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An Analysis of Argumentation Discourse Patterns in Elementary Teachers' Science Classroom Discussions

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Abstract This multiple case study investigated how six elementary teachers' argumentation discourse patterns related to students' discussions in the science classroom. Four categories of classroom characteristics emerged through the analysis of the teachers' transcripts and recorded class periods: *Structure of teacher and student argumentation*, *directionality*, *movement*, *and structure of student talk*. Results showed that the differences between the teachers' discourse patterns were related to their modified reformed teaching observation protocol (RTOP) scores and to how the interaction of those differences affected student learning. Teachers with high RTOP scores were more likely to challenge their students' claims, explanations, and defenses and to provide less guidance and more waiting time for their students' responses than teachers with medium- and low-level RTOP scores. Students in the high-level teachers' classes challenged, defended, rejected, and supported each other's ideas with evidence and required less guidance than students in the medium-level and low-level teachers' classes.

Keywords Discourse pattern · Inquriy · Argumentation · Elementary teachers

Introduction

Many researchers have studied the importance of argumentation discourse in science education (Erduran & Osborne, 2005; Pontecorvo, 1987; Schwarz, Neuman, Gil, & Ilya, 2003). Studies have suggested that a teacher's primary role is to boost students' argumentation in the science classroom. According to Erduran, Simon, and Osborne (2004), "argumentation is a form of discourse that needs to be

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appropriated by children and explicitly taught through suitable instruction, task structuring, and modeling (p. 916)." Even though teachers are aware of the importance of argumentation in the science classroom, they still struggle to implement it (Cazden, 2001; Newton, Driver, & Osborne, 1999). The majority of previous studies have focused on secondary science teachers, so there is relatively little research on elementary teachers (Cavagnetto, Hand, & Norton-Meier, 2010).

This study was meant to encourage elementary science teachers to implement argumentation in the science classroom through an investigation of six elementary teachers' teaching practices in Science Writing Heuristic (SWH) professional development sessions using a modified framework based on Chen's framework (2011). Hand, Vaughan, and Carolyn (2002) explained that SWH "…is intended to help students construct understanding during practical work. Students are required to produce written explanations of the processes involved in the activity through completion of a template, with particular emphasis placed on claims, evidence and reflection (p. 20)."

The purpose of the study was to evaluate how the six participating teachers utilized the components in the construction and critique categories from the modified framework based on Chen's framework (see Table 1) when leading discussion during class and how that was related to the structure of student talk. Modified reformed teaching observation protocol (RTOP) scores (Martin & Hand, 2009) were used to classify the teachers into different levels. The original version had 25 items, but the modified version is comprised of 13 items, which focus primarily on the interactions between teachers and students, and between students through argumentation. The modified RTOP was developed before the SWH project started. The modified RTOP was used to analyze all of the participating teachers in the SWH project and to select teachers for the current study. Teachers with high RTOP scores were classified as high-level teachers, and teachers with medium or low RTOP scores were classified as low-level teachers. This study analyzed teachers' argumentation discourse patterns to determine student learning during discussion in the class.

Literature Review

In traditional science classrooms, teacher talk has been prevalent (Crawford, 2005). The *Initiate–Respond–Evaluate* (IRE) pattern is an example of teacher talk being dominant in traditional class discussion. In this pattern of discourse, the teacher *initiates* discussion by asking questions, students *respond* to the questions, and the

