한국학교수학회논문집 제 22 권, 제 4 호
Journal of the Korean School Mathematics Society
Volume 22, Number 4, 439-460, December 2019
http://doi.org/10.30807/ksms.2019.22.4.005

Exploring the Relationships Among Teacher Questions, Turn-Taking Patterns, and Student Talks in Mathematics Classrooms

Hwang, Sunghwan[1]

In this study, we examined classroom interaction to explore the relationships among teacher questions, turn-taking patterns, and student talks in mathematics classrooms. We analyzed lessons given by three elementary teachers (two first-grade teachers and one second-grade teacher) who worked in the same school using a conversation-analytic approach. We observed individual classrooms three times in a year. The results revealed that when teachers provided open-ended questions, such as "why and how" questions and "agree and disagree" questions, and used a non-IRE pattern (teacher initiation - student response - teacher feedback; Mehan, 1979), students more actively engaged in classroom discourse by justifying their ideas and refuting others' thinking. Conversely, when teachers provided closed-ended questions, such as "what" questions, and used an IRE pattern, students tended to give short answers focusing on only one point. The findings suggested teachers should use open-ended questions and non-IRE turn-taking patterns to create an effective math-talk learning community. In addition, school administrators and mathematics educators should support teachers to acquire practical knowledge regarding this approach.

Key words : Teacher questions, turn-taking patterns, student talks, classroom discourse, math-talk learning community

Ⅰ. Introduction

Mathematics educators have emphasized the importance of an effective "math-talk learning community" (Hufferd-Ackles, Fuson, & Sherin, 2004, p. 81). The National Council of Teachers of Mathematics (NCTM, 2000) claimed teachers should construct classroom environments that elicit and express students' mathematical ideas. The National Curriculum of England also suggested teachers should provide students with opportunities to express and justify their thinking and reasoning (United Kingdom Qualifications and Curriculum

* 2010 Mathematics Subject Classification : 97D40
1) Seoul Gaju Elementary School (ihwang413@gmail.com)

Authority, 1999). Similarly, the 2015 revised Korean mathematics curricula (Ministry of Education, 2015) emphasized students' active engagement in classroom discourse. The curricula named mathematics communication as one of the six competencies students should achieve through school education. Specifically, the curricula highlighted that students need to not only communicate their mathematics ideas to peers and teachers but also analyze and evaluate others' mathematical thinking and strategies (Ministry of Education, 2015). However, unlike other subject areas (e.g., Korean language), many Korean students in mathematics classroom are not given such opportunities; instead, they are expected to provide short answers following teachers' simple questions without exploring mathematical concepts through discussion (Ko, Kim, & No, 2015; Mullis, Martin, Foy, & Hooper, 2016).

Although many factors have contributed to this phenomenon, ineffective teacher questions and turn-taking patterns in whole-class discourse may have resulted in passive student roles and poor interactional behaviors (McHoul, 1978; Hufferd-Ackles et al., 2004; Ingram & Elliott, 2014; Seedhouse, 2004). In every mathematics classroom, teachers present a variety of questions and ask students to respond to them. Some teacher questions and turn-taking patterns might promote students' mathematical thinking and increase their interactions, whereas others might inhibit their reasoning and arguments. For example, when teachers encourage students to express their mathematical ideas and refute others' thinking, students are provided opportunities to evaluate both their and their peers' ideas. Meanwhile, when teachers focus on only the correct answers, only the few students who know these answers can engage in whole-class interaction (Boaler & Brodie, 2004; Franke, Webb, & Chan, 2009; Graesser & Person, 1994).

Social constructivists have claimed that teachers' discourse affects not only students' prompt response but also their learning identity (Cobb & Yackel, 1996; Meyer & Turner, 2002). Teachers regulate students' learning through guidance and feedback. Instructors provide feedback following students' responses and expect students to change their speaking patterns to follow the instructor's preferred rules of speech (Yackel & Cobb, 1996). Because most student talks are subject to evaluation by their teachers, they interpret sociomathematical norms in the classroom and wittingly and unwittingly engage in classroom discourse following these norms. Based on continuous feedback, students realize what their teachers want to hear from them and acquire a certain turn-taking pattern that governs whole-class interaction (Seedhouse, 2004; Wortham, 2004).

Previous authors have reported a positive relationship between teachers' questioning strategies and student talks in whole-classroom discourse (e.g., Franke et al., 2009; Nathan & Knuth, 2003). These researchers counted the frequency of utterances of teachers and students separately and conducted statistical analyses to examine their association. Although these studies provided valuable information with which to understand the importance of teachers' discourse patterns, very few authors have focused on the turn-taking structure, which reveals sequential interaction patterns in the whole-class discourse. Understanding the turn-taking structure as well as teacher questions and student responses in Korean mathematics classrooms might help researchers and teachers gain insight into how to change teachers' discourse practice to align with innovative curricula, which might support student engagement and mathematical learning. Therefore, the objective of this study was to understand how teacher questions and turn-taking patterns influenced student talks in mathematics classrooms.

Ⅱ. Literature Review

1. Theoretical Framework

This paper draws upon sociocultural theory to illustrate how teacher questions and turn-taking structure in the classroom are associated with student talks, including student response, silence, and engagement. The sociocultural theory has been widely used in research to study the influence of classroom culture on student learning (Lerman, 2001). According to this theory, learning is achieved through social interaction, and the outside world influences people's learning (Vygotsky, 1986). Vygotsky (1986) claimed students' "mental functions must be viewed as products of mediated activity...[by] means of interpersonal communication" (p. xxiv). In mathematics education, researchers have also reported that cultures and norms in the classroom influence the development of individual students' learning (Yackel & Cobb, 1996). Because students learn mathematics within a certain culture constructed by their teacher, interpersonal communication within the classroom, mainly with their teachers, influences them in terms of who can speak, how, and when. In particular, linguistic interaction with their teacher results in the development of individual students' learning identity. Hence, students intentionally select specific stances, roles, and talking strategies in a classroom to follow the prevailing culture (Bucholtz & Hall, 2005).

Meanwhile, individuals also contribute to their own learning (Vygotsky, 1980). Vygotsky (1980) argued that "an interpersonal process is transformed into an intrapersonal one" (p. 57). Students in the classroom interpret the knowledge transmitted by their teacher and then construct their own meaning through self-reflection (Warford, 2011). Furthermore, they can decide how to participate in the classroom discourse community. Thus, it is likely that students' talk patterns might conflict with the turn-taking structure governing the whole-class discourse (Wortham, 2004). For example, although teachers ask students to use long answers, students might want to express their ideas using short answers (e.g., yes or no; Hufferd-Ackles et al., 2004). However, because the teacher has a more powerful status in class, a student will follow the classroom culture over time to be a "normal or a good student" (Wortham, 2004, p. 173). Building on sociocultural theory and previous research, therefore, the assumption in this study is that the teacher's questioning strategies and turn-taking patterns regulate student talks and engagement in the classroom.

