A MIDDLE SCHOOL SCIENCE TEACHER'S CLASSROOM TALK: DISCOURSE CHARACTERISTICS AND QUESTION TYPES IN A UNIT ON ENERGY

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The purpose of this research study is to explore the discourse characteristics and question types as a middle school science teacher develops common knowledge on the concepts of energy in her classroom. The teacher uses a standards-based curriculum and accompanying student workbook that promotes mediation of oral knowledge referred to as "dialogic discourse." The whole-class discussions between the teacher and her students are audio-recorded and transcribed verbatim. Analysis of one representative discourse excerpt, that is, "understanding kinetic energy" reveals the teacher constantly asking questions in order to develop common knowledge. The sample excerpt also reveals four types of questions: fill-in-the-blank, second-order, descriptive, and explanatory. Although the teacher in this study had professional development to implement science lessons from a sociocultural perspective, the excerpt shows that the teacher struggles to engage students in productive talk. Thus, the study implies the need for professional development that promotes a give-and-take exchange of ideas that centers on student engagement and thoughtfulness as the standards-based curriculum intends. As the study suggests teachers who are willing and trying to adopt dialogic discourse need to be supported, monitored over time and not left to their own discretion during implementation.

Keywords: dialogic discourse, sociocultural perspective, common knowledge

INTRODUCTION

Most science educators and current curriculum documents endorse "give and take" discussion methods as a preferred form of classroom discourse (e.g., Shwartz, Weizman, Fortus, Krajcik & Reiser, 2008). The reality, however, is that teachers typically resort to a question-and-answer discussion format that puts teachers at the center of the classroom experience while relegating students' questions (and consequently their learning) to the background of the classroom experience (Krajcik, Reiser, Fortus & Sutherland, 2008). Barnes (1976) has cautioned that teachers do not provide students with opportunities "to ask their own questions, to formulate hypotheses, or to make intelligent responses other than those predetermined by the teacher's own implicit associations of thought and frames of reference" (p. 30). Even in contemporary times, Mercer and Howe (2012) have noted that in whole-class settings, teacher-student interaction is dominated by "teacher talk"—a type of interaction in which teachers use closed questions simply to seek brief responses in order to ensure that at least some students repeat the right answers. However, teacher questions: How did you know that? Why? Enable students to use language as a tool for reasoning and to express key ideas in their own words (Wolf, Crosson & Resnick, 2006). In order to check students' understanding, provide them with accurate information, or correct their misunderstandings, teachers should strategically balance authoritative talk with dialogue (Mortimer & Scott, 2003). Eshach (2010) has noted that whole-class teaching is the most common instructional approach and it has been insufficiently studied. Lehesvuori et al. (2013) have recommended that in order to capture the essence of classroom communications between teachers and students, more micro-scale exploration is needed of classrooms. Thus it is important to understand through a fine-grained analysis of transcripts, how a middle school science teacher, who has received professional development in a standards-based science curriculum, developed and established common knowledge about energy across time.

THEORETICAL FRAMEWORKS

Science curricula and pedagogical practices are being shaped by national policies (NRC, 2012) that have been informed by a sociocultural perspective; language is at its core for individual and collective thinking and learning (Vygotsky, 1978). According to Vygotsky, language is both a cultural tool and a psychological tool that transforms thinking. It is a cultural tool because it is used to develop and share knowledge among members within a community, and it is a psychological tool because it provides structure and content to the process of producing individual thoughts. The mediation of oral language is referred to as "dialogic discourse," and it is consistent with teaching models that have adopted the notion that knowledge is co-constructed within a sociocultural context (Driver, Asoko, Leach, Scott & Mortimer, 1994). In this process of knowledge construction, students are encouraged to question, evaluate, and challenge the ideas of others (Berland & McNeil, 2010). The statements of others are not simply accepted but undergo scrutiny through critical analysis, and in this process, students justify their own views as well as support or refute the ideas of their peers (Mercer, 2009). Teachers use language to provide a cumulative, continuing, contextual frame that enables students to engage with new information they encounter (Alexander, 2004).

A critical analysis of the few existing studies on science classroom discourse from a sociocultural perspective of learning revealed the character of dialogue between teachers and students in four interrelated ways: (a) "productive disciplinary engagement" (Eshach, 2010; Scott & Ametller, 2007; Scott, Mortimer & Aguiar, 2006, p. 607), (b) solving open-ended problems (McNeill & Pimentel, 2010), (c) wonderment questions (Aguiar, Mortimer & Scott, 2010), and (d) dialogue that connects past and present learning experiences (Mercer, Dawes & Staarman, 2009). In line with discourse studies, the following research questions guided this study: What discourse characteristics and question forms are evident as a middle school science teacher attempts to develop common knowledge related to the concept of energy?