Table 1 Frameworks

Construction	Critique
Information seeking	Challenging
Elaboration	Defending—with or without evidence
	Supporting—with or without evidence
	Rejecting—with or without evidence

teacher then *evaluates* the students' responses immediately without allowing much student–student interaction or giving the students opportunities to contemplate their responses on their own. In this process, students are deprived of displaying much of the reasoning required to understand the concept in depth. The IRE pattern focuses on students providing the right answers regardless of their degree of understanding of the concept. Scott, Mortimer, and Aguiar (2006) have labeled this type of discourse as authoritative discourse. Traditional science classes are different from inquiry-based classrooms since they are teacher-driven and look for fixed answers (Polman & Pea, 2001). In order to facilitate inquiry in the science classroom, teachers try to encourage their students to use their scientific reasoning and thinking during discussion to have a better understanding of a concept (Lehrer & Schauble, 2006). Science is learned through the process of students engaging in talking about science, challenging each others' ideas, and playing an important role in the direction of their discussion about the topic (Lemke, 1990; McNeill & Pimentel, 2010). Science is a social process in which scientists continue to argue, rebut, and disprove each other's ideas by providing evidence until they come to an agreement about their claims (Driver, Newton, & Osborne, 2000). Students are required to have the ability to generate and assess scientific explanations and evidence and play an active role in class discourse to learn science appropriately (Duschl, Schweingruber, & Shouse, 2007). In order for student talk to be prevalent in the science classroom, the roles of teacher and student and instructional teaching strategies should be investigated (Kuhn & Reiser, 2006).

Argument is a crucial component in science. Through argument, students are able to develop their own ideas the same way as scientists (Jiménez-Aleixandre & Erduran, 2008; Zohar & Nemet, 2002). Argumentation is defined as the act of organizing evidence and theory to support and rebut an explanatory conclusion, model, and prediction for the purpose of justification and persuasion of one's idea to others (McNeill & Pimentel, 2010; Suppe, 1998). The National Science Education Standards (NRC, 1996) states that "student understanding is actively constructed through individual and social processes" (p. 28). A number of studies have suggested argumentation discourse in science education as a resolution to fulfill NRC's definition of inquiry (Erduran & Osborne, 2005; Pontecorvo, 1987; Schwarz et al., 2003). Results have suggested that a teacher should encourage students' argumentation in the science classroom. One of the ways to advance argumentation skills is to encourage student talk in the science classroom. A number of researchers have underlined the role of talk in learning both within and beyond the science education community (Barnes, 1976; Britton, 1982; Bruner, 1986; Corson, 1988; Lemke, 1990; Pea, 1993; Prawat, 1993; Rivard & Straw, 2000; Schoenfeld, 1989). Britton (1982) emphasized how the understanding of a concept could be strengthened through talking:

> We come to an understanding in the course of communicating it. That is to say, we set out by offering an understanding and that understanding takes shape as we work on it to share it. And finally we may arrive co-operatively at a joint understanding as we talk or in some other way interact with someone else. (p. 115)

Argumentation requires students to make a claim based on proper evidence and reasoning in order to generate an alternative explanation through the process of

criticizing the claim (Duschl et al., 2007). Through this process, students are able to deepen their understanding of the concept compared to traditional ways of learning science.

The role of teacher should be shifted from traditional practices to inquiry-based practices to facilitate student talk in the science classroom. This shift places many burdens on the teacher. The teacher has to have a good understanding of classroom culture for discussion and be able to take advantage of discussion skills and strategies for their students (Polman & Pea, 2001; Tabak & Baumgartner, 2004). The teacher should encourage student–student interactions in the classroom by supporting the student (McNeill & Pimentel, 2010); however, this is not the norm in most science classrooms (Herrenkohl, Palincsar, DeWater, & Kawasaki, 1999). The teacher should be a role model for the student critiquing and rebutting others' claims (Ford, 2008). If the student is not familiar with this type of discourse (e.g., critique and rebuttal), then role modeling is a method for the student to learn to perform their role in discussions.

Purpose

This study analyzed the differences in argumentation discourse between teachers with high-level RTOP score, medium-level RTOP score, and low-level RTOP score teachers in terms of leading discussions in science classrooms and how the interaction of those differences affected student learning in terms of student talk. The progress of the individual teachers across time was not analyzed in the study.