2. Teacher Questions and Student Talks

Student talks are regarded as a major vehicle for mathematics learning (Walshaw & Anthony, 2008). The NCTM (1991) claimed: “Students must talk, with one another as well as in response to the teacher” (p. 34). Researchers have reported two explanations for the value of student talks. First, talking helps students clarify their mathematical ideas and address misunderstandings (Chi, 2000; Franke et al., 2009; NCTM, 2000). When students orally represent their ideas, they can evaluate their own ideas before talking, which might help them develop a new understanding. After talking, they internalize and solidify orally expressed mathematical ideas. Moreover, student talks help them detect and remediate misunderstandings. Students may evaluate their own ideas and find failures in their mathematics comprehension during communication with others. In a qualitative study to examine the relationship between students’ self-explanation and knowledge acquisition, Chi (2000) found student talks are more effective than listening to teachers’ instruction for facilitating learning. Because students’ self-explanation is repaired through their mental model, it would more make sense than didactic knowledge from teachers from their perspective.

Second, student talks not only allow students to evaluate peers’ strategies and provide feedback but also allow teachers to gauge students’ comprehension and help them improve the latter’s mathematical understanding (Franke et al., 2009; Nathan & Knuth, 2003; NCTM, 2000; Webb et al., 2014). In a quantitative study on elementary students to analyze the influence of classroom discourse on student mathematics achievement, Webb et al. (2014) found teacher‐student and student‐student interactions—such as adding details, proposing feedback on peers’ correct and incorrect ideas, and working together to identify problem-solving strategies—significantly influenced students’ mathematics outcomes, taking into account their previous mathematics achievement. The researchers concluded students can acquire accurate mathematical understanding when they share ideas, discuss alternative strategies, and reach an agreement via mutual communication.

However, researchers have cautioned that not all student talks are conducive to learning (Sfard, Nesher, Streefland, Cobb, & Mason, 1998). Sfard and Kieran (2001) reported that despite many researchers’ assumption that promoting students’ mathematics conversation is the best way to learn the subject, increased student talks do not necessarily indicate enhanced mathematical learning. After analyzing two 12-year-old students’ mathematical conversations, they concluded their collaboration was unhelpful and ineffective in terms of their learning. The researchers suggested student talks might be effective for their learning if they discovered how to communicate effectively using certain questions and patterns, which might increase their motivation for engaging in mathematical conversations. Webb and Palincsar (1996) also claimed the types of talks used determine the outcome of student talks. Describing answers alone is negatively associated with student outcomes, whereas presenting explanations and justifications is positively connected with student outcomes. Moreover, Moschkovich (1999) pointed out that student talks are helpful for learning when students engage in “explaining solution processes, describing conjectures, proving conclusions and presenting arguments” (p. 19).

Investigators have reported the types of students’ talk are mainly influenced by the types of their teachers' questions (Boaler & Brodie, 2004; Franke et al., 2009; Hufferd-Ackles et al., 2004; Hwang, 2018). As explained by sociocultural theorists, interpersonal communication with teachers changes many aspects of students' learning (Bucholtz & Hall, 2005; Vygotsky, 1986). In a year-long case study, Hufferd-Ackles et al. (2004) found student talks patterns changed following their teacher's questions and turn-taking strategies. When a teacher presented "what" questions and expected to receive a correct answer, students rarely presented their mathematical ideas or took any responsibility for their peers' learning. In such interaction, teachers are the only person who can nominate the next speaker, and students are passively engaged in the discourse. Conversely, when mathematics teachers used "why" and "how" questions, encouraged student–student discourse, and allowed students to initiate discourse, student talks focused more on explanation and justification, and conversation lasted longer while learners investigated various problem-solving strategies. Similarly, Hwang (2018) examined the discourse patterns of Korean elementary mathematics classrooms and found a positive relationship between teacher–student discourse patterns. When teachers provided high-cognitive questions, including requirements to evaluate, correct, reject, and doubt others' ideas, their students tended to mimic such a high-cognitive approach.

The NCTM (2014) suggested classifying teacher questions into two categories—funneling and focusing questions—in an elaboration of studies by Wood (1998) and Herbal-Eisenmann and Breyfogle (2005). Funneling (closed-ended) questions relate to mathematical ideas and answers teachers consider important, such as the equation of the area of a triangle. In this case, student talks are guided to follow teachers' specific directions, and students are not allowed to express their own mathematical ideas. Students are encouraged to give short answers. Moreover, only teachers can select which students can express their ideas. Hence, student talks only include exact answers to the question, and learners' individual thought processes are disregarded (Herbal-Eisenmann & Breyfogle, 2005; NCTM, 2014).

Conversely, focusing (open-ended) questions ask students to express their thoughts to both teachers and peers (Herbal-Eisenmann & Breyfogle, 2005). When teachers plan lesson goals and questions, they devise "why and how" questions (such as "Can you explain why you think like that?"), students' thinking is respected as members of learning communities, and their ideas are investigated further as valuable learning resources (NCTM, 2014; Wood, 1998). Students can self-select to engage in classroom discourse without waiting for teachers to call on them. Moreover, they can discuss a single mathematics topic for a relatively long period. Because the learning is focused on acquiring mathematical understanding, teachers attend to students' responses, participation, explanation, and problem-solving strategies (Herbal-Eisenmann & Breyfogle, 2005).

3. Turn-Taking Patterns and Student Talks

Turn-taking is widely applied in our daily lives. Traffic regulation, game playing, food ordering and serving, and talking during interviews and meetings are all related to turn-taking (Sacks, Schegloff, & Jefferson, 1974). In linguistics, turn-taking refers to the patterns of verbal interaction among more than two people. Hence, it governs "who speaks, when, how long for and what can be said" (Ingram & Elliott, 2014, p. 2). Community members share a certain turn-taking pattern and adjust their talk to comply with it. Because the pattern regulates people's interaction and social system (Sacks et al., 1974), the harmonious nature of relationships would be destroyed when participants violate turn-taking structures (Wortham, 2004). In ordinary conversation, people can engage in dialogue without waiting for someone to nominate them. In addition, anyone in a conversation can nominate the next speaker to give his or her opinion (Sacks et al., 1974). In most classroom-based conversations, however, teachers are the only people who can nominate the next speaker, and students cannot talk until their teachers allow them to speak. Only nominated students have the right to intervene in the turn (McHoul, 1978; Seedhouse, 2004). In sum, the turn-taking patterns related to teachers' questioning strategies regulate students' engagement and response and the construction of the math-talk learning community.

