

4. Results and Discussion

4.1 Talk Moves for Eliciting Students' Mathematical Thinking during Discussions

Five talk moves that Ms. Watson used for eliciting students' mathematical thinking and facilitating mathematical discussions were identified from the classroom observations. Three of them including *probing a student's thinking*, *gathering students' ideas or observations*, and *asking students to engage with another's reasoning* were drawn from the predefined set of talk moves in the *Teacher Discourse Moves Framework*

(Herbel-Eisenmann et al., 2013). The other two talk moves, *challenging a student's conjecture* and *asking students to make predictions*, arose from the data. Descriptions of these talk moves were presented along with examples illustrating how Ms. Watson used them to elicit students' mathematical thinking and facilitate whole class and small group discussions. All names in this section are pseudonyms.

Probing a student's thinking describes a talk move that the teacher takes to explore an individual student's thinking based on the student's initial responses, so the student has an opportunity to talk more about her or his thinking. Questions that correspond to this talk move require a student to expand, clarify, elaborate on, or justify her or his thinking rather than only provide a short answer. In small group discussions, the teacher may direct a question to a group rather than an individual student. Some examples of this type of questions are: "Why do you…?", and "How did you get…?"

In Ms. Watson's classroom, *probing a student's thinking* was used during whole class and small group discussions. The first excerpt demonstrates how Ms. Watson utilized *probing a student's thinking* during a whole class discussion. The goal of the discussion was to derive a general formula for finding the volumes of any prisms. Ms. Watson asked her students to think about how volumes of the prisms with the same heights changed as the areas of their bases increased. Abella responded.

Excerpt 1 Ms. Watson requests Abella to justify her claim

Ms. Watson: Okay. If I'm just telling you that you don't know the formula at all. Say that you don't have formulas for any of these bases. And, I just tell you that the area of the base is increasing, what you can then say about the volumes of the… the 3-D shapes that I made or the 3-D prisms I should say or the 3-D right prisms that I made if the area of the base is increasing. Think about how we find the volume of a solid that looks like these. Abella.

Abella: I think it would increase as well.

Ms. Watson: Why?

Abella: Because it does not matter what formula we are using.

Ms. Watson: Okay.

Abella: The area is still the area no matter the formula is.

As seen in Excerpt 1, Abella responded that the volumes of prisms increased as their areas of the bases increased. Initially, she did not provide any reason to justify her thinking, so Ms. Watson utilized *probing a student's thinking* by asking Abella, "Why?" for her response. At this point, Ms. Watson elicited an explanation from Abella that only the areas of the bases were crucial, not the formulas for finding the areas of the bases.

The second example of a small group discussion shows how Ms. Watson used *probing a student's thinking* when a student's misunderstanding of mathematical ideas appeared. In Excerpt 2, Rebecca and Jasmine discussed how to find the volume of their cylinder. Rebecca was not sure about the volume formula for a cylinder, so she asked Jasmine. Jasmine did not reply, so Rebecca suggested finding the areas of two circles first. At that point, Ms. Watson was close by their table group, so Rebecca raised her hand and told Ms. Watson that she was confused about how to find the volume of a cylinder. Ms. Watson asked Rebecca what she remembered about the strategy for finding the volume of a prism that was discussed in the previous classes. However, Rebecca seemed to be unsure what it was, so Ms. Watson asked Jasmine.

Excerpt 2 Ms. Watson probed students during a small group discussion

Ms. Watson: So, Jasmine, do you remember how did we find the volume of the right prism?

Jasmine: Umm...base times height.

Ms. Watson: And what do you mean by base times height? What are those? What part of the base?

Jasmine: Area.

Ms. Watson: Okay. So, we find the area of the base times the height. Did we do anything with multiple bases? Or, is it just one base times the height?

Rebecca: Two.

Ms. Watson: The formula we came up with was the volume equal to big *B* times the capital *H*, area of the base times the height. How many bases are there represented in the formula?

Rebecca: One.
Ms. Watson: Ahh... there is one in the formula.
Rebecca: But that should be two.
Ms. Watson: Why?
Rebecca: Because there are two bases.
Ms. Watson: Well, we definitely need that for the surface area. We definitely need that, right? Okay? But when we do volume, remember we said was like how many slices we could stack up. And so, we take the area of whatever the base is. And then we measure how many slices. And then we called it the height. Right? We we...because the slices go all the way to the top. And that's already been that that slice area's already been measured. We need to measure all at once. So, we just need one base times the height.