Theoretical Framework

Chen (2011) developed a framework to analyze the teachers' argumentation discourse characteristics when they engaged in discussions in the science classroom. Even though Chen's framework was originally designed to analyze how student learning occurs through argumentation, teachers' discourse characteristics, which help facilitate students' reasoning processes in the science classroom, can be evaluated via a modified framework based on Chen's framework. In argumentation, the construction and critique of knowledge play an important role (Cavagnetto, 2010; Ford, 2008; Roth et al., 2006; Weiss, Banilower, McMahon, & Smith, 2001). Critique of ideas is the key point in argumentation because it contributes to the construction of ideas (Ford, 2008). Teachers are encouraged to introduce these two factors in science classes. Chen's framework includes these two factors as two overarching categories. Therefore, his framework was utilized as the basis of our framework when we analyzed teachers' discourse patterns. Our framework based on Chen's framework contains two categories: Construction and critique (Table 1). The components under the two main categories in the framework were used as codes when analyzing the teachers' discourse patterns to determine characteristics (Table 2).

Table 2 Example of each component from the structure of teacher and student argumentation

Components	Example
Challenging	"How do you know that muscles come in pairs?", "How do you know?"
Defending	"We have two arms so that means…We have like the same muscle in each arm", "Because it would be like stronger in this one than this one if we didn't.", "Biceps are in your arms and they are muscles. And then triceps, I think, are somewhere in your arm or in your leg."
Supporting	"You can do basically like what Mike said. If you have like a bicep put them in groups.", "Well, I think it's a muscle". "Otherwise, I agree with Mike he said 'it moves'", "Ok, so because it said muscle let's put them together", "So then it would have to be like that. Ok, so if it wasn't for the movement then the baby wouldn't come out.", "I think you're probably right, cause if you didn't have an embryo there'd be nothing for."
Rejecting	"Listen, they have a different idea. Fibers go with heart.", "I don't think it does because movement means you run and you move your arms.", "it always just doesn't have to be in an egg. It could be like, like a baby bird that falls out of the nest and stuff"
Information seeking	"What was the first one?", "Does electricity, will it travel through it?", "What is electricity?", "what kind of world was that in?"
Elaboration	"The best animal adaptation is the tail for the alligator, fish and possum.", "It moves like that.", "I know two more animals that live there. A spider…", "There is no more brown"

Construction relates to how students build their own knowledge and articulate it as the preparation stage of argument.

- Information seeking was defined as a process of finding information related to the topic without critiquing (e.g., "What is the heat then?", "Ok, you gotta tell us what, what, what, umm, layers you're putting those animals in").
- Elaboration was defined as a process of substantiating ideas or activities based on the information students or teachers found or their background knowledge (e.g., "Like if I or something hits plastic, I'll turn into static," "You should be able to do this without any arguing").

Critique explains how students and teachers discuss each other's ideas. This category consists of four components. Each component has a different emphasis on discussion or argumentation in class.

- Challenging was defined as a process of critiquing how much students and teachers understand their ideas without judgment or having to agree or disagree (e.g., "What do you think about what they're saying?", "In your big group, and why did you group all those together again?").
- Defending was defined as a process of validating ideas using evidence or experience or without using evidence (e.g., "Because they both have the same word in them but involuntary and voluntary.", "Well, yeah because I've watched my brother break lots of his bones and stuff").

- Supporting was defined as a process of agreeing with others' ideas with or without evidence (e.g., "Yeah. Oh! Like wheat thins, like wheat thins! Fiber's in there and breakfast cereal and all that.", "Okay, so you were specific also, that's important").
- Rejecting was defined as a process of critiquing and disagreeing with others' ideas contingent on judgment based on evidence or without evidence (e.g., "I thought of a question, you're not really moving when you're relaxing. You're not moving at all really. So, I don't know if we should have put movement and relaxing together").

