Horizons of Holistic Education
April-June-2020, 7 (2), 123-154

p ISSN : 2349-8811
eISSN : 2349-9133

A Grade Seven Science Teacher's Discursive Interactions in Developing Common Knowledge: Question Types, Discourse Patterns, and Communicative Approaches

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Received : 03-05-2020 Accepted : 15-06-2020

ABSTRACT

The purpose of this research is to characterize the nature of discourse between a middle school science teacher and her students as the teacher develops the physics concepts of "forms and transformation of energy" using a standards-based curriculum that promotes "dialogic discourse." The whole-class discussions between the teacher and her students are video-recorded and transcribed verbatim. Four instructional activities are analyzed using a discourse framework based on the consistency of students' completion of workbook lessons and references made by the teacher to these lessons as she developed common knowledge on the concepts of forms and transformation of energy. The teacher-posed questions portrayed the following characteristics: cued, second-order, descriptive, and explanatory. There are straightforward and a combination of discourse patterns based on the moves in the same lesson at various points. The communicative approach is predominantly interactive/authoritative where the teacher leads students with the aim of establishing the correct answer. The study implies the need for professional development on teacher-students' interactive/dialogic discourse that fosters common knowledge development in science.

Key words: *- dialogic discourse, sociocultural perspective, common knowledge.*

Introduction

Understanding the discourse between teachers and students that fosters the development of common knowledge in science is particularly crucial at a time when science curricula and pedagogical practices are shaped by national policies worldwide (Lai, Li, & Gong, 2016: Huang and Asghar, 2016; National Research Council, 2012) and informed by the sociocultural perspective of science learning (Vygotsky, 1978). Communicating in written or spoken form is a fundamental practice of science; it requires scientists to describe observations precisely, clarify their thinking, and justify their arguments (NRC, 2012). According to Achieve (2013), reasoning and argument in science are essential in science for identifying the strengths and weaknesses of a line of reasoning and for finding the best explanation for a natural phenomenon. Constructing and critiquing arguments are both a core process of science and one that supports science education. Interaction with others is the most cognitively effective way of learning**.** As stated by the Ontario Ministry of Education (2006), "communication is essential and students need to be able to communicate effectively" (p. 9). The Australian, Curriculum, Assessment, and Reporting Authorities (2014) observe that communicating scientific ideas and information for a particular purpose, including constructing evidence-based arguments and using appropriate scientific language, conventions, and representations is critical. Hong Kong science curriculum (Mullis, Martin, Goh, & Cotter, 2016) state that it is essential for students to become familiar with the language of science and be equipped with the skills to communicate ideas in science-related contexts. Norway's science curriculum, according to Mullis et al. (2016) emphasize the following:

> Listening and speaking in order to communicate knowledge and formulate questions, arguments, and explanations in natural science; adapting to different forms of expression, concepts, and examples to suit different objectives and recipients; progressing from simple experiences and observations to the ability to discuss progressively more complex themes, involving an increasing use of scientific concepts to express understanding, to form opinions, and to participate in academic discussions are key components in science. (p. 6)

England's science curriculum (Statutory Guidance, 2015) states that:

> The national curriculum for science reflects the importance of spoken language in pupils' development across the whole curriculum – cognitively, socially and linguistically. The quality and variety of language that pupils hear and speak are key factors in developing their scientific vocabulary and articulating scientific concepts clearly and precisely. They must be assisted in making their thinking clear, both to themselves and others, and teachers should ensure that pupils build secure foundations by using discussion to probe and remedy their misconceptions. (p. 4)

Common to various curriculum noted above point to the criticality of classroom discourse, adopting the Vygotskian sociocultural theory of learning that refers to the development of scientific knowledge and its cultural norms and tools by members of a classroom sharing knowledge. Language is at the core of a

Vygotskian sociocultural perspective, which affects individual and collective thinking. Based on Vygotsky's sociocultural perspective, science reforms promote "dialogic discourse" or "give and take" (Krajcik, Reiser, Fortus, & Sutherland, 2008). In practice, however, Mercer and Howe (2012) note that in whole-class settings, teacher-student interaction is dominated by "teacher talk"—a type of interaction in which teachers use closed questions to seek brief responses to ensure that at least some students repeat the right answers. This type of teacher-student interaction usually consists of the form "initiation-reply-evaluation" (IRE) (Mehan, 1979, p. 37), "initiation-response-feedback" (IRF) (Sinclair & Coulthard, 1975, p. 21), and "triadic dialogue" (Lemke 1990, p. 8).