As seen in Excerpt 2, after the conversation between Ms. Watson and Jasmine about the strategy for finding the volume of a right prism, which was the area of the base times height (V = Bh), Ms. Watson asked Jasmine and Rebecca whether or not they had to alter the formula for finding the volume of a right prism as the cylinder had multiple bases. Rebecca replied, “two”. Even though Rebecca responded to Ms. Watson that there was only one base representing in the formula, V = Bh, she insisted that the number of the bases should be two, rather than one. Here, Ms. Watson utilized *probing a student’s thinking* by asking Rebecca “why?” Rebecca explained that because the cylinder had two bases. Therefore, Ms. Watson suggested that the areas of two bases were used for finding the surface area of a cylinder and described her ideas for finding the volume as the area of the base times height to Rebecca.

Challenging a student’s conjecture describes a talk move that the teacher takes to question a student’s claim by raising counterexamples or more precise terms to request refinement of the claim or to dispute the claim. To show how Ms. Watson used *challenging a student’s conjecture*, an example of a situation during a small group is presented in Excerpt 3. As students were working on comparing the volumes of right prisms, Ms. Watson stopped by one group. Then the conversation between Ms. Watson and students is as follows:

Excerpt 3 Ms. Watson challenges the claim of students during a small group discussion
Ms. Watson: Okay. So, what...let me read what you wrote. Then I want to put a challenge to the table. Okay. (Reading the responses from Sadie’s notes) We found the area of the base times the height of the prism. That makes sense to me. Okay. (Keeps reading Sadie’s notes) If it doesn’t say the area of the base. I like how you included that. Okay. You time the two legs of the base (reading Sadie’s responses). Now, I’m going to change the word times because it is “multiply”. This is not a problem. But you said the two legs of the base. What if it's not a base that has two legs? What if it’s a trapezoid?
Maya: Can we just do…like you time the width and the...?
Ms. Watson: Let me repeat the first part of the answer. (Reading Sadie’s responses.) We found the area of the base times the length of the prism. What if the base is a trapezoid?
Phillip: You change the area, and you time the height.
Ms. Watson: The area of the…what?
Phillip: The base.
Ms. Watson: Which is what? What shape?
Phillip: Trapezoid.
Ms. Watson: Okay. Do you see why you multiply the two legs…the two legs of the base would not make sense if it's a trapezoid?
Phillip: Uh-huh [yes].
Ms. Watson: Does the trapezoid have legs? No. So, can you guys come up with... And I don’t know if the rest of you got... maybe one of you has an answer that addresses that. But come up with an answer that addresses bases that [we] might not have formulas for. But how could we say generally? Okay?

As seen in Excerpt 3, Ms. Watson read the responses on Sadie's notes aloud. Based on what Ms. Watson read, Sadie's responses to the focus question, which seemed to be the group's responses as well, appeared to say that "We found the area of the base times the length of the prism. If it doesn't say the area of the base, you time the two legs of the base." The Ms. Watson used *challenging a student's conjecture* to question the second part of the response that said, "If it doesn't say the area of the base, you time the two legs of the base." Ms. Watson brought up a case that the base of a prism was a trapezoid to challenge that part of the responses and asked whether or not their claim applied to a trapezoid. After nine seconds of silence, Maya tried to reply to Ms. Watson's question, but she repeated some of what Sadie had written. Ms. Watson repeated her question. This time, Phillip replied. Ms. Watson further explained that the second part of the response did not apply to the case when the base was a trapezoid because the trapezoid did not have two lengths of legs (that could be multiplied to find the area of this shape). At the end of the excerpt, before Ms. Watson let the students continue their discussion, she encouraged them to refine their answer.

Gathering students' ideas or observations describes a talk move that the teacher takes to ask students to share their prior knowledge or their observations from a particular situation related to a topic of the discussion. The questions often have multiple answers, so several students have opportunities to participate in discussions. Some examples of this type of questions are: "What do you notice about…?", "What do you think?", "Any observation?", and "What do you know about…?"

The following excerpt shows how Ms. Watson utilized *gathering students' ideas or observations* when she led a whole class discussion to review students' knowledge about circles before they started exploring surface area of a cylinder in small groups.

Excerpt 4 Ms. Watson asks students to recall what they remember about circles

Ms. Watson: Okay. What else do you remember about circles, Madelyn?