Methods

Subjects and Settings

This is a multiple case qualitative study. Thirty elementary school teachers in Midwestern elementary schools took part in SWH professional development sessions. The SWH project was designed to study how argument-based inquiry can help students learn any science topic regardless of the content. The PD sessions focused on this aspect. The main purpose of this study was to evaluate not the progress of the individual teachers across time but differences in discourse patterns between argument-based inquiry classes (SWH) and traditional classes that were enrolled in the SWH project including student talk patterns. The teachers in the treatment group of the project received an intensive PD session each summer before their fall semester started and one short PD session during each semester. The overall focus of all of the PD sessions for the treatment group explained the SWH approach and provided practice sessions with the researchers' feedback. The short PD sessions focused on listening to the teachers' issues and resolving them. The intensive summer PD sessions focused on analyzing other teachers' classes. In addition, teachers from the treatment group shared their experiences with each other. The teachers also had opportunities to design classes with every topic that they needed to teach during the semester (Table 3).

The teachers in the control group of the project received PD sessions to blind them. However, they did not receive the same type of PD sessions as the treatment

Table 3 Example of each component from directionality

Components	Example
Direction	"No, that's, I mean that's just, that's part of it, too.", "How about animals? Are you looking at the animals? Is there anywhere to put them?", "Ok, iguana! Do you know what layer he's gonna go in?", "Explain your model"
Non-direction	"I don't know, what you guys think?", "What about now after some discussion?", "He made a new claim, say that again.", "Now what can we do next? So we can find out what we're thinking and saying is right? What can we do?"

Table 4 Example of each component from movement

Components	Example
No circulation	High level—rarely stood in one spot with asking simple questions such as information seeking or elaborating
	Low level—stood in one spot with usually asking questions that require information and elaboration about the topic rather than asking questions that require students' thinking process
Circulation with interaction	High level—moved around the students asking questions that induce students' thinking process through challenging, defending, supporting and rejecting teachers and students' ideas
	Low level—rarely moved around the classrooms to interact with students

group. Instructions about the SWH approach were provided in the form of a PD session during summer. Each control school continued with the normal PD efforts for teachers. Each district is responsible for implementing a coherent plan for their teachers, including the emphasis on science. All control schools continued with this effort, and thus, both the SWH teachers and control teachers were involved in PD efforts each year (Table 4).

Six female elementary teachers out of the thirty teachers were chosen for this study using modified RTOP scores. The six teachers were selected because they had 100 % inter-rater agreement on RTOP scores. The participants consisted of three high RTOP score teachers, one medium RTOP score teacher, and two low RTOP score teachers. The modified RTOP items were administered to evaluate the differences between argument-based inquiry classes and traditional classes. There were no high RTOP score teachers from the traditional classes (control group). There were no low RTOP score teachers from the argument-based inquiry classes (treatment group). However, there were medium RTOP score teachers from argument-based inquiry and traditional classes. In order to further analyze the differences between the teachers in argument-based inquiry and traditional classes, we coded three randomly selected teachers with high RTOP scores, one teacher with a medium RTOP score, and two teachers with low RTOP scores. There was no difference between the medium RTOP score and low RTOP score teachers in terms of their discourse patterns; therefore, the medium RTOP score teacher was incorporated into the low RTOP score teachers. The high RTOP score teachers represented argument-based inquiry classes and medium and low RTOP score teachers represented traditional classes. The teachers in the control group represented low RTOP score teachers since there were no high RTOP score teachers in the control group. The participating teachers taught from third to fifth grade. The average class size was 15 students across the classrooms. Teachers were asked to record their classes at the beginning of a semester and at the end of the semester and send them to the researchers. When we chose the six teachers for the study, we excluded the teachers who had not sent two video clips. One video clip from each teacher was selected and analyzed. Therefore, a total of six video clips for the study were coded to evaluate the teachers' discourse patterns. In some cases, research assistants were sent to teachers' classrooms to provide technical assistance

Table 5 Example of each component from the structure of student talk

Components	Example
Challenging	"I'm just wondering how they break apart. How can it break and then connect together?", "what if there was an owl that was two yards long?"
Defending	"Because we thought it would be like the same, like you're moving. Like when you exercise you move your legs and your arms"
Supporting	"I agree with you guys because uh, uh, seeds do have roots and leaves, because when they start to grow out of the soil, kind of like a flower, it grows roots, I mean a tree grows roots and leaves just like a regular seed does"
Rejecting	"Owls can't really be that tall, that's 2 feet nine inches", "Your bicep is like all the way down your arm right here.", "I think they go together because it just says two kind of muscles"

when the teachers asked for help recording their classes. The videotaped classroom sessions were 48 min in duration on average (Table 5).