As such, researchers have argued that common classroom discourse practices are teacher initiation-student response-teacher evaluation (IRE; Mehan, 1979) or teacher initiation–student response–teacher feedback (IRF; Sinclair & Coulthard, 1975), in which teachers "have the right to speak at any time and to any person; they can fill any silence or interrupt any speaker; they can speak to a student anywhere in the room" (Cazden, 2001, p. 54). More recent authors, however, have reported different turn-taking structures in classrooms (Barwell, 2005; Ingram & Elliott, 2014; Radford, Blatchford, & Webster, 2011). In a study to examine UK middle-school mathematics classrooms, Ingram and Elliott (2014) found while IRE patterns were the most widely used, other turn-taking structures existed. The authors reported three instances in which these exceptional turn-taking structures occur in classrooms: (a) during debate, (b) when students ask questions, and (c) when students initiate a repair of others' misunderstanding by initiating discourse without waiting for teachers to call on them and selecting a peer as the next speaker to solicit additional information. Cazden (2001) also reported that when teachers provided questions asking students to justify their arguments, the turn-taking pattern did not follow the IRE model; instead, student–student interactions continued, such as teacher initiation–student response–student response (IRR pattern) or student initiation–teacher response–student response (sIRR pattern). Notably, Cazden (2001) did not name the new patterns while describing them in her study.

4. The Current Study

Although researchers have highlighted the importance of teacher questions and student talks, few have analyzed the relationships among teacher questions, turn-taking patterns, and student talks. The purpose of this study was to examine the associations by analyzing classroom discourse in Korean elementary mathematics classrooms. Two research questions guided this study. First, what were the teacher questions, turn-taking patterns, and student talks in the classrooms? Second, what were the associations among turn-taking patterns, teacher questions, and student talks?

Ⅲ. Methods

1. Participants

Three teachers from Jeil Elementary School participated in this study; the names of the school, teachers, and students are pseudonyms. Jeil is a public school located in the eastern part of the city of Seoul. The three teachers (two first-grade teachers and one second-grade teacher) voluntarily participated in this study and were notified that they had the right to withdraw at any time and to refuse to answer any question. Most students are from a poor socioeconomic background, and their mathematics achievement is lower than that of other students in Seoul. The three teachers were intentionally selected for this study because they had fairly different from each other, including teaching experiences and majors, which may have led to a different math-talk learning community. One teacher, Ms. Hwang, was a first-grade teacher and had 14 years of teaching experience. She graduated from the middle school teacher preparation program (Sabum-dae) and studied the Korean language for her bachelor's degree. During her college years, she never learned about elementary mathematics education but was hired as an elementary school teacher due to a staffing shortage. The second teacher, Ms. Park, was a first-grade teacher with 6 years of teaching experience. She graduated from the elementary school teacher preparation program (Kyo-dae) and attended a graduate school to study mathematics education. The third teacher, Mr. Choi, was a second-grade teacher with more than 20 years of teaching experience. He graduated from the elementary school teacher preparation program and had a master's degree in elementary mathematics education. These three teachers' beliefs about mathematics teaching and learning and general instructional practices, derived from the interview data, are described in Table Ⅲ-1.

2. Data Sources

Data sources included video and audio tapes of classroom observations, interviews, and field notes. We observed individual classrooms three times in a year. Most lessons lasted 40 minutes. An overview of the observed lessons is shown in Table Ⅲ-2. The lessons included various activities, including individual problem-solving and small group tasks. Meanwhile, this study was focused solely on whole-class discussion, composed of teacher–student and student–student interactions, to examine turn-taking structure, teacher questions, and student talks. For example, when students talked to their peers publicly so other students could hear, this was analyzed as student–student interaction. However, when teachers whispered to students to provide feedback and only a few students could hear the conversation, this was not analyzed. Moreover, nonmathematical talks and questions, such as classroom management talk, were not analyzed. Across the data collection period, we asked teachers to implement mathematics lessons that would represent their typical content and allowed them to select any material they wanted to show. We placed one video camera and three audio recorders in the classrooms to capture the discourse as clearly as possible. After individual classroom observations, we asked teachers to evaluate their classes to determine whether the observed lessons aligned with their mathematical beliefs and general instructional practices. Based on teachers' evaluations, we selected one representative classroom from the individual teachers and described the class in detail to illustrate the characteristics of teacher questions, turn-taking patterns, and student talks in classrooms. In addition, we analyzed overall math-talk learning communities.

<Table Ⅲ-1> Teachers' Mathematical Beliefs and General Instructional Practices

Name	Mathematical Beliefs and General Instructional Practices
Ms. Hwang	She believed that teachers should instruct students in exact procedures and that students should memorize the procedures to solve mathematics problems quickly. In the classroom, she demonstrated how to solve problems and asked students to follow the suggested problem-solving sequences. Moreover, she provided many basic questions to check their mathematical understanding.
Ms. Park	She emphasized student participation and investigation in the classroom. She also believed that teachers should teach exact mathematics knowledge and procedures to prevent students from becoming confused. Hence, she evaluated student answers directly and provided feedback immediately.
Mr. Choi	He believed that students could solve mathematics problems without teachers' direct instruction. He viewed the roles of teachers and students as facilitators and active investigators, respectively. In the classroom, he was reluctant to directly provide answers or evaluate student ideas; instead, he expected students to find various answers using discussion, collaboration, and personal examination.