Madelyn: You can find the circumference by multiply pi with diameter [πd]. Or, you could do 2, pi, r [$2\pi r$].

Ms. Watson: (Writes "C = πd = $2\pi r$" on the board). Okay. Is this sound familiar with you guys, since we did last semester? (Pauses 2 seconds) maybe? Let's just quickly review (draws a circle on the board). This's a circle. Shh... What's a diameter?

In Excerpt 4, Ms. Watson began the discussion to review about circles by utilizing *gathering students' ideas or observations*. That is, she asked her students to share what they remembered about circles. After Owen shared his response, Ms. Watson used *gathering students' ideas or observations* again by asking, "What else do you remember about circles?" Therefore, Madelyn shared the formula for the circumference of a circle, which are πd or $2\pi r$, where r and d are a radius and a diameter of a circle, respectively.

Asking students to engage with another's reasoning describes a talk move the teacher takes to get students engage with ideas of other students by asking other students to justify the ideas or asking other students to explain why they agree with or why they do not agree with the ideas.

Excerpt 5 shows how Ms. Watson utilized *asking students to engage with another's reasoning* by asking students to explain another student's ideas during whole class discussions. Ms. Watson began the whole class discussion on strategies for finding the surface area of a cylinder. As Ms. Watson displayed two cylinders in her hands, she asked students to share their ideas for finding the surface area of a cylinder. Then, Madelyn commented that the areas of two circles, which were $2\pi r^2$, should be added to the area of the lateral surface, so she said the radius was needed. Adam added that, to find the area of the lateral surface that was a rectangle, the base and the height of the rectangle were needed. Then, a discussion follows.

Excerpt 5 Ms. Watson invites students to engage with Adam's and Samuel's ideas

Ms. Watson: Okay. So, umm… Adam's trying to umm...he knows that we need to do this (moves her palm along the lateral face). And, he said the formula is base times height. You can use that. So, what do we need? (Pauses 2 seconds) What do we need to find the area of this rectangle? Samuel, do you want to give a shot?

Samuel: Yeah. You need the circumference of the circle and the height of the cylinder.

Ms. Watson: Okay. So, why do I need the circumference of the circle when I said I was finding the rectangle not the circle? Why did Samuel say...so Adam told us we needed to find the base and the height of the rectangle in order to find the area. And, Samuel said, well, to do that, you needed the circumference of the circle. And then my responses, but I'm finding the circle. I want to find the rectangle. So why did Samuel say that I needed this umm the circumference of this circle? John.
John: Because when you like wrap it up, then like the base is like the circumference.
Ms. Watson: It is the circumference. Does it make sense to you, Adam (directs to Adam)?
Adam: (Nods his head [yes].)
Ms. Watson: Okay. Then, so, Samuel said we needed this (moves her finger along the length of the rectangle). And he also said we needed the height of the cylinder. Why? I'm trying to find the rectangle again not the cylinder.
Madelyn: Because the height of the cylinder is also the height of the rectangle.
Ms. Watson: Do you guys see that? Who did not see that? (Pauses 3 seconds). Because it is okay. We just need to work on it.

Here, Ms. Watson used *asking students to engage with another's reasoning* by asking other students to explain Samuel's ideas. John commented that the base of the rectangle was the circumference of the circle. Ms. Watson again used *asking students to engage with another's reasoning* by asking other students to explain another part of Samuel's idea that said the height of the cylinder was needed. Madelyn filled in the reason why Samuel said the height of the cylinder was needed for finding the area of the rectangular part.

Asking students to make predictions describes a talk move the teacher takes to get students started thinking about a particular problem by asking them to make guesses or possible answers to the problem before they actually solve it. The excerpt below occurred before students learned about the relationship between the volume of a cylinder and the volume of a cone that had the same base radius and the same height as the cylinder from Ms. Watson's demonstration of the idea.

Excerpt 6: Students predict the fraction that the cone would fill the cylinder

Ms. Watson: Okay. Here is my question. What part of the cylinder will I fill with the cone? Claire.
Claire: Three-fourths.
Ms. Watson: Three-fourths (writes $\frac{3}{4}$ on the board). Walter.
Walter: One-third.
Ms. Watson: One-third (writes $\frac{1}{3}$ on the board). Okay.