Data Collection and Analysis and Response Definitions

The data were collected from transcripts and video clips using our components based on Chen's framework (2011). These videos were transcribed word for word by the research team. When we initially coded teachers' transcripts that were not included in the current investigation, we found that the definitions of the components from Chen's framework needed modification to describe teachers' argumentation discourse patterns. In order to better identify teachers' argumentation discourse patterns, we redefined each component from Chen's framework. For example, in Chen's framework, there was no distinction between "with and without evidence" among all of the components in the critique category. We added "with or without evidence" to each component in the critique category because students did not provide evidence from time to time when utilizing the critique components. It is important for students to critique ideas with evidence to make their assertions logical. In the construction category, the information seeking component and the elaboration component were distinguished by the following standards. In the original framework, information seeking was described as asking for information. This description conflicted with "elaboration" in the construction category and the challenging component in the critique category. We made a clear distinction between them. Information seeking was defined as a process of finding information related to the topic without critiquing, such as asking for a definition or asking questions that required "yes" or "no" answers. Elaboration was defined as a process of substantiating the information based on one's experience. The difference between information seeking and challenging is whether or not to include "critique." When one was to ask for information with critiquing, it was defined as challenging. While coding the teachers' transcripts with our components, three characteristics emerged: the structure of teacher and student argumentation, directionality, and the structure of student talk. Movement also emerged as a distinction between the two class types (SWH and traditional). Therefore, we added teacher movement as an additional

characteristic because our data analysis showed that it differentiated between high RTOP score (high-level) and a medium and low RTOP score (low-level) classes.

There were two main categories in our components based on Chen's framework. The occurrence of the six components from both main categories was counted and calculated using the transcripts from all of the participating teachers' discourse patterns to determine characteristics. Percentages of each component were calculated by dividing the frequency of the occurrence of each component by the total number of components recorded in a session.

The teachers' physical motion combined with an interaction with students in the classroom was measured via observing the video clips and calculated by dividing the minutes of classroom movement with an interaction with students by the total minutes of (the) class time. The four categories, which determined the high-level and low-level teachers' discourse characteristics, were measured and examples were used under pseudonyms.

We practiced and discussed coding video transcripts and video clips from teachers who were not included in the current investigation until we had the same understanding of each component. Practice sessions were conducted until data coders achieved an average of 90 % inter-rater agreements across six practice sessions. One researcher coded all transcripts and video clips, and a second researcher coded 40 % of the transcripts and video clips to determine inter-rater agreement. The inter-rater agreement was 95 %.

1. *Structure of teacher and student argumentation* was defined as interactions in which the teacher and students challenged, defended, supported, or rejected each other's ideas with or without evidence rather than seeking for information or elaborating information in the class.
2. *Directionality* was defined as the teacher giving explicit information to the students about what to do during a science lesson rather than leaving the students to find the information about what to do on their own.
3. *Movement* was defined as the teacher's physical motion within the classroom as he or she interacted with the students about a specific topic.
4. *Structure of student talk* was defined as interactions in which students defended, supported, and rejected each other students' statements or ideas with or without experience or evidence when their statements or ideas were either being challenged or not being challenged.