<Table Ⅲ-2> Overview of Observed Lessons

Name	Observed lessons	
Ms. Hwang (1st grade)	Lesson 1	1-1, Unit 3 Addition and Subtraction Topic: Write and read subtraction equations
	Lesson 2	1-1, Unit 4 Measurement Comparison Topic: Which one is longer?
	Lesson 3	1-2, Unit 6 Addition and Subtraction Topic: Solving addition problems (2)
Ms. Park (1st grade)	Lesson 1	1-1, Unit 3 Addition and Subtraction Topic: Write and read addition equations
	Lesson 2	1-1, Unit 4 Measurement Comparison Topic: Which one is bigger?
	Lesson 3	1-2, Unit 6 Addition and Subtraction Topic: Solving addition problems (3)
Mr. Choi (2st grade)	Lesson 1	2-1, Unit 2 Various Figures Topic: Making various shapes with Tangram
	Lesson 2	2-1, Unit 4 Measuring Distance Topic: Understanding 1 cm
	Lesson 3	2-2, Unit 6 Finding Patterns Topic: Finding patterns in multiplication tables

3. Data Analysis

For this study we used the conversation analysis method to examine the associations among teacher questions, turn-taking patterns, and student talks in mathematics classrooms. Conversation analysis helps researchers describe and understand the structural organization of interaction (Seedhouse, 2004). First, we transcribed all video and audio data from the observed classrooms. We then selected episodes that included only teacher–student and student–student interactions and examined them as units of analysis. Second, for the first research question, we coded transcripts in five stages, building upon previous studies that examined classroom discourse focusing on teacher questions, student talks (Herbal-Eisenmann & Breyfogle, 2005; Hufferd-Ackles et al., 2004), and turn-taking patterns (Cazden, 2001; Ingram & Elliott, 2014). The coding process is as follows: (a) Who is talking (teachers or students)? (b) What is the type of teacher question (funneling or focusing questions)? (c) Who is the respondent of student talk (teacher–student or student–student interaction)? (d) What is the type of student talk (short or long responses and answer- or explanation-focused talk)? and (e) What are the types of turn-taking patterns (IRE, IRF, IRR, or sIRR)? Third, we examined how the turn-taking structure and questioning strategies of individual teachers were related to their student talks. Finally, after completion of individual case analysis, we identified common themes that emerged across the three cases. These themes resulted in findings to answer the second research question. Table Ⅲ-3 shows the data coding and examining process.

<Table Ⅲ-3> Data Coding and Examining Process

Coding	a) Who is talking (teachers or students)? b) What is the type of teacher question (funneling or focusing questions)? c) Who is the respondent of student talk (teacher–student or student–student interaction)? d) What is the type of student talk (short or long responses and answer- or explanation-focused talk)? e) What is the type of turn-taking pattern (IRE, IRF, IRR, or sIRR)?
Examining	How are the turn-taking structure and questioning strategies of individual teachers related to their student talks? What common themes span the lesson of the three teachers?

Ⅳ. Results

In this section, we first present three teachers' instructional practices, including details concerning teacher questions, turn-taking patterns, and student talks. We also provide short quotations from individual teachers that represent their typical interaction patterns. Then, we synthesize the three cases and describe how teacher questions and turn-taking patterns influence student talks.

1. Case 1: Ms. Hwang

Ms. Hwang's classroom interaction was similar to traditional teacher-centered instructional practices in which teachers give questions and students only respond to them. The goal of Ms. Hwang's questions was to check whether students had found the answers to problems. Ms. Hwang usually presented funneling questions (NCTM, 2014) and rarely asked students for additional explanations. In class, she usually used "what" questions, which required students to give only short responses. In addition, she tended to provide questions without nominating a student and moved to the next question if a few students provided a correct answer. Moreover, when students did not provide a correct answer, she directly provided a correct answer without providing additional time for investigation. After students' responses, the teacher repeated the talk to clearly express it for the class.

The following interaction (Excerpt 1) in Ms. Hwang's first-grade mathematics class shows teacher provides only a simple question (counting numbers or figures) and students focus on providing only the correct answers; students do not need to think about mathematical ideas to justify their reasoning. When Tae-ho provided a wrong answer, Ms. Hwang directly corrected him rather than allowing him to identify and modify his error. Ms. Hwang then moved to the next question, saying to the class, "OK, let's look at the next question," without checking other students' understanding of the answer. In terms of turn-taking structure, Ms. Hwang followed IRE or IRF patterns (Mehan, 1979; Sinclair & Coulthard, 1975). She initiated new discourse, and students were expected to respond to them correctly. Following the question, the students promptly speak a short answer ("There are 5 seats"). Because Ms. Hwang offered less cognitively demanding questions, students provided less cognitively demanding responses (Hwang, 2018). Hence, she did not need to provide additional feedback and solicit students' explanations; instead, the teacher and students could quickly move to the next question. With regard to feedback, she only provided short appraisals to applaud students' responses ("Good job") or to evaluate their answers ("No, I want you to read it in another way").

[Figure Ⅳ−1] A textbook task used by Ms. Hwang's class (1-1, Unit 3 addition and subtraction, p. 73)

<Excerpt 1> Ms. Hwang lesson 1

Ms. Hwang: OK, how many students in the amusement park?

Students: There are 8 students.

Ms. Hwang: Then, how many seats in the rollercoaster?

Students: There are 5 seats.

Ms. Hwang: Good job, can you guys make a subtract equation using two numbers?

Students: Eight minus 5 is equal to 3.

Ms. Hwang: Yes, 8 minus 5 is equal to 3. We have learned how to read a subtract equation in two ways. Can you read it in another way? (students raise their hands)

Ms. Hwang: Tae-ho speaking.

Tae-ho: Eight minus 5 is equal to 3.

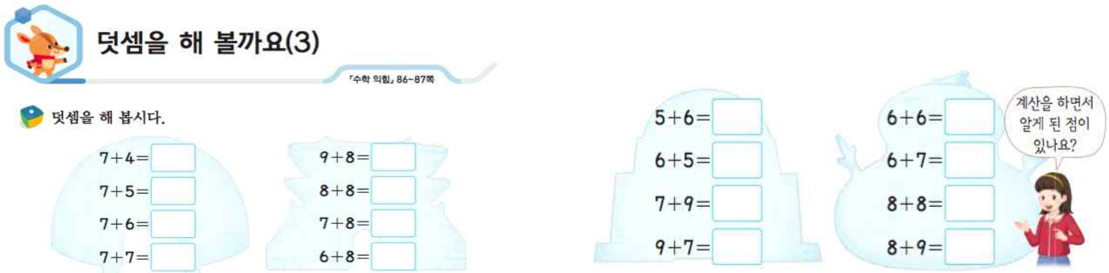
Ms. Hwang: No, I want you to read it in another way. We can read the equation as "the difference between 8 and 5 is equal to 3."

Ms. Hwang: OK, let's look at the next question. How many students at the bike station?

2. Case 2: Ms. Park

Compared to Ms. Hwang, Ms. Park's questions were more focused on students' mathematical thinking. The teacher first asked a "what" question. She then nominated a student and provided follow-up "why" and "how" questions soliciting the student's mathematical ideas. If the student's explanation was unclear, she repeated the response and filled it out to be a more reasonable explanation. Ms. Park also nominated more than one student per question to increase student engagement. When one student provided an incorrect answer, she nominated another student to listen to the next student's ideas rather than directly providing an answer. Hence, the time taken to discuss one question was longer than in Ms. Hwang's class. However, similar to Ms. Hwang, she used IRE or IRF turn-taking patterns. The teacher was the only person who could pose questions and nominate the next speaker, and students had to wait until their name was called. Furthermore, Ms. Park was the main source of mathematics learning by evaluating student responses and giving feedback.

