The Roles of Teacher Questioning in Argument-Based Inquiry (ABI): Approaches that Promote Cognitive Thinking and Dialogical Interaction

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Abstract: The purpose of this study was to investigate the various questioning roles elementary teachers adopt to scaffold dialogical interaction, students' cognitive responses, and the use of evidence for constructing and critiquing ideas in argumentation over time. This study was designed as a follow-up study after a four-year professional development program that emphasized an argument-based inquiry approach. Data sources included 30 science lessons focusing on whole-class discussion from three early elementary teachers' classes. Data were analyzed through constant comparative method and enumerative approach. The findings indicated: (1) teachers used multiple roles in establishing argumentative discourse as they persistently implemented an argument-based inquiry approach, (2) as teachers used multiple roles in establishing patterns of questioning, framing classroom interaction, students' higher levels of cognitive thinking was promoted, and (3) as teachers' patterns of questioning changed, the frequency of students' talk increased and the dialogical interaction between students and teachers became more evidence-based and connected.

Introduction

The emphasis on argumentation in science education shifts the focus of science classrooms from memorizing facts to engaging students in an authentic scientific practice in which they search for data patterns to shape evidence for the support of scientific claims and debate those claims publicly to identify the weaknesses of their arguments (Cavagnetto, 2010; Berland & Reiser, 2009). In this form, learning science is not simply about how to define vocabulary to explain content, but is rather about the ways in which questioning and evolving questioning techniques can be used to extend one's conceptual understanding of the subject matter. The importance of argumentation has been explicitly endorsed by two recent U.S. reform documents, Taking Science to School (National Research Council (NRC), 2007) and A Framework for K-12 Science Education (NRC, 2012), as a critical approach utilized in science classrooms for promoting student conceptual understanding and cognitive thinking.

However, A Framework for K-12 Science Education (NRC, 2012) raised the critical point that argumentation "has too often been underemphasized in the context of science education" (p. 44, NRC, 2012). The problem has not been so much the content of the lessons (Banilower et al., 2013) or the pedagogical knowledge of the teachers (Ball, 2000), but rather the way teachers ask questions to engage students in the practice of actively constructing and critiquing scientific knowledge (Hmelo-Silver & Barrows, 2008). A national observation survey in the United States conducted by Banilower et al. (2013) found that more than 90% of questioning patterns in science lessons consist of low-level "fill-in-the-blank" questions, asked in rapid-fire fashion to obtain the correct answer and move on, in effect short-circuiting student cognitive thinking. Teachers struggle with developing appropriate and diverse roles for asking a series of high quality questions to establish argumentative discourse and foster students' conceptual understanding and cognitive thinking (Oliveira, 2010). For Chin (2007), teachers' questions "play an important role in determining the nature of discourse" (p. 815) for argumentation, including eliciting, comparing, challenging, and synthesizing students' arguments in different conditions.

Developing appropriate and multiple roles of questioning in the establishment of argumentative discourse is challenging and takes time (Martin & Hand, 2009; McNeill, & Pimentel, 2010). Addressing this challenge requires examining teacher roles of questioning in the establishment of argumentative discourse as well as examining the dynamic discourse patterns among teachers and students that can influence students' cognitive thinking (Oliveira, 2010). Many studies of this subject have dichotomized the types of teacher questions into open- and closed-ended questions, which tend to oversimplify the role of teacher questioning in the complexity of argumentative dialogue. This dichotomy also prevents teachers from developing multiple roles for argumentation. There is still much to be learned about supporting the development of teacher roles of questioning in promoting student ownership of learning, as well as about the relationship between teacher roles of questioning and the way students use evidence to actively construct and critique knowledge.

In addition, although U.S. national reform documents (NRC, 2007, 2012) have called for argumentation as a core practice of science classrooms across the entire K-12 grade span, the opportunities for early elementary students to participate in scientific argumentation are practically "epistemologically impoverished" (p. 51, Metz, 2011). Deficiencies in the cognitive development of early elementary students have

been misinterpreted as reasons why they are not able to participate successfully in scientific argumentation. Most previous studies have focused on upper elementary (e.g., Martin & Hand, 2009), middle (e.g., Nam, Choi, & Hand, 2011; Chin, 2007), and high school levels (e.g., McNeill, & Pimentel, 2010; Scott, Mortimer, & Aguiar, 2006). Little information currently exists on early elementary classrooms, even though research suggests that early elementary science practices are fundamental for developing cognitive thinking and scaffolding readiness capacities in multiple domains (Lee & Kinzie, 2012).