SIGNIFICANCE OF THE STUDY

This study is significant for three primary reasons. First, understanding how this teacher conducted whole-class discussions and how she developed students' conceptual understanding on the topic of energy in order to establish common knowledge over time will provide insights into the nature of classroom discourse at a time when standards-based curriculum are promoted. Secondly, because the teacher implemented a standards-based science curriculum from a sociocultural perspective of learning, it is important to know whether classroom discourse parallels the curriculum's intentions. Finally, this study also provides a platform for future research that probes into ways of developing common knowledge through classroom discourse. This research will allow teachers and administrators to become aware of why and how such discourse plays out in the reality of an urban classroom in ways that can transform teaching and learning in more meaningful ways.

METHODOLOGY

Research Design

This was an interpretive discourse study that adopted notions advocated by Mortimer and Scott (2003) that explain how teachers use discourse to mediate students' conceptual understanding of science concepts from a macro perspective as well as Hoon and Hart (2006) that emphasize situating classroom discourse within a sociocultural perspective of learning to develop scientific knowledge, support student meaning making, and maintain a narrative.

Study Context

The Science and Mathematics Academy (SMA) is situated in the heart of a large urban city in a mid-western state. SMA is a Public School Academy secondary school that focuses on science and math with students in grades seven and eight. The total school population is 387, with 331 students living in an urban city and 56 students living in the surrounding areas. Of the 387 students, 227 students are on free or reduced lunch. At the time the study was conducted, 161 students were in the seventh grade, which is the focus grade of this study; of these, 155 were African-American, three were Caucasian, two were Hispanic, and one was Arab-American. There were 94 boys and 67 girls in seventh grade.

The teacher who participated in this study implemented the Investigating and Questioning Our World Through Science and Technology (IQWST) curriculum and the associated project-based learning approach (Kracjik, Czerniak & Berger, 2002; Schneider, Krajcik & Blumenfeld, 2005) that promotes inquiry and reflection as well as student engagement in student-directed scientific practices supported by technology and collaboration. The major learning goals in the seventh-grade physics unit are to understand that (a) there are different types of energy, and that (b) energy can be transformed from one type to another.

Participants

The participants, referred to by pseudonyms, in this study consisted of a seventh-grade science teacher and her students. In all, the teacher taught 68 students, ages 13-14, in four sections of seventh-grade science class. For the purpose of this study, one section consisting of 18 students was used of which ninety six percent of the students were African-American.

At the time of the study, the teacher had approximately three years of teaching experience. The teacher holds a Bachelor of Science in Elementary Education and an Associate of Arts in Liberal Arts. Along with her colleagues, the teacher participated in a five-day summer institute conducted by University of Michigan professors and graduate students as well as a lead teacher. The professional development program included support strategies for teachers in the areas of science content, inquiry pedagogy, and contextualized learning focusing on Big Ideas using the IQWST curriculum. The institute emphasized coherence (development of science ideas), deep and meaningful student understanding, concepts and explanations, and assessment of students. A major goal for teachers in the summer institute was to understand how to use IQWST pedagogies within the framework of an educative curriculum. The session also focused on how to implement the IQWST seventh-grade physics unit curriculum.

Data Collection

The classroom and science center visit portion of a two-year study took place from January 2010 to May 2010 during 30 periods consisting of 55 minutes each. The researcher personally observed all of the classroom sessions and related events and recorded field notes. At the same time, the researcher used integrated circuit (IC) system and videotapes to record the large-group classroom discussion during which the teacher developed the concepts of energy with students using the IQWST workbook activities that focused on the concepts underpinning the science center energy exhibits. These IC recordings of discourse were transcribed verbatim. A sampling of student IQWST workbooks that contained activities were collected as evidence of the work completed in the classroom. The IQWST workbooks provided evidence of student work correlated to the forms and transformation of energy lessons taught by the teacher.

DATA ANALYSIS

An interpretive discourse analysis following the notions of Hoon and Hart (2006) as well as Mortimer and Scott (2003) was used to analyze teacher-student classroom discourse transcripts. Four representative instructional events were selected from the large corpus of data. The rationale underpinning this sampling is based on consistency of students' completion of workbook lessons and references made by the teacher to these lessons as she developed common knowledge on the forms and transformation of energy. The dialogue in these transcripts portrayed consistent use of question forms used by the teacher. No a priori codes from the discourse analysis literature were imposed on the data.