The following excerpt (Excerpt 2) shows Ms. Park introducing an addition table to her first-grade students and asking them to find patterns. Students talked about an answer to a question for the first time only when Ms. Park presented a "what" question ("What can we get if we add the two numbers?"). However, Ms. Park made the transition by providing consecutive questions to make students explain their thinking more clearly ("Why do you think the answer is 11?"). Because she asked students to explain different ideas ("Do you guys find another rule or have another idea?"), students should have attended not only to the teacher's questions but also to peers' responses, including what ideas were presented and whether they were right or wrong. Notably, the goal of the task in the textbook was solving the addition table; however, she modified the task and encouraged students to think about the pattern ("I was wondering whether you could find any rules in these addition equations"). These focusing questions (NCTM, 2014) initiated new discourse to investigate a rule in the addition table and resulted in a more effective and cooperative math-talk learning community than in Ms. Hwang's class.



[Figure Ⅳ−2] A textbook task used by Ms. Park's class (1-2, Unit 6 addition and subtraction, p. 124)

<Excerpt 2> Ms. Park lesson 3

Ms. Park: We are going to add 7 and 4 (7 + 4). What can we get if we add the two numbers?

Students: Eleven.

Ms. Park: I want to listen to your mathematical ideas. It is a critical point in learning mathematics. (Students raise their hands.) Ju-hyun, why do you think the answer is 11?

Ju-hyun: I first add 4 and 4 and then add 3.

Ms. Park: You mean, you divided 7 into 4 and 3. Then, you added the three numbers? (4 + 4 + 3). That's a great idea. Perhaps I think we have another way to solve it. What is that? (Students raise their hands.) Sang-ok speaking.

Sang-ok: I divide 4 into 3 and 1. Seven plus 3 is equal to 10, so 10 plus 1 is equal to 11.

Ms. Park: Right, as Sang-ok said, 7 plus 4 is equal to 11 (7 + 3 + 1). Then, what can we get when adding 7 and 5 (7 + 5 = ?).

Students: Twelve.

Ms. Park: Then, what about 7 plus 6 (7 + 6 = ?).

Students: Thirteen.

Ms. Park: Wow, you did a good job. We did 7 plus 4, 7 plus 5, and 7 plus 6. Then, I was wondering whether you can find any rules in these addition equations. (Students raise their hands.) Kang-yoon speaking.

Kang-yoon: The answer is bigger by 1.

Ms. Park: Kang-yoon has great insight. Then, why is the answer bigger by 1?

Kang-yoon: Um, 11 is a combination of 7 and 4, 12 is a combination of 7 and 5, and 13 is a combination of 7 and 6. So, when I look at the left side, it increases by 1.

Ms. Park: You mean the left side or right side of the plus symbol? Where is the 7?

Kang-yoon: Seven is on the left side. I mean, the right-side number is increasing by 1 from 4 to 6.

Ms. Park: Then, how about the left-side number? Is it changed?

Kang-yoon: No, it's the same.

Ms. Park: OK, everybody, let's look at the number in the first place. Is it the same or different?

Students: All numbers are the same.

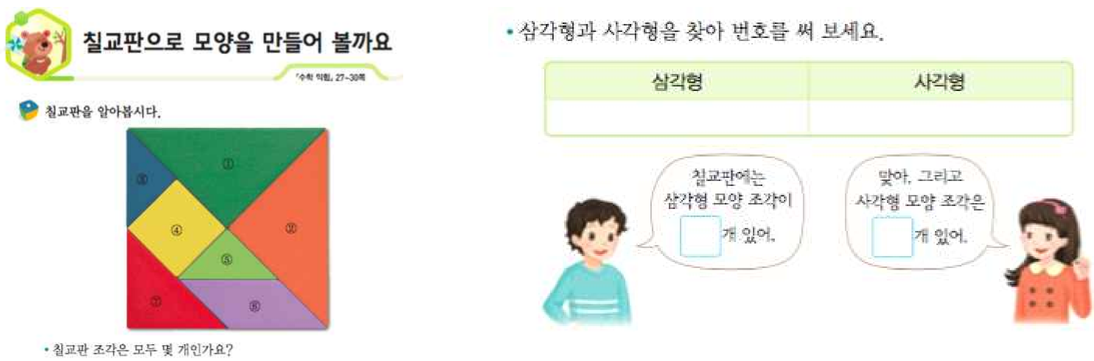
Ms. Park: How about the right-side number? Is it the same or different?
Students: It's different.
Ms. Park: How does the number change?
Students: It's increasing by 1.
Ms. Park: Oh, we now know that the answer is increasing by 1 because the right-side number is increasing by 1, too. Do you guys find other rules or have other thoughts? Ji-hyun speaking.
Ji-hyun: It's going a reverse way.
Ms. Park: A reverse way? Can you explain that more clearly?
Ji-hyun: Look at the outcome from the bottom.
Ms. Park: Oh, I see what you are saying. When we look at answers from the bottom, how does the answer change?
Students: Decreasing (from 13 to 11).
Ms. Park: It's decreasing. Now, we can easily find the answer to the next problem (7 + 7) by using the rules that we found. The left side is always 7, and the right side increases by 1 from top to bottom. Hence, the answer to the next problem is increasing by 1 from the answer to the previous problem. Do you guys understand?

3. Case 3: Mr. Choi

Mr. Choi focused not on answers but on students' mathematical ideas. Most of his questions were open-type focusing questions (NCTM, 2014). He encouraged student - student talk and asked students to evaluate others' ideas. When students explained their ideas, Mr. Choi wrote them on the blackboard, allowing all students to see and evaluate peers' strategies. Compared to other teachers, Mr. Choi did not repeat students' explanations as much; instead, he asked them to compare a peer's ideas with their own ideas. Mathematical conjecture and argumentation were common practice in his class. The teacher continuously asked students to compare various ideas by providing follow-up questions and used student error as an opportunity for further investigation. Students did not feel afraid to share their thinking. Moreover, some students initiated a new conversation and provided additional descriptions of their ideas to defend those thinking.