This multiple-case study aimed to explore and conceptualize the roles of questioning that developed as early elementary teachers attempted to implement an argument-based inquiry approach over four successive years and how those changes in teacher roles impacted on student engagement in argumentative processes. The study was framed by the following research questions: (1) What roles do early elementary teachers adopt in argumentative discourse, especially in whole class discussion, when they use questioning as a tool to engage students in cognitive response over the course of four years? (2) How do the roles teachers adopt impact on students' cognitive response? (3) How do the roles teachers adopt impact on the way students use evidence for dialogical interactions?

Theoretical Framework

Research has suggested that teacher questioning is a major contributing factor to shape the role of teachers for promoting dialogical interaction and students' ownership of ideas (Scott, Mortimer, & Aguiar, 2006). However, Roth (1996) argued that teacher questioning is activity dependent. That is, the function of teacher questions is not just about discussing ideas with students, but the teachers also need to have awareness of the ownership of activity situated in the moment of that context. For example, some classroom activities are still controlled by the teachers even if the ownership of discussion ideas belongs to students (Chin, 2007). In contrast, there are cases where activities are maintained by students but teachers may serve in the role of a coach to nudge students towards an understanding of canonical science knowledge. Thus, the role of teachers' questions should be conceptualized based on ownership of ideas and activities. The following four categories of dialogical approach emerge.

a. *Teacher's ownership of ideas/ Teachers' ownership of activities* involves the teacher guiding students and directing them to develop ideas and strategies for argument. Teachers control the ideas and activities during dialogue.
b. *Students' ownership of ideas/ Teacher's ownership of activities* involves encouraging students to develop their own ideas through teacher-led dialogue. The teacher only intervenes in recognizing, comparing, and integrating students' ideas to reach consensus. Teachers control the activity, but the direction of dialogue follows students' ideas.
c. *Teacher's ownership of ideas/ Students' ownership of activities* involves the teacher allowing students to conduct activities but challenging students' ideas and resolving their difficulties by asking questions. The teacher guides students' ideas during the students' activities.
d. *Students' ownership of ideas/ Students' ownership of activities* involves the teacher and the students exchanging ideas and developing activities collaboratively through student-led negotiation. Students control their ideas and activities and the teacher is open to learning new concepts.

By analyzing various questioning approaches and the associated teacher–student discourse, we used these four aspects to explicate the critical roles of the teacher in argumentation and to reveal some of the limitations and functions of teacher roles of questioning for establishing dialogical patterns and students' ownership of learning.

Methods

This study took place in three early elementary science classrooms (Brielle and Susan were third grade teachers; Lynette was a second grade teacher) utilizing an argument-based inquiry (ABI) approach (Chen, & Steenhoek, 2014; Martin & Hand, 2009) over a span of four consecutive years. This multi-case study employing a mix methods approach (Creswell, 2003) was designed as a follow-up study after a four-year professional development project that emphasized learning science as a negotiation process by embedding arguments in scientific inquiry activities using the ABI approach. This project attempted to aid elementary science teachers in designing instruction around unit big ideas and provided opportunities for teachers to tie learning theory to pedagogical practice. Three teachers were purposefully selected for this study from the 31 participating teachers. The criteria of selection was that (1) they taught early elementary grade levels, (2) they had no experience with implementing argument-based inquiry in their classrooms before they participated in the project, and (3) they had completed data sources that enabled the researchers to trace their changes over time.

Data Collection

The major data sources were 30 science lessons taught by the three teachers over four consecutive years. Those lessons were recorded by the three teachers when they engaged their students in public negotiation about claims and evidence. Each lesson recorded was 25-45 minutes in length and focused on whole-class discussions after a small group of students presented their written claim and evidence about a concept in science. The total time of Brielle's video-taped classroom observation was 364 minutes; Lynette's was 280minutes; and Susan's was 337 minutes. The units taught in the three teachers' classrooms were covered by National Standards (NRC, 1996) and State Standards, and included units such as plants, force, the three phases of water, and sound, etc.