Results

There was no distinct difference between medium-level and low-level teachers in terms of students' engagement in argumentation. However, there was a clear difference between high-level and low-level teachers. The medium-level teacher's argumentation discourse characteristics were incorporated into the low-level teachers' argumentation discourse characteristics. Details about the four characteristics that have come up from the participating teachers' classrooms are explained as follows:

The first characteristic was "structure of teacher and student argumentation." This referred to an overall picture of how argumentation took place between teacher and students, and student to student in the classroom. Table 6 shows the average percentages of teachers and students' challenging, defending, rejecting and supporting with or without evidence, information seeking, and elaborating characteristics in argumentation that were measured during each teacher's classroom (e.g., among all of the components in each teacher's class, "information seeking" accounted for 19 % of the total frequency of all of the components). The results were averaged across high-level and medium- and low-level teachers' classrooms. In the high-level classes, teachers and students challenged or questioned other students' ideas and students defended, rejected, or supported teachers and students' questions or challenges with or without evidence or experience during 41 % of the discourse. The medium- and low-level teachers and their students showed the same characteristics 16 % of the time. The medium- and low-level teachers' discussions led their students to reiterate the same knowledge or information in a slightly different way. Students simply talked about either information or definitions, repeated, or rejected others without evidence (e.g., "No"). Their discourse patterns were primarily "information seeking" and "elaborating" 84 % of the time. In other words, there was often no evidence of reasoning in the students' explanations and argumentation compared to high-level teachers. The high-level teacher classrooms' discourse patterns revealed that "information seeking" and "elaborating" accounted for 59 % of the discourse. This indicated that high-level classes used less constructing components such as information seeking and elaborating, than the medium- and low-level classes.

The second characteristic was "directionality" (Table 7). Results showed that high-level teachers used non-directional statements and questions 86 % of the time on average during teaching, whereas medium- and low-level teachers used non-directional remarks 72 % of the time across their classes. Overall, the high-level teachers were less-directive during classroom discussions than medium- and low-level teachers. High-level teachers tended to offer student talk time more frequently and for longer durations than medium- and low-level teachers.

The third characteristic was "movement," This referred to the teachers' actual physical locations when interacting with their students (Table 8). High-level

Table 6 Structure of teacher and student argumentation in high-, medium- and low-level teachers' classrooms

Structure of teacher and student argumentation	High-level teachers' classrooms (%)	Low- and medium-level teachers' classrooms (%)
Information seeking[a]	19	25
Elaborating[a]	40	59
Challenging[a]	16	5
Defending[a]	15	5
Rejecting[a]	3	4
Supporting[a]	7	2

[a] Average percentage of each component across classes

teachers circulated in the classroom while interacting with their students 27 % of the time. In contrast, the medium- and low-level teachers circulated <1 % of the time. This difference showed that high-level teachers circulated more frequently when interacting with their students rather than standing in one place when compared to medium- and low-level teachers.

The last characteristic was "structure of student talk." This indicated the degree of reasoning presented in students' arguments (Table 9). In high-level teachers' classes, students challenged, defended, rejected, and supported their teachers' and other students' ideas with evidence or experience 58 % of the time. When using evidence, the students tried to connect their experience or evidence to their discussion. In medium- and low-level teachers' classes, students used evidence or experience when discussing 41 % of the time. In medium- and low-level teachers' classes, student talk had fewer references to experience or evidence.

Table 10 shows which components were presented with or without evidence. There was no occurrence of whether or not providing evidence when challenging others' ideas in both high- and low-level classes. In high-level classrooms, students defended their ideas with evidence during 39 % of the argumentation, supported others' ideas with evidence during 12 % of the argumentation, and rejected others' ideas with evidence during 7 % of the argumentation, whereas they defended others' ideas without evidence during 19 % of the argumentation, supported others' ideas without evidence during 18 % of the argumentation, and rejected others' ideas without evidence 5 % of the argumentation. In medium- and low-level classrooms, students defended their ideas with evidence during 25 % of the argumentation, rejected others' ideas with evidence during 13 % of the argumentation, and supported others' ideas with evidence during 2 % of the argumentation, whereas they defended others' ideas without evidence during 17 % of the argumentation, supported others' ideas without evidence during 20 % of the argumentation, and rejected others' ideas without evidence during 23 % of the argumentation. In medium- and low-level teachers' classes, students' rejecting accounted for a higher percentage than students in high-level teachers' classes. However, students in high-level teachers' classes engaged in rejecting with evidence compared to students in medium- and low-level teachers' classes (Table 11).