Mr. Choi was reluctant to evaluate students' ideas directly; instead, he accepted most students' responses and wrote them on the board. Then, he asked students to vote on which ideas were correct and to explain why they agreed or disagreed. Interestingly, while sometimes he did not use "why and how" questions and merely said "Speaking, please," his students naturally described their reasoning and evidence. Moreover, when they wanted to make an argument and refute others' ideas, they raised their hands or initiated new discourse without waiting for him to call them by name. That is, they could initiate mathematical discourse and evaluate peers' ideas when they wanted and did not need to be silent. In sum, the turn-taking patterns in his class were IRR or sIRR.

The following excerpt (Excerpt 3) depicts a typical discourse in Mr. Choi's classroom. He asked students to identify similarly shaped tangram pieces. Unlike the textbook, however, he did not ask students to classify them only into triangles or quadrilaterals; he allowed them to classify them any way they wanted ("Yes, you can find anything, as long as they have the same shape"). Several students attempted to justify their reasoning and challenge others' ideas ("Teacher, my idea is similar to Jae-ho's. However, I think that…"). While the teacher mediated student - student interaction, students did not wait for the teacher to solicit their response. Instead, they actively raised their hands to engage in the discourse. Moreover, because the teacher did not present the correct answers, students could continuously express their ideas and contribute to their learning through ongoing interactions. Mr. Choi sometimes intervened to clarify student explanations. However, in most cases, he asked for students' opinions to evaluate others' mathematical thinking ("Do you guys agree with her?"). Another difference was that while Ms. Park's students provided mathematically incomplete information ("It's increasing by 1" and "It's going a reverse way"), which was hard to understand without teachers' further explanation, Mr. Choi's students gave mathematically complete justifications consisting of arguments and evidence, such as "I think numbers 1, 2, 3, 6, and 7 are the same [argument] because they are all triangles [evidence]."



[Figure Ⅳ-3] A textbook task used by Mr. Choi's class (2-1, Unit 2 various figures, p. 42).

<Excerpt 3> Mr. Choi lesson 1

Mr. Choi: Please look at the seven tangram pieces. As a first activity, we are going to find pieces that are similar shapes.

A student: Can we find anything that we want?

Mr. Choi: You can find anything if they have the same shape.

(After having them conduct individual investigations, he asks students to share their thinking.)

Mr. Choi: Hyun-su raised his hand. Everybody, please stop what you're doing and listen to Hyun-su's explanation and think about whether it is similar to yours or not.

Hyun-su: I think numbers 1 and 2 are similar because they are both big triangles. Also, numbers 6 and 7 are similar because they are both small triangles.

Mr. Choi: Thanks for your explanation, Hyun-su. (He writes Hyun-su's name and ideas on the board.) Does anybody have any other ideas?

Mr. Choi: Jae-ho is speaking.

Jae-ho: I think numbers 1, 2, 3, 6, and 7 are the same because they are all triangles.

Mr. Choi: Great, Jae-ho. Unlike Hyun-su, Jae-ho thought that 1, 2, 6, 7, and 3 are similar shapes. (He writes Jae-ho's strategy on the board.) Is there anybody who has any different ideas? How about numbers 4 and 5?

Mr. Choi: Su-mi is speaking.

Su-mi: Teacher, my idea is similar to Jae-ho's. However, I think that numbers 4 and 5 are different shapes.

Mr. Choi: Why do you think so? Let's listen to Su-mi's explanation.

Su-mi: I think the side of number 5 looks longer than that of number 4, so there are different shapes.

Mr. Choi: Does everybody agree with Su-mi's idea?

Tae-il: Teacher, I think Su-mi's ideas are incorrect. They both have four sides and points. Thus, the shapes of numbers 1, 2, 3, 6, and 7 are the same, and the shapes of numbers 4 and 5 are the same.

Mr. Choi: Do you guys agree with Tae-il's idea?

4. The Associations Among Teacher Questions, Turn-Taking Patterns, and Student Talks

The three teachers enacted different interaction practices to support students' mathematics learning, as shown in Table Ⅳ-1. Ms. Hwang only focused on the answer, not on students' mathematical thinking, and frequently used funneling (closed-ended) questions such as "what" questions. She dominated turn taking and did not call on students to nominate the next speaker; instead, she presented a question to the whole class, expecting a few smart students would provide an answer. Moreover, Ms. Hwang was the only person to evaluate student ideas, and students were allowed to provide only a short answer. Because students had to be silent until she approved them to speak, most of the turn-taking structure was IRE or IRF.

Ms. Park attended to students' mathematical thinking to a greater degree than Ms. Hwang. She presented both funneling and focused questions and asked students to explain their reasoning beyond merely talking about the answer. Furthermore, she nominated students to facilitate individual learners' engagement in the math-talk learning community. Similar to Ms. Hwang, Ms. Park established different roles between teacher and student. Teachers could nominate the next speaker and evaluate their ideas, whereas students could not nominate others. They silently waited in their seats until the teacher called their names. All turn taking was managed by the teacher as IRE or IRF patterns, and the teacher took many more turns than any other student.

The math-talk learning community in Mr. Choi's classroom was totally different. He used focused (open-ended) questions and encouraged students to take on a new role. He used not only “why and how” questions but also “agree and disagree” questions to encourage student explanation and involvement. Mr. Choi supported students to evaluate, justify, add details, and work together to figure out problem-solving strategies. Although some students presented incorrect answers, he was reluctant to evaluate them; instead, he used the incorrect answer as a way to facilitate mathematical discussion. Consequently, the students' responses continued as IRR or sIRR patterns to find more accurate thinking.

<Table Ⅳ-1> Comparison of Math-Talk Learning Communities

Teacher	Turn-Taking Patterns	Frequently Used Teacher Questions	Types of Student Responses
Ms. Hwang	IRF or IRE	“What” questions (funneling questions)	Short and answer focused (no conjecture or argument)
Ms. Park	IRF or IRE	“What, why, and how” questions (funneling and focusing questions)	Short and explanation focused (conjecture without explanation)
Mr. Choi	IRR or sIRR	“Why and how” questions “Agree or disagree” questions (focusing questions)	Long and explanation focused (conjecture with explanation)