Data Analysis

To triangulate the dynamics of and changes in the role of teachers' questioning and the resulting impact on students' engagement in argumentation, data were analyzed through two approaches: (1) the constant comparative method (Strauss & Corbin, 1990) and (2) the enumerative approach (LeCompte & Preissle, 1993). What follows is a description of each approach.

Constant Comparative Method

All 30 science lessons focusing on whole class discussion were first transcribed and each transcript was broken into individual utterances. An utterance was defined as a unique idea contributing to the discussion. The total number of utterances in Brielle, Lynette, and Susan's classrooms were 1991, 1451, and 2407, respectively. Four different coding frameworks were developed to code the utterances to address three research questions respectively: teacher roles for questioning to address Research Question 1; student cognitive responses to address Research Question 2; evidence of quality and dialogical interaction to address Research Question 3. The coding system was established by five graduate students in the field of science education through an interactive process of reviewing the transcripts. Any disagreements were discussed weekly until a consensus was reached

Teacher roles for questioning: The coding system was established through an interactive process of reviewing the transcripts without utilizing a pre-existing coding system. As a result, the coding system included: *lecture, guide, recognize, compare, integrate, challenge, elicit, exchange,* and *encourage*. In order to simplify and capture the representation of teacher questioning roles, we attempted to group these nine codes into more comprehensive categories. The nine codes were categorized based upon these four roles. As a result, *lecture* and *guide* were categorized as dispenser; *recognize, compare,* and *integrate* were categorized as moderator; *challenge and elicit* were categorized as coach; and *exchange and encourage* were categorized as participant.

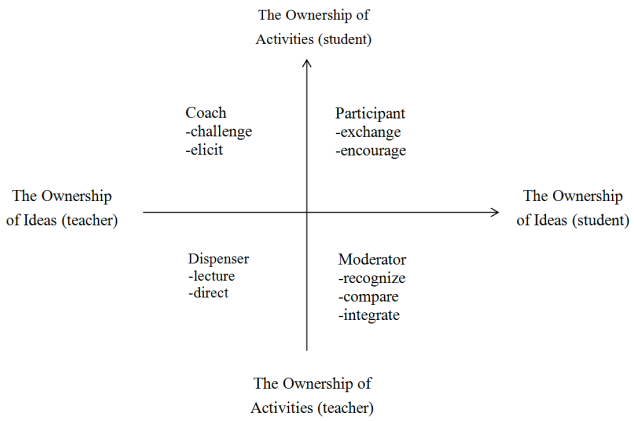


Figure1. Framework for teacher roles of questioning from two combinations of ownership of ideas and ownership of activity

Student cognitive responses: Codes developed through the analysis included: *retrieve, express, elaborate, reframe, defend, synthesize, challenge,* and *justify*. In order to categorize the codes into a hierarchical typology, the codes for cognitive processes were clustered into three levels using Bloom's taxonomy. As a result, *retrieve* and *express* were clustered in the low level (knowledge/comprehension); *elaborate* and *reframe* were clustered in the medium level (application/analysis); and *defend, synthesize, challeng*e, and *justify* were clustered in the high level (evaluation).

Evidence of quality: Evidence is an explanation consisting of data and reasoning to show how or why a claim is supported (Chen, Hand, & McDowell, 2013). Two coding schemes were developed to classify the quality of student evidence: *without reasoning* and *with reasoning*. If students simply expressed experience, reported data, or quoted information from books or the Internet as their evidence, it was coded as without

reasoning. If the evidence included a justification for why it supported or rejected a student's claim or evidence, it was coded as with reasoning.

Dialogical interaction: The scheme included three codes: independence, trivialization, and connection. Utterances coded as *independence* represent any reaction that was not connected to evidence or ideas that had been previously raised in classroom discussion. Utterances coded as *trivialization* represent any reaction that was shut down or that ignored previous evidence or ideas. Utterances coded as *connection* represent any reaction that challenged, rejected, supported, or asked for elaboration about evidence or ideas that had been previously proposed during discussion.