Inter-Rater Reliability

An external audit consisting of two US-based researchers with Ph.Ds. (one in science education, one in English literature, and both with experience in discourse analysis) was conducted to evaluate the accuracy of the coding and to determine whether the findings, interpretations, and conclusions reflected the data. Both external researchers agreed that the research was dependable. Establishing the inter-rater reliability is one important way to validate a qualitative study because Lincoln and Guba (1985) have stated that reliability and validity in qualitative research are congruent.

RESULTS AND DISCUSSION

Based on the four instructional events cited in Table 1, four discourse characteristics were identified: (a) teacher-posed questions, (b) teacher-explanations, (c) teacher responses, and (d) teacher references to past learning. The overall data revealed five types of teacher-posed questions: (a) fill-in-the-blank questions to prompt students to provide her with correct responses, (b) affirmation questions to ensure that there is no doubt in their minds, (c) second-order questions that reinforce ownership of student understanding, (d) descriptive questions to elicit information, and (e) explanatory questions to probe students' scientific explanations. For the purpose of this submission, we focus on the analysis of second instructional event, understanding kinetic energy, to provide our results and discussion.

Understanding Kinetic Energy

Cathy guides students through an investigative activity designed to identify the factors that influence kinetic energy. The purpose of the entire investigation lesson was for students to learn that objects in motion have kinetic energy and that the amount of kinetic energy an object has is dependent on the object's mass and speed. Another purpose that directly connects to the goal of "questioning and designing investigation," which is a critical attribute of the IQWST curriculum, is to develop students' ability to recognize variables and design a fair test to isolate the effect of a single variable. Excerpt 2 reveals how Cathy develops students' understanding of kinetic energy.

Excerpt 2:

2.1 Cathy: Please read the purpose for this activity…

2.2 Bridget: The purpose of this activity is to determine which factors affect the amount of kinetic energy a falling object has. You will design a scientific experiment by changing one variable at a time.

2.3 Cathy: We have two findings, the independent and dependent. You are going to use Play-Doh to measure how much energy something has. How can you use Play-Doh to measure how much energy something has? I have a little, tiny piece of Play-Doh. And I have a medium-sized piece of Play-Doh. I have two pieces. If I put them in my fingertips and press—which one is going to squish first?

2.4 Tasha: The smaller one…

2.5 Cathy: Why?

2.6 Tasha: It has less mass.

2.7 Cathy: If I take two cans, and this is what you're going to do… Corey, please read the instructions.

2.8 Corey: Use the table to record your data when investigating how the speed of the falling object can affect the change in thickness of the modeling clay.

2.9 Cathy: How does speed affect what somebody is doing? If I'm testing speed… and I'm going to use these two cans… To make it a fair test… this is the question… if I'm changing the speed, how many things should you change in the experiment? Listen to the question… how many things should you change in the experiment?

2.10 Avery: One

2.11 Cathy: Avery said it. If I'm changing the speed, should I change anything else in the experiment?

2.12 Corey: No

2.13 Cathy: You're going to take a ball of Play-Doh. You're going to measure it to about two centimeters. You're going to take one can. You're going to put a piece of newspaper on the floor, and you're going to take your Play-Doh. You're going to take your ball of Play-Doh and put it on here. You're going to take one can and you're going to drop it onto that Play-Doh. First off, you're going to measure that Play-Doh. You're going to take a ruler and tell me how high is this Play-Doh? Right now, it's about two centimeters. You're going to take the can and drop it. You're going to measure the Play-Doh again. What do you think is going to happen when I drop it?

2.14 Michael: It's going to get smashed.

2.15 Cathy: It's going to get squished. I dropped it. It squished. You're going to measure it again. You're going to take it and take it back to the same size. It was two centimeters before. If it was two centimeters before, how big are you going to make it again?

2.16 Michael: Two centimeters…

2.17 Cathy: Thank you! It's two centimeters again, and you're going to take the same can… instead, this time, you're going to not throw it hard enough so I have open cans of food in my room. You're going to throw it down at the Play-Doh. After you throw it, what do you think you're going to do? You're going to measure it again. From now until 10:30, you should be independently writing your predictions. You can actually write in your books your predictions. What do you think is going to happen with that Play-Doh when you drop it versus throwing it? What's going to happen and why? When you are finished with the predictions, go ahead and use the equipment. The great things about predictions are that you don't have to be right (Classroom Video, 1-8-10)

Excerpt 2 reveals that Cathy is following the IRE pattern of interaction (Mehan, 1979), or triadic dialogue (Lemke, 1990), by constantly asking questions to guide her instruction on scientific investigation. Excerpt 2 also reveals 11 teacher-posed questions and no student questions. Cathy asks four types of questions (frequency included): There are three fill-in-the-blank questions, requiring brief oral responses from students (2.5, 2.9, 2.11, 2.13, 2.15); four second-order questions (2.9, 2.13, 2.17); four descriptive questions (2.3, 2.13, 2.17); and two explanatory questions (2.5, 2.17).