Even though rejecting in the medium- and low-level teachers' classes occurred more frequently than the high-level teachers' classes (Table 11), the percentage of evidence provided within the rejecting component was higher in the high-level teachers' classes than the medium- and low-level teachers' classes.

Table 7 Directionality in high-, medium- and low-level teachers' classrooms

Directionality	High-level teachers' classrooms (%)	Low- and medium-level teachers' classrooms (%)
Direction[a]	14	28
Non-direction[a]	86	72

[a] Average percentage of each component across classes

Table 8 Movement in high, medium- and low-level teachers' classrooms

Movement	High-level teachers' classrooms (%)	Low- and medium-level teachers' classrooms (%)
No circulation[a]	73	99
Circulation with interacting[a]	27	1

[a] Average percentage of each component across classes

Table 9 Structure of student talk in high-, medium- and low-level teachers' classrooms

Structure of student talk	High-level teachers' classrooms (%)	Medium- and low-level teachers' classrooms (%)
Without evidence[a]	42	60
Evidence[a]	58	40

[a] Average percentage of each component across classes

Table 10 Structure of student talk in high-, medium- and low-level teachers' classrooms

Structure of student talk	High-level teachers' classrooms (%)	Low- and medium-level teachers' classrooms (%)
Challenging—without evidence[a]	0	0
Challenging—evidence[a]	0	0
Defending—without evidence[a]	19	17
Defending—evidence[a]	39	25
Rejecting—without evidence[a]	5	23
Rejecting—evidence[a]	7	13
Supporting—without evidence[a]	18	20
Supporting—evidence[a]	12	2

[a] Average percentage of each component across classes

Table 12 shows the four discourse pattern characteristics between high-level teachers' classrooms and low- and medium-level teachers' classrooms. High-level teachers' classes showed more frequent challenging, defending, supporting, and rejecting compared to the medium- and low-level teachers' classes in terms of argumentation. High-level teachers' discourse patterns displayed more non-directional statements than medium- and low-level teachers' discourse patterns. High-level teachers circulated actively when interacting with their students. Medium- and low-level teachers tended to be stationary, that is, they did not circulate, when interacting with their students. In high-level teachers' classes, students utilized evidence more frequently during discussions than students in medium- and low-level teachers' classes.

The results showed the relations between the structure of teacher and student argumentation, directionality, movement, and the structure of student talk. The

Table 11 Structure of rejecting in high-, medium- and low-level teachers' classrooms

Rejecting	High-level teachers' classrooms (%)	Low- and medium-level teachers' classrooms (%)
Without evidence[a]	42	60
Evidence[a]	58	40

[a] Average percentage of each component across classes

structure of teacher and student argumentation represents an overall picture of how argumentation occurred between teacher and students, and student to student in the classroom by two categories: (1) construction and (2) critique. The construction category was related to directionality. The critique category is related to the frequency of providing evidence and the amount of movement during classes. High-level teachers often utilized the critique category (e.g., challenging, defending, supporting, and rejecting) and were non-directional when teaching a topic and circulated while interacting with their students. Relations between these classroom behaviors warrant further investigation. At the same time, directionality was related to the other two characteristics inversely. Medium- and low-level teachers' classes utilized the construction category more often than high-level teachers' classes. This indicated that directionality and non-movement is related to the use of construction. Classes that relied on the construction category most of the time in argumentation showed a pattern of being direct to their students when they were off topic and being less interactive with their students while moving less during the classes. The interaction among these three characteristics was related to the structure of student talk. The more critique combined with non-direction and circulation was used, the more evidence was provided when students defended, supported, and rejected their or others' statements or ideas. In contrast, when construction combined with direction and non-movement was dominant, students tended to defend, support, and reject their own or others' statements or ideas without evidence most of the time.