Lemke (1990) argues the triadic dialogues referred to above can be beneficial for maintaining control over the direction of discussion and progression of the lesson content. However, Lemke also cautions that the overuse of triadic approaches does not provide students with opportunities to link their ideas to the course content. As well, Leshesvuori, Viiri, Rasku-Puttonen, Moate, and Helaakoski (2013) point out that the triadic approaches can create a learning environment that limits student participation, minimizes contributions, and inhibits critical reasoning because the questions posed merely elicit facts (Myhill & Dunkin, 2005) or the answer that students already know (Ahtee, Juuti, Lavonen, & Suomela, 2011). Krajcik et al. (2008) raise our awareness that the triadic forms put teachers at the center of the classroom experience while relegating students' questions and their ideas (and consequently their learning) to the background of the classroom experience. Thus, these authors recommend "give and take" discussion methods as a preferred form of classroom discourse for the development of "common knowledge"—the overlap of knowledge of the novice and expert (Author et al., Edwards & Mercer, 2013; Mercer & Howe, 2012) Common knowledge is based upon shared understanding as participants pursue common goals (Edwards & Mercer, 1987)

For common knowledge development, Eshach (2010) notes that whole-class teaching is the most common instructional approach, but the studies are few. Lehesvuori et al. (2013) recommend that to capture the essence of classroom communications between teachers and students, more micro-scale, moment-by-moment exploration is needed of classrooms in which teachers attempt to implement a standards-based curriculum. Although Polman (2004) addresses how dialogue develops between teachers and students through fine-grained analysis of transcripts, he also suggests that the way teacher-led, whole-class discussions constitute specific lesson sequence structural entities (e.g., question-types, discourse patterns, and communicative approaches) that are not fully understood. Thus, it is essential to know how the teacher in this study who most often focuses on whole-class teaching develops and establishes common knowledge on the physics concepts of *forms* and *transformation of energy* across activities through a fine-grained analysis of transcripts.

The study at hand thus focuses on a middle school science teacher, "Cathy," (pseudonym) because she received professional development on a standards-based inquiry science curriculum, namely, Investigating and Questioning our World through Science and Technology (IQWST). The IQWST curriculum for all learners specifically addresses inquiry processes that connect with technology. The IQWST curriculum builds science content and scientific practices through projects across content strands. It addresses requirements of the *National Science Education Standards* (NRC, 1996), *A Framework for k-12 Science Education* (NRC, 2012), and *The Next Generation of Science Standards (Achieve, 2013).* More specifically, IQWST inquiries promote dialogic discourse involving event, claim, evidence, reason, and explanation, constituting argumentation. This in-depth discourse study on one teacher using the IQWST curriculum contributes to similar research with the pedagogical practice of reform-based curricula in other countries.

In her seventh-grade science classroom, Cathy uses the IQWST curriculum and the associated workbook to teach students the concepts of forms and transformation of energy and in this process helps students to identify claims and reasons for their arguments through teacher-students' classroom discourse. Cathy did not have small group peer discourse in the unit on forms and transformation of energy, although the workbook can be used in a small group setting. This study serves as a context to qualitatively analyze classroom discourse transcripts using well researched analytical tools (Mortimer & Scott, 2003) to understand the processes and mechanisms the teacher uses to create and develop common knowledge as she attempts to implement standards-based inquiry science curriculum within a sociocultural framework. This qualitative analysis provides insight into whether Cathy's classroom discourse aligns with the goals of IQWST enacted in this study. This classroom discourse study, although USA-based, is vital in an era of science education policies and reforms globally that advocate discursive interactions in science classrooms (Bansal, 2018) and professional development of teachers is happening worldwide. Montenegro (2017) supports the notion of “teaching as a discursive practice as a tool for improving teaching practices from a dialogical perspective” (p. 265).