Enumerative Approach

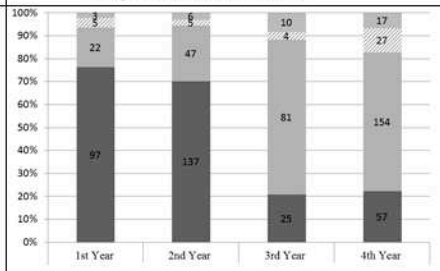
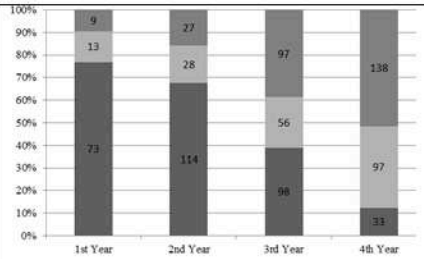
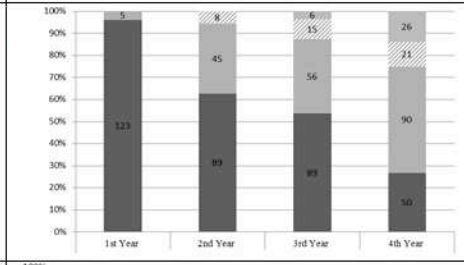
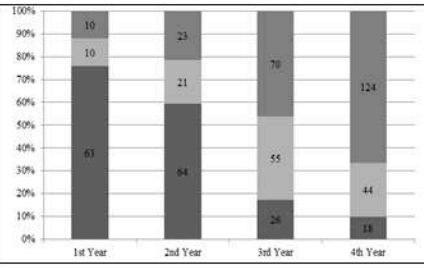
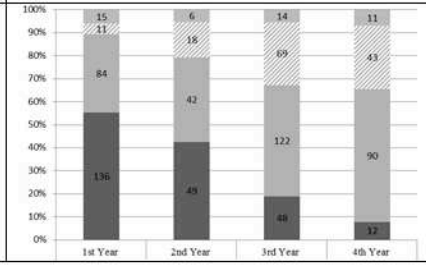
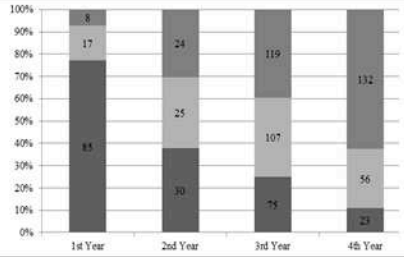
In order to clearly and explicitly portray the changes over a four-year period in teacher use of questioning to engage students in argumentation, an enumerative approach was employed to quantify verbal data (LeCompte & Preissle, 1993).

Findings

Teachers Increasingly Used Multiple Roles in Establishing Argumentative Discourse as They Persistently Implemented an Argument-Based Inquiry Approach

Four different roles in establishing patterns of questioning were increasingly adopted by the three teachers over the four-year period. These included: dispenser, moderator, coach, and participant. In the first year, the most typical role adopted by teachers in classroom discussion was the dispenser, focused on getting a specific response. As Table 1 shows, 76% (193/254), 96% (123/128), and 56% (136/246), respectively, of Brielle, Lynette, and Susan's questioning strategies fell in the role of dispenser in the first year.

Table 1. Number and percentage of teacher roles for questioning used by the three teachers and students' cognitive responses over four years

Teacher	Teacher roles for questioning	Student cognitive response
	Participant (Exchange, Encourage) Coach (Challenge, Elicit) Moderator (Recognize, Compare, Integrate) Dispenser (Lecture, Director)	High (Defend, Challenge, Synthesis, Justify) Medium (Elaborate, Reframe) Low (Retrieve, Express)
Brielle (3rd grade)		
Lynette (2nd grade)		
Susan (3rd grade)		

However, as teachers consistently implemented an argument-based inquiry approach, they developed different roles for questioning in order to establish students' ownership of ideas and activities. The moderator

role was employed to synthesize students' ideas as a consensus, leading the students to the development of canonical science concepts that were consistent with the teachers' lesson goals. This type of questioning is similar to Chin's (2007) "verbal jigsaw" and "semantic tapestry" approach in that the teachers still maintained their position of ownership for the discussion activity but students played active roles in verbalizing their ideas.Taking Brielle as an example, the percentage of utterances coded as moderator increased from 17% (44/254) in the first year to 60% (154/255) in the fourth year.