Discussion

The structure of teacher and student argumentation characteristic showed a clear difference between the participating teachers' classroom argumentation discourse patterns. In high RTOP score teachers' classes, teachers and students challenged, supported, rejected, and defended their own and other's ideas more frequently than the teachers and students in medium and low RTOP score teachers' classes.

The directionality characteristic showed that medium and low RTOP score teachers provided more explicit information (e.g., asking for information, definition, or elaboration) when their students got lost in discussions than high RTOP score teachers.

The movement characteristic showed that high RTOP score teachers circulated around the classroom while interacting with their students with the components from both categories (e.g., construction and critique) more frequently than medium and low RTOP score teachers.

Table 12 Four discourse pattern characteristics in high-, medium- and low-level teachers' classrooms

Characteristics	High-level teachers' classrooms	Low- and medium-level teachers' classrooms
Structure of teacher and student argumentation	Challenging/defending/supporting/rejecting	Information seeking/elaborating
Directionality	Non-directional	Directional
Movement	More extensive circulation in classroom	Less circulation in classroom
Structure of student talk	More experience and evidence provided during discussions	Less evidence and more elaborating were provided

The structure of student talk characteristic showed that the challenging, supporting, and defending components in the critique category occurred more frequently in the high RTOP score teachers' classrooms than the medium and low RTOP score teachers' classrooms. The rejecting component in the critique category was used more frequently in the medium and low RTOP score teachers' classrooms than in the high RTOP score teachers' classrooms. One exception led us to delve into the quality of the components from the critique category. The quality of the critique category was defined by whether evidence was provided or not. Even though the frequency of rejecting ideas was lower in high RTOP teachers' student talk than the student talk in medium and low RTOP score teachers' classes, the frequency of providing evidence with the components in the critique category was higher in high RTOP score teachers' student talk across all of the components. In sum, the degree of using reasoning (e.g., the percentages of providing experience or evidence in defending, supporting and rejecting ideas) was higher across all of the components in the high RTOP score teachers' classes.

High-level teachers had four characteristics. First, high-level teachers were more likely to ask questions that elicited reasoning from students rather than "yes" or "no" responses, or definitions. Second, high-level teachers were more likely to wait for students to recover a direction when they become lost in the middle of discussion and ask open questions in the form of challenging ideas that encouraged students to come up with their own answers. Third, high-level teachers were more likely to interact with their students while circulating around the classroom. Finally, high-level teachers were more likely to facilitate conversation between students in a way that enabled them to use evidence and experience in their discussion by keeping on challenging their ideas. Through this process, students were able to connect their experience to their studies when they were not able to come up with evidence. This is important for students to learn new concepts. In the beginning of a unit, some students are not comfortable with providing evidence about their ideas. If teachers encourage students to use personal experience or background knowledge, students are able to understand the concept more easily and learn how to use evidence in discussion.

There were several limitations to this study. First, there were no teacher interviews. Without interviews, it is difficult to determine how well the teachers understood the SWH approach and how it related to their teaching practices.

Second, the question of how teachers' physical locations affected students' learning directly was not addressed. Third, the relation between teacher understanding of SWH and their practices was not evaluated. Finally, it was difficult to show all of the distinctions between high-, medium-, and low-level teachers with this small sample.

Measuring variables in the learning environment that enable students to engage in argumentation needs to be investigated further. Levels of student engagement in an SWH class are important, because students' responses affect teachers' questioning. The stage of the unit may also affect teachers' questioning. For example, at the beginning of a topic, teachers focused on information, whereas at the end of a topic, questioning may be more directed to the students' reasoning. The relations between the stage and questioning types should be investigated. The elements within the critique component that affected student talk directly and how each element affected student talk should be investigated. The results were not able to explain what caused the differences between high- and medium- and low-level teachers' classes. Future research should also address the variables that hinder low-level teachers from becoming high-level teachers.

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