Ⅴ. Conclusion and Discussion

1. Conclusion

Many mathematics educators have emphasized the importance of constructing an effective math-talk learning community, which helps students acquire accurate mathematical understanding and to engage in a mathematical investigation (NCTM, 2000, 2014; Ministry of Education, 2015). However, teachers struggle to develop these learning communities because they are unfamiliar with those learning cultures in which students reason, justify, and argue for various types of mathematical thinking (Hufferd-Ackles et al., 2004; McHoul, 1978). Previous studies that examined the relationship between teacher questions and student talks have paid little attention to turn-taking patterns in mathematics classrooms. Given that turn-taking patterns influence student learning identity (Cobb & Yackel, 1996), analyzing them might help researchers examine characteristics of individual math-talk learning communities. As such, the purpose of this study was to investigate how turn-taking structure and teacher questions facilitated or halted the construction of an effective math-talk learning community. The findings revealed when teachers employed “why and how” and “agree - disagree” questions, their students focused more on mathematical explanation and argumentation than when teachers employed “what” questions. Moreover, we found turn-taking patterns influence student talks. When teachers allowed students to initiate discourse and refrain from evaluating student responses, the latter were consecutively continued (IRR or sIRR patterns), and they refuted others' ideas and justified their reasoning (Cazden, 2001). Conversely, when teachers implemented IRE or IRF patterns and tried to provide direct feedback, students became passive learners and attended only to provide answers. This study revealed the influences of teacher questions and turn-taking patterns on student talks. These findings align with those of previous studies (Hufferd-Ackles et al., 2004) and support the idea that teachers should use focusing questioning and non-IRE turn-taking patterns to incorporate student ideas into the mathematics classroom. These endeavors might help teachers construct effective math-talk communities and enhance student participation, investigation, reasoning, and mathematical understanding (NCTM, 2014).

The study findings suggest several implications for professional development, teachers, and research. In terms of professional development, the influence of teachers' questions and turn-taking patterns on student talks suggest school administrators and mathematics educators should provide helpful practical knowledge to support teachers in creating an effective math-talk learning community. Given that teacher education programs are generally focused on content knowledge, not discourse skills, mathematics teachers might have limited understanding of skills facilitating productive student talks. Therefore, mathematics educators and school administrators should design professional development programs to provide teachers with more appropriate learning experiences connected with their classroom culture; these efforts would lead them to construct effective math-talk learning communities.

The second implication is the importance of teachers' awareness of their discourse's critical roles. When students are given opportunities to construct knowledge through communications, they could acquire accurate mathematical understanding (Chi, 2000; Franke et al., 2009; NCTM, 2000). Hence, teachers should evaluate their discourse patterns and modify them to support student learning, as described in this study. Moreover, teachers should reexamine textbook tasks. As described in Ms. Park's and Mr. Choi's cases, modification of textbook tasks increased productive student talks. Similarly, teachers should check whether textbook tasks support students' reasoning, justification, and argument. If this is not the case, they should consider redesigning tasks to construct an effective math-talk learning community. The final implication is for researchers. Previous authors studying the association between teacher questions and student talks have paid less attention to turn-taking patterns (Ingram & Elliott, 2014). In this study, we followed the conversation analysis approach and found authentic information on the relationship between turn-taking patterns and student talks. In the same vein, researchers might use turn-taking structures to examine teachers' trustworthy instructional practices.

2. Suggestion and Limitation

In this study we examined the relationship among teacher questions, turn-taking patterns, and student talks. The results revealed when teachers provided open questions, including "why and how" and "agree and disagree" questions, and used IRR or sIRR patterns, students provided longer responses to explain their ideas and refute others' thinking. Meanwhile, this study has some limitations. First, we examined only three elementary mathematics teachers with few observation data. Hence, the findings cannot be generalized to all mathematics teachers. Further research should be conducted with additional participants. Another limitation is that we did not ensure student talks patterns were solely influenced by their current teachers' discourse. Their previous learning experiences and nonclassroom factors (e.g., home backgrounds) might have influenced their current talk patterns. Hence, readers should be cautious when interpreting this study's findings. A future longitudinal study might explain how student talks patterns change and develop. Despite these limitations, these findings indicate that to construct an effective math-talk learning community, teachers should change discourse patterns to promote student engagement in mathematics discourse. This study provides an insight for improving student talks through a change in teacher questions and turn-taking patterns.

References

Barwell, R. (2005). Integrating language and content: Issues from the mathematics classroom. *Linguistics and Education, 16*(2), 205 - 218.

Boaler, J., & Brodie, K. (2004). The importance of depth and breadth in the analysis of teaching: A framework for analysing teacher questions. In the *Proceedings of the 26th Meeting of the North America Chapter of the International Group for the Psychology of Mathematics Education*. Toronto, Ontario

Bucholtz, M., & Hall, K. (2005). Identity and interaction: A sociocultural linguistic approach. *Discourse Studies, 7*, 585 - 614.

Cazden, C. B. (2001). *The language of teaching and learning*. Portsmouth, NH: Heinemann.

Chi, M. T. H. (2000). Self-explaining: the dual processes of generating inferences and repairing mental models. In R. Glaser (Ed.), A*dvances in instructional psychology*, (pp. 161 - 238). Mahwah, NJ: Lawrence Erlbaum Associates.

Choi, S. H., Ha, J. M., & Kim, D. J. (2016). An analysis of student engagement strategy and questioning strategy in a peer mentoring teaching method. *Journal of the Korean School Mathematics Society, 19*(2), 153-176.

Cobb, P., & Yackel, E. (1996). Constructivist, emergent, and sociocultural perspectives in the context of developmental research. *Educational Psychologist, 31*(3 - 4), 175 - 190.

Franke, M. L., Webb, N. M., & Chan, A. G. (2009). Teacher questioning to elicit students' mathematical thinking in elementary school classrooms. *Journal of Teacher Education, 60*, 380 - 392

Graesser, A. C., & Person, N. K. (1994). Question asking during tutoring. *American Educational Research Journal, 31*(1), 104 - 137.

Herbal-Eisenmann, B. A., & Breyfogle, M. L. (2005). Questioning our patterns of questioning. *Mathematics Teaching in the Middle School, 10*(9), 484 - 489.

Hong, W. J., & Pang, J. S. (2008). An analysis of teacher-student communication and students′ mathematical thinking in six grade mathematics classrooms. *Journal of the Korean School Mathematics Society, 11*(2), 201-219.

Hufferd-Ackles, K., Fuson, K. C., & Sherin, M. G. (2004). Describing levels and components of a math-talk learning community. *Journal for Research in Mathematics Education, 35*(2), 81-116.

Hwang, S. H. (2018). Teachers' beliefs, classroom norms and discourse, and equity in mathematics classrooms. *Journal of Korean Society of Mathematics Education. Series C: Education of Primary School Mathematics*, *21*(2), 163-192.

Ingram, J., & Elliott, V. (2014). Turn taking and 'wait time' in classroom interactions. *Journal of Pragmatics, 62*, 1 - 12.

Ko, J. H., Kim, T. E., & No, W. K. (2015). An analysis of the actual status about the connection of teaching and learning mathematics between elementary school and junior high school. *Journal of Korea Society Educational Studies in Mathematics: School*

Mathematics, 17(1), 135-156.