Another role developed by the three teachers was that of the coach. For example, the coach role in Susan's class increased from 4% (44/246) in the first year to 28% (43/156) in the fourth year. The purpose of this role was to elicit and challenge students to resolve discrepant views to build and strengthen the connections among their preconceptions and a new concept, thereby broadening and deepening their conceptual network.

The participant role was another salient strategy that the three teachers developed for argumentative environments. For example, the coach role in Lynette's class increased from 0% (0/128) in the first year to 14% (26/187) in the fourth year. This role provides students ownership of ideas and activities in which they actively ask questions, pose problems, and seek an explanation as a class.

Taken together, the findings show a series of shifts in teacher roles for questioning from one single role focusing on controlling the ownership of ideas and activities toward multiple roles that provide for students' ownership of ideas and activities.

As Teachers Used Multiple Roles in Establishing Patterns of Questioning, Framing Classroom Interaction, Students' Higher Levels of Cognitive Thinking Was Promoted

The findings shows that as these teachers simply adopted the dispenser role for interacting with students, the students mainly engaged in lower-level cognitive activities, such as retrieving scientific vocabularies and providing short answers (See Table 1). While the dispenser role is usually pitched at short answers and lower-level cognition, the moderator, coach, and participant roles usually required much longer student responses to defend, challenge, synthesize, and articulate claims and evidence as well as further prompted higher-level cognition.

Taking Brielle as an example, as her questioning patterns shifted away from a single, more teacher-centered role to multiple, student-centered roles, students' higher-level cognitive thinking was encouraged. Evidence of the shift in students' cognitive response is supported by the increase of their utterances categorized as medium and high, which grew from 14% (13/95) and 9% (9/95), respectively, in the first year to 36% (97/268) and 51% (138/268) in the fourth year.

In the following discussion, several examples will be provided to demonstrate the differences and trends in the four roles of teacher questioning over the four years as well as to illustrate how those questioning patterns impacted students' cognitive levels of response.

As Teachers' Patterns of Questioning Changed, the Frequency of Students' Talk Increased and the Dialogical Interaction Between Students and Teachers Became More Evidence-Based and Connected

As the teachers' roles in establishing patterns of questioning were examined further, the data showed a parallel shift between teachers' questioning patterns and students' verbal participation. Figure 2 shows that students' argumentative utterances in an hour increased from the first to the fourth year (Brielle's class from 140.1 to 301.1; Lynette's class from 177.6 to 295; Susan's class from 199.8 to 321.1). Figure 3 portrays the trend of the changes in students' verbal participation in an hour. These changes in the relative frequency of students' argumentative utterances suggest that the learning environment became more student-centered and unthreatening, and that thus students were more willing to articulate their arguments.

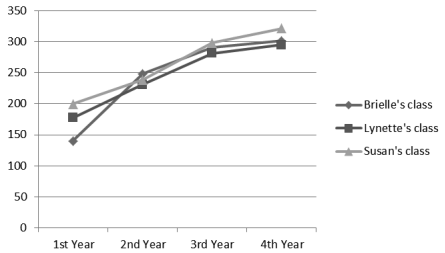


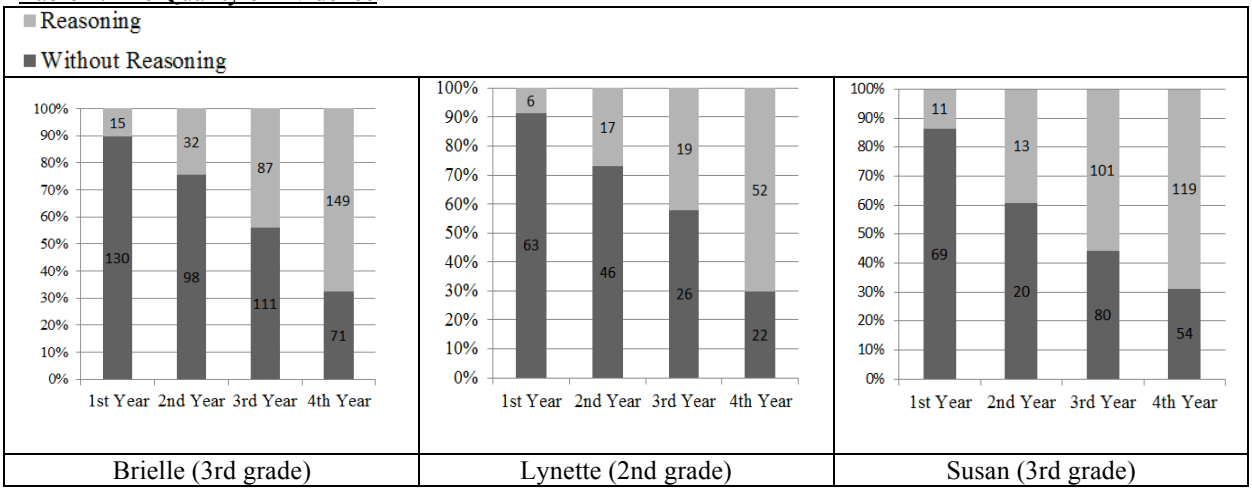
Figure 2. The Trend of Students' Utterances over Four Years