4.2 Ms. Watson's Perspectives on Using Talk Moves

Ms. Watson's perspectives on using probing a student's thinking. According to the follow-up interviews, Ms. Watson revealed that she used *probing a student's thinking* during whole class and small group discussions for one of these following purposes: to ensure students' mathematical understanding, to learn more about a student's thinking, to orient students' mathematical thinking, and to help her make decisions about the next steps in lessons. Ms. Watson's second purposes were similar to the purpose that Brodie (2010) identified in the studies. However, Ms. Watson's last two purposes on using *probing a student's thinking* did not appear in the review literature.

Ms. Watson revealed that she utilized *probing a student's thinking* not only for incorrect answers but also for correct answers. She elaborated that a student sometimes provided a right answer but she or he did not show work. Or, she noticed that a student had a right answer while other students were still unsure about what to do with the problem. In these cases, Ms. Watson used *probing a student's thinking* to request the student to explain her or his thinking to ensure that she or he had valid reasoning for the right answer. Ms. Watson noted that she asked students to explain their answers regardless of the correctness because she did not want students to assume her questions meant their solutions were wrong. Sometimes, the questions meant their solutions were right as well. This purpose of Ms. Watson was similar to the purpose that was interpreted from the work of teachers in previous studies (Rickard, 2014; Herbel-Eisenmann et al., 2013).

Ms. Watson elaborated that when she noticed students had incorrect answers or headed to unproductive directions, she would do as follows:

> [To use *probing a student's thinking* to orient students' thinking] I mostly ask them about their thinking and why they're choosing things. Or, when I see a mistake, point it out to them that there is something wrong but not exactly tell them what is wrong. They have to think through what is not logical about what they've done. Asking more questions to have them think in the right direction.

That is, Ms. Watson explained that by asking the students to talk about their thinking, the students typically figured out their illogical thinking on their own. In other words, in Ms. Watson's view, *probing a student's thinking* appeared to be a teaching tool for learning about students' thinking and for orienting students' mathematical thinking.

Ms. Watson's perspectives on using challenging a student's conjecture. According to the follow-up interviews, Ms. Watson identified two purposes of her use of *challenging a student's conjecture*. First, she aimed to promote students' precision in their use of mathematical language, so they could effectively communicate in mathematics. Second, she aimed to orient students' thinking. As previously reported, when Ms. Watson noticed students' incorrect or incomplete answers, she would point out to the students that something was incorrect. However, she avoided telling them exactly what it was. Ms. Watson revealed that *challenging a student's conjecture* was one kind of questions she used to trigger students' current mathematical thinking. By raising a counterexample, they were likely to notice illogical ideas in their claim on their own, which in return allow them to refine their initial conjecture and their mathematical thinking.

Ms. Watson's perspectives on using gathering students' ideas or observations. According to Ms. Watson's responses on the follow-up interviews, her purpose of using *gathering students' ideas or observations* was to learn about students' prior knowledge and their current ideas. By taking this talk move, she could decide on the next step she would take to support student learning. While Ms. Watson's perspectives on using *gathering students' ideas or observations* was to learn about students' background knowledge for deciding on the next step, Herbel-Eisenmann and colleagues originally suggested using this talk move to include more students in discussions (Herbel-Eisenmann et al., 2013). Ms. Watson specifically described the situation in Excerpt 4. She revealed that she did not originally intend to spend a lot of time on the review about circles. However, after she utilized *gathering students' ideas or observations* by asking students to share what they remember about circles during the whole class discussion, she decided that the review was necessary. Ms. Watson continued to explain that she also used *gathering students' ideas or observations* by asking what they were working on or how they were doing with a particular task during small group discussions for the same purpose as well.

Ms. Watson's perspectives on using asking students to engage with another's reasoning. During the follow-up interviews, Ms. Watson and the researcher viewed a video record of Excerpt 5 together, she particularly shared her perspectives on her use of *asking students to engage with another's reasoning* based on the conversation presented in the excerpt. Ms. Watson pointed out four purposes of her use of this talk move. Her first purpose and a goal of this talk move that proposed in the previous study were similar. That is to get other students to contribute to whole class discussions (Franke et al., 2015). Ms. Watson's other three purposes were not previously mentioned in other studies. The first purpose was to learn about other students' understanding of the topic that they were discussing. Her second purpose was to individualize the needs of an individual student like Adam who had low self-confidence issues. In order to support Adam's needs, she decided to recognize his contribution by referring to his idea, but she did not ask him to expand on or justify his idea further. Her last purpose was to get other students' attention. Ms. Watson noticed that at that point many students did not seem to be following the discussion because it had been happening for a while. By using this talk move, Ms. Watson thought that other students might pay more attention.