Lerman, S. (2001). Cultural, discursive psychology: A sociocultural approach to studying the teaching and learning of mathematics. *Educational Studies in Mathematics, 46,* 87 - 113.

McHoul, A. (1978). The organization of turns at formal talk in the classroom. *Language in Society, 7*(2), 183 - 213.

Mehan, H. (1979). *Learning lessons*. Cambridge, MA: Harvard University Press.

Meyer, D. K., & Turner, J. C. (2002). Using instructional discourse analysis to study the scaffolding of student self-regulation. *Educational Psychologist, 37*(1), 17 - 25.

Ministry of Education (2015). *Mathematics curricula*. Seoul: The Ministry of Education.

Moschkovich, J. (1999). Supporting the participation of English language learners in mathematical discussions. *For the Learning of Mathematics, 19*(1), 11 - 19.

Mullis, I. V. S., Martin, M. O., Foy, P., & Hooper, M. (2016). *TIMSS 2015 international results in mathematics*. Retrieved from Boston College, TIMSS & PIRLS International Study Center website: http://timssandpirls.bc.edu/timss2015/international-results/

Nathan, M. J., & Knuth, E. J. (2003). A study of whole classroom mathematical discourse and teacher change. *Cognition and Instruction, 21*(2), 175 - 207.

National Council of Teachers of Mathematics. (1991). *Professional standards for teaching mathematics*. Reston, VA: Author.

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

National Council of Teachers of Mathematics. (2014). *Principles to actions: Ensuring mathematical success for all*. Author Reston, VA.

Radford, J., Blatchford, P., & Webster, R. (2011). Opening up and closing down: How teachers and TAs manage turn-taking, topic and repair in mathematics lessons. *Learning and Instruction, 21*(5), 625 - 635.

Sacks, H., Schegloff, E. A., & Jefferson, G. (1974). A simplest systematics for the organization of turn-taking for conversation. *Language, 50,* 696 - 735.

Seedhouse, P. (2004). *The interactional architecture of the language classroom: A conversation analysis perspective*. Malden, MA: Blackwell.

Sfard, A., & Kieran, C. (2001). Cognition as communication: Rethinking learning-by-talking through multi-faceted analysis of students' mathematical interactions. *Mind, Culture, and Activity, 8*(1), 42 - 76.

Sfard, A., Nesher, P., Streefland, L., Cobb, P., & Mason, J. (1998). Learning mathematics through conversation: Is it as good as they say? *For the Learning of Mathematics, 18*(1), 41 - 51.

Sinclair, J., & Coulthard, M. (1975) *Towards an analysis of discourse*. Oxford: Oxford University Press.

United Kingdom Qualifications and Curriculum Authority. (1999). *The national curriculum: Handbook for primary teachers in England*. Crown copyright & Qualifications and Curriculum Authority: London.

Vygotsky, L. S. (1980). *Mind in society: The development of higher psychological processes*. Cambridge: Harvard university press.

Vygotsky, L. S. (1986). *Thought and language*. Cambridge: MIT Press.

Walshaw, M., & Anthony, G. (2008). The teacher's role in classroom discourse: A review of recent research into mathematics classrooms. *Review of Educational Research, 78*(3), 516 - 551.

Warford, M. K. (2011). The zone of proximal teacher development. *Teaching and Teacher Education, 27*(2), 252 - 258.

Webb, N., Franke, M., Ing, M., Wong, H., Fernandez, C., Shin, N., & Turrou, A. (2014). Engaging with other's mathematical ideas: Interrelationships among student participation, teachers' instructional practice, and learning. *International Journal for Educational Research, 63*, 79 - 93.

Webb, N. M., & Palincsar, A. S. (1996). Group processes in the classroom. In D. Berliner & R. C. Calfee (Eds.), *Handbook of educational psychology* (pp. 841 - 873). New York: Simon Schuster/Macmillan.

Wood, T. (1998). Funneling or focusing? Alternative patterns of communication in mathematics class. In H. Steinbring, M. G. BartoliniBussi, & A. Sierpinska (Eds.), *Language and communication in the mathematics classroom* (pp. 167-178). Reston, VA: National Council of Teachers of Mathematics.

Wortham, S. (2004). From good student to outcast: The emergence of a classroom identity. *Ethos, 32*(2), 164 - 187.

Yackel, E., & Cobb, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics. *Journal for Research in Mathematics Education, 27*(4), 458 - 477.

수학 교실에서 교사 질문, 말하기 차례 규칙, 학생 발화 사이의 관계 분석

황성환[2)]

본 연구는 교사 질문, 말하기 차례 규칙, 학생 발화 사이의 관계를 파악하고자 수학 교실 내의 언어적 상호작용을 분석하였다. 이를 위해 같은 학교에 근무하고 있는 세 명의 초등학교 교사들(1학년 교사 2명과 2학년 교사 1명)의 수학 수업을 대화분석 기법을 사용해서 분석하였다. 각 교사들의 수업은 일 년에 걸쳐 총 3회 관찰되었다. 분석 결과, 교사가 열린 질문(예를 들어 "왜" 그리고 "어떻게" 질문들과 "동의합니까" 그리고 "동의하지 않습니까" 질문들)을 사용하고 비전통적인 말하기 차례 규칙(교사발문-학생답변-교사 피드백; Mehan, 1979)을 사용하였을 때는 학생들이 자신의 생각을 정당화하고 다른 사람의 생각을 반박하기 위해 교실 담화에 보다 적극적으로 참여하여하는 것으로 나타났다. 하지만, 교사가 닫힌 질문(예를 들어 "무엇" 질문들)을 사용하고 전통적인 말하기 차례 규칙을 사용하였을 때 학생들은 정답을 말하는 것에만 관심을 갖고 짧은 발화만을 사용하는 것으로 드러났다. 본 연구의 시사점은 다음과 같다. 첫째, 교사들은 효과적인 수학-대화 학습공동체를 만들기 위해 열린 질문을 사용하고 비전통적인 말하기 차례 규칙을 사용해야 한다. 둘째, 교사들이 발화기법에 관한 실질적인 지식을 얻을 수 있도록 교육 행정가와 수학 교육자들이 지원해야 한다.

주요용어 : 교사 질문, 말하기 차례 규칙, 학생 발화, 교실 담화, 수학-대화 학습공동체

Received November 15, 2019
Revised December 13, 2019
Accepted December 16, 2019

* MSC2010분류 : 97D40

2) 서울가주초등학교 교사 (ihwang413@gmail.com)