As students' oral participation increased over the years, two distinct shifts regarding the quality of discussion were found: (1) students came to discuss their ideas based on evidence, and (2) students began to connect pieces of evidence to other evidence they had found.

Evidence-Based Discussion

Table 2 shows that the proportion of utterances where students used evidence to discuss their ideas increased from 10% (15/145) in Brielle's classroom, 9% (6/69) in Lynette's classroom, and 14 % (11/80) in Susan's classroom in the first year to 68 % (149/220), 70 % (52/74), and 69% (119/173), respectively, in the fourth year.

Table 2. The Quality of Evidence

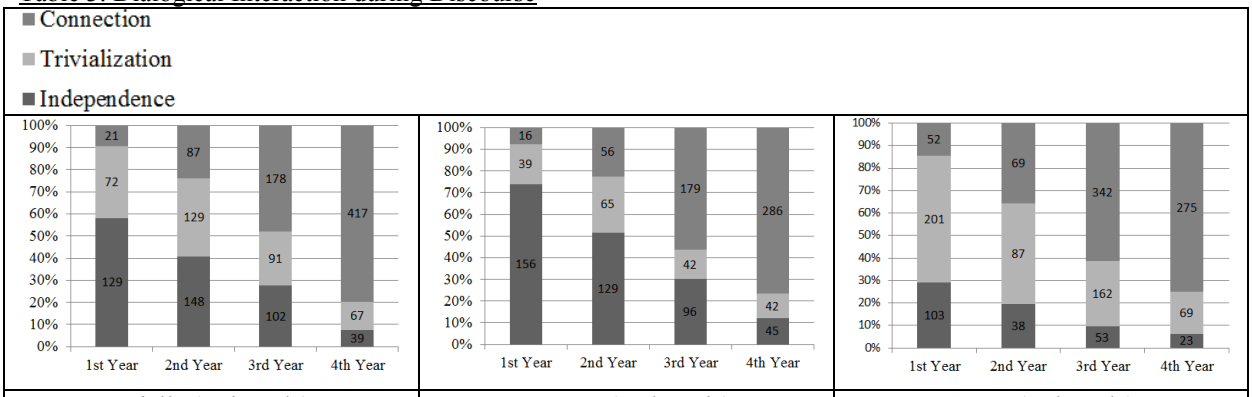


Brielle (3rd grade)	Lynette (2nd grade)	Susan (3rd grade)

Dialogical Interaction

Figure 5 presents our analysis of the interactions during classroom discussion. In the first year, only 10% (21/222) of the utterances during discussion in Brielle's class, 8% (16/211) in Lynette's class, and 15% (52/356) in Susan's class were linked to previous ideas in that the ideas reworded, justified, clarified or posed an elaborating question. However, in the fourth year, the utterances connected to previous ideas increased to 80% (417/523) in Brielle's classroom, 77% (286/373) in Lynette's classroom, and 75% (275/ 367) in Susan's classroom.