Ms. Watson's perspectives on using asking students to make predictions. In the follow-up interview, Ms. Watson revealed that her purpose of using *asking students to make predictions* was to get students start thinking about a problem. She elaborated that when students put in some mental energy to think about something as opposed to just listen to the teacher, they tended to remember things better. She claimed that even if students made incorrect guesses, they would still remember the actual answer.

5. Conclusion

This observational and interview study explored how an experienced teacher, Ms. Watson, from a middle school in a small college town in a Midwestern state in the United States used talk moves to elicit students' thinking and establish mathematical discussions during both small group and whole class discussions to accomplish her particular goals. The findings showed that five talk moves including *probing a student's thinking*, *challenging a student's conjecture*, *gathering students' ideas or observations*, *asking students to engage with another's reasoning*, and *asking students to make predictions*, were used to elicit students' mathematical thinking, and facilitating mathematical discussions. Ms. Watson utilized each of these talk moves for several purposes. Although some of her purposes for a particular talk move and the purposes identified in literature were similar, some of them were not. Therefore, Ms. Watson's voices on using these talk moves were crucial for helping mathematics educators understand more about how to support teachers to utilize these talk moves during mathematical discussions more effectively. This study can greatly contribute to the gaps in research about leading mathematical discussions and to bring to light the teacher's perspectives on using talk moves and leading discussions.

In addition to the contribution, this study has a limitation. As a quiet observer, the researcher might not learn as much about the teachers' work in leading discussions and students' thinking as possible. After data analysis, it was found that being an observer who was barely present in the classrooms, as the researcher had been, had some advantages because the teachers and students could continue their normal routines. However, if the researcher had performed more of a participant role, the data could have been richer.

Future studies could also explore how students' thinking develops when particular discussions happen and how they influence students' thinking to better understand the implications of these results. Because both teachers and students are participants of mathematical discussions, in any interactions, the teachers' use of talk moves in leading discussions can influence students' thinking and their reactions, and vice versa. Thus, the development of students' thinking during particular discussions could depict a more complete picture of mathematical discussions in classrooms.

6. References

Bennett, C. A. (2010). "It's hard getting kids to talk about math": Helping new teachers improve mathematical discourse. *Action in Teacher Education*, *32*(3), 79–89.

Brodie, K. (2010). Pressing dilemmas: Meaning-making and justification in mathematics teaching. *Journal of Curriculum Studies*, *42*(1), 27–50.

Cengiz, N., Kline, K., & Grant, T. J. (2011). Extending students' mathematical thinking during whole-group discussions. *Journal of Mathematics Teacher Education*, *14*(5), 355–374.

Cobb, P. (2000). Conducting teaching experiments in collaboration with teachers. In A. E. Kelly & R. Lesh (Eds.), *Handbook of research design in mathematics and science education* (pp. 307–333). Mahwah, NJ: Erlbaum.

Franke, M. L., Turrou, A. C., Webb, N. M., Ing, M., Wong, J., Shin, N., & Fernandez, C. (2015). Student engagement with others' mathematical ideas: The role of teacher invitation and support moves. *Elementary School Journal*, *116*(1), 126–148.

Herbel-Eisenmann, B. & Breyfogle, M. L. (2005) Questioning our patterns of questions. *Mathematics Teaching in the Middle School, 10*, 484–489.

Herbel-Eisenmann, B., Drake, C., & Cirillo, M. (2009). "Muddying the clear waters": Teachers' take-up of the linguistic idea of revoicing. *Teaching and Teacher Education, 25*(2), 268–277.

Herbel-Eisenmann, B. A., Steele, M. D., & Cirillo, M. (2013). (Developing) teacher discourse moves: A framework for professional development. *Mathematics Teacher Educator*, *1*(2), 181–196.

Jacobs, V. R., & Spangler, D. A. (2017). Research on core practices in K-12 mathematics teaching. In J. Cai (Eds.), *Compendium for research in mathematics education* (pp. 766–792). Reston, VA: National Council of Teachers of Mathematics.

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

National Council of Teachers of Mathematics. (2014). *Principles to actions*. Reston, VA: National Council of Teachers of Mathematics.

Saldana, J. (2013). *The coding manual for qualitative researchers*. Los Angeles, CA: Sage Publications.