While attempting to adopt a new way of teaching, Cathy falls into the trap of repetitive talk as a method of ensuring that students clearly understand what she is trying to teach them. Rather than probing for students' deeper understanding, Cathy continues to give long-winded instructions about what her students need to complete (2.13, 2.17). After asking a question, Cathy immediately gives specific instructions about how to answer that question (see 2.3). Cathy demonstrates the procedure before allowing students to conduct the investigation (2.13, 2.15). Cathy explains how to design and conduct a fair scientific test that enables students to assess the influence of one variable on another variable while all other variables are held constant (2.9). As well, Cathy wants students to understand the importance of multiple trials to establish the validity of a constant answer (2.15).

Cathy uses explanatory questioning to guide students to respond in writing (2.17). Besides questions that elicit obvious answers (2.4, 2.5, 2.10, 2.12, 2.14, 2.16), she asks "Why?" questions (2.5, 2.17) to elicit explanations and "What do you think?" (2.17), a second-order question (Ebenezer et al., 2010), to probe their predictions. A mixture of questioning types constitutes "authoritative" teaching that may be identified as teacher modeling, and then Cathy allows her students to conduct the investigation as they construct meanings for themselves. This type of teaching simulates what Scott et al. (2006) have described as "productive disciplinary engagement" (p. 607) although there is much show and tell on Cathy's part. Although Cathy uses the IQWST workbook lessons that foster classroom discourse as an essential component of inquiry through experimentation and argumentation (Krajcik & Sutherland, 2010), only a few questions are explanatory.

The instructional events reveal that Cathy's classroom discourse is akin to Mercer and Howe's (2012) observation of whole-class settings in which teacher-student interactions are dominated by teacher talk and in which teachers use closed questions simply to seek brief responses in order to ensure that at least some students repeat the right answers. A way of improving the teacher's interaction model is to apply less authoritative and more dialogic dialogue to help students construct their own knowledge about the concept of energy. The predominant fill-in-the-blank-type questions should be sparse and be replaced with questions that encourage students to put main ideas into their own words and press students to elaborate on these ideas. For example, asking, "How did you know that?" or "Why do you think that?" develops students' understanding (Wolf, Crosson & Resnick, 2006). The art of questioning is important in developing students' knowledge and understanding of scientific concepts.

IMPLICATION

The preferred form of classroom discourse in the IQWST curriculum is a give-and-take exchange of ideas that centers on student engagement and thoughtfulness (Krajcik et al., 2008). Cathy attempted to parallel classroom discourse to the curriculum's intentions by probing her students to discuss their reasoning. However, the questioning did not extend beyond students providing one or few word statements and Cathy giving detailed instruction at every instance. Even though Cathy participated in professional development specific to the implementation of the unit on energy, she falls back on teacher-dominated talk. Thus, the results of this discourse study reflect only a fraction of a sociocultural perspective of learning advocated by discourse researchers mentioned above. The reasons might be because the professional development is only one week-long and it may not have included the art of dialogic communication. As well, it is Cathy's first attempt at implementing the IQWST curriculum with its discourse practice. One way of improving the IQWST professional development program is to develop teacher training videos that embed different possible branch points in a classroom discourse that might be very useful in the type of communication it aspires in its teachers. This video approach might provide more insights into the classroom communication that is needed for implementing standards-based curriculum such as the IQWST.

It is important to understand that learning mediated through dialogue happens over time and should be studied over time (Mercer, 2008) with the goal of conceptualizing the interactive cognitive development and learning of the teacher. Administrators and researchers who are observing the implementation of science lessons from a sociocultural perspective should be intellectually empathetic as teachers struggle to move towards dialogic discourse because it takes time to develop proper language use. As well as being empathetic with the time needed to develop dialogic discourse, teachers who are willing and truly trying to implement dialogic discourse need to be supported, monitored in their use of this type of communicative approach, and not left to their own discretion during implementation. Follow up from colleagues, administrators, and researchers regarding how teachers are progressing over a specific time period should be consistent and a part of job-embedded professional development in order to ensure that teachers are implementing dialogic discourse where appropriate.

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