Table 3. Dialogical Interaction during Discourse



Brielle (3rd grade)	Lynette (2nd grade)	Susan (3rd grade)

Summary of Findings

Table 4 summarizes the findings across the four major features that emerged along the time span involved. The first feature was that during the four years of the study the teachers increasingly used four roles to establish argumentative discourse; this is referred to as an increasing richness of the teacher role, rather than relying only on the dispenser role as they had in the first year. As the shift in the use of multiple roles occurred, students' cognitive responses were promoted to higher and more complex levels. Students were also observed constructing and critiquing ideas in a more evidence-based form. The final feature was that students also became more likely to link their ideas back to previous contributions made by the teacher and their peers through defending, challenging, synthesizing, and justifying. The findings imply that to promote student engagement teachers should go beyond one single role for questioning and should play multiple roles to tackle different situations by considering student ownership of ideas and activities (Crawford, 2000; Walshaw & Anthony, 2008). With the support of teacher questioning, this study suggests that even early elementary students

can successfully engage in productively argumentative practices.

Table 4. Trend of features of teacher questions and classroom discourse over four years

	Year 1	Years 2 & 3	Year 4
Teacher Role of Questioning	Single role: Teachers focused on dispenser role to lecture and direct classroom discourse. The ownership of ideas and activities controlled by the teachers.	Transition: Teachers gradually developed moderator, coach, and participant roles in questioning to promote students' diverse dialogue. The ownership of ideas and activities shifted from the teacher to the students.	Richness: Teachers used multiple roles of questioning to support students' thinking and conversation. Students had many opportunities to take ownership of ideas and activities.
Students' Cognitive Response	Simplicity: Students' discourse was restricted to low-level cognition, such as retrieving and expressing ideas.	Transition: Students' discourse shifted to medium- and high-level, such as elaborating, reframing, defending challenging, synthesizing, and justifying ideas.	Complexity: Students' discourse was in high-level cognition, such as defending, challenging, synthesizing, and justifying ideas.
Evidence-based Discussion	Simple: High proportion of utterances focused on simple response.	Transition: Students came to use evidence to discuss their ideas.	Evidence-based: High proportion of utterances focused on evidence.
Dialogue Interaction	Independence: Students' utterances were independent. Classroom discussion was dominated by teacher talk.	Transition: Students came to link back to what other students had said. Student voices increased, and teacher's voice decreased.	Connection: Students actively connected their utterances to previous ideas. Classroom discussion was dominated by student talk.

Discussion

While many studies on teacher role of questioning have simply dichotomized the type of questions into open/ closed end and disconnected the two types of questions, this current study conceptualizes four roles of teacher questioning based on the tension between ownership of both ideas and activities to better represent the complexity of argumentative environment. Significant is that the ABI approach requires students to engage in knowledge construction and critique; therefore, the function of the shifting roles of teacher questioning is to fully implement an approach that pushes students to be involved in and take ownership of construction and critique in generating arguments. The function of teacher questions is not just about discussing ideas with students, but the teachers also need to have awareness of the ownership of activity situated in the moment of that context. As the examples demonstrate in the four role, the purpose and function of teacher questions can be varied depend on the tension between ownership of ideas and activities.

Although the moderator, coach, and participant roles promoted higher-level cognition in student responses, the three teachers in this study also continued to adopt the dispenser role in the fourth year (Brielle: 22%; Lynette: 31%; Susan: 8 %). This finding raises essential questions about whether teachers should eliminate the dispenser role to successfully engage students in argumentative practices. Oliveira (2010) suggested that teachers should aim to better understand the important cognitive functions of different questioning strategies and the situations in which they can apply those strategies to help students effectively and productively develop conceptual understandings. Thus, instead of simply abandoning the adoption of the dispenser role, educators should realize how the different roles can elicit different cognitive results for different purposes and contexts. More research is needed to determine both the best times and contexts to use the different roles in argumentative environments and the most appropriate sequence for using different roles to advance students' conceptual understanding.

The development of different roles to support student argumentation requires time. In this study, it took the three teachers years to shift their classroom environments to a more reform-based model. An increasing body of empirical evidence suggests that it takes more than 18 months before significant shifts in teachers' questioning pedagogy are observed (Martin & Hand, 2009). Therefore, this study supports Luft's (2001) suggestion that teacher professional development should be designed systematically and should consist of ongoing training. The various roles of teacher questioning should be viewed as an essential component of

professional development in order to expedite the shift in teachers' practices from a teacher-centered approach to a more student-centered orientation.

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