An essential component of teacher professional development should include the study of the various roles that teachers can play when questioning for establishing dialogic interaction in argumentation (Chen, Hand, & Norton-Meier, 2017). An explicit focus on talk and discursive interaction is necessary if teachers are to understand and enact interacting moves, therefore knowledge of dialogic talk moves are critical (Edwards-Groves, 2018) This study seeks to characterize the nature of discourse between a middle school science teacher and her students by analyzing whole-class discussions between one teacher and her students. The contribution from this study to the field of science education research on classroom discourse is that it provides a glimpse of one teacher’s classroom discursive interaction in the context of world-wide reform.

Theoretical Frameworks

A Sociocultural Perspective of Learning

According to Vygotsky (1978), communication is both social and psychological that transforms students’ thinking. The social aspect develops and shares knowledge among members within a community, and the psychological part provides structure and content to the process of producing individual thoughts. The preceding statement appears construing a divide between social aspects and the psychological part of learning, but it is not. Both the social and psychological work together in developing knowledge. In line with Vygotsky, Prawat (1993) claims there is a dialectical relationship between knowledge that is constructed by reflecting (psychological) on an activity and by negotiating (discursive interaction) knowledge. This mediation of oral language is known as “dialogic discourse,” and it is consistent with teaching models that adopt the notion knowledge is co-constructed within a disciplinary sociocultural context that follows the norms and tools (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 merely accepted but undergo scrutiny through critical analysis, and in this process, students justify their views as well as support or refute the ideas of their peers (Mercer, 2009**).** Dialogic discourse aligns with the belief that the construction of knowledge through a social process fosters the development of shared experience (Edwards & Mercer, 1987).

Science Classroom Discourse

Scott et al. (2006) term the process of shaping students’ responses into scientific explanations "productive disciplinary engagement" because classroom discourse between teachers and students reflect a combination of "authoritative and dialogic interactions" (p. 606). The authors also caution that the use of teacher language in shaping students' conceptions will reveal a tension between "authoritative and dialogic interactions" (p. 606), mainly when authoritative language is used to reach scientific explanations. The use of authoritative or dialogic classroom language depends on the interactions between teachers and students through negotiating and adjusting the explanatory structure to the students' understandings. This adaptation, or shifting, between authoritative and dialogic approaches, is required to support meaningful learning that involves connections between students' evolving ideas and scientific knowledge (Scott & Ametller, 2007). Therefore, Scott et al. (2006), based on their 2003 study, provided "analytical frameworks with criteria used in identifying authoritative and dialogic communicative approaches" (p. 608). Scott et al. (2006) support dialogic inquiry in a classroom where learning is dialogically co-constructed, which characterizes the Initiation-Response-Feedback, Initiation-Response-Evaluation, and Initiation-Response-Feedback-Response-Feedback patterns of interaction, and discourse assumes various forms depending on the teaching purpose and goals of the activities. These authors have drawn attention to the tension between authoritative and dialogic approaches using the framework based on a sociocultural perspective of teaching and learning developed by Mortimer and Scott (2003). Scott et al. (2006) conclude that this framework can assist teachers in reflecting upon and developing their teaching practices in professional development sessions.

Engaging students in dialogic interactions requires teachers to be skilled in this type of instruction. It also needs teachers to possess insight and expertise in engaging students in dialogic discourse while at the same time linking communicative approaches and patterns of dialogue (Alexander, 2004; Scott & Ametller, 2007). Teaching decisions to "open up" or "close down" instruction in either a dialogic or authoritative way must take into consideration the content taught and the degree of difference between students' ideas and scientific explanations (Scott & Ametller, 2007). The insights of the studies above on classroom discourse can be translated into the implementation of Krajcik et al.'s (2008) standards-based curriculum that incorporates argumentation. This study, although with one middle school science teacher, is crucial when Krajcik's group has not yet studied the discourse that takes place in classrooms that use their curriculum while other notable work is underway (e.g., Geier, Blumenfeld, Marx, Krajcik, Fishman, Soloway, & Clay- Chambers, 2008; Krajcik, McNeill, & Reiser, 2008; Krajcik & Sutherland, 2010). The study at hand analyzes and interprets the discursive interactions that transpire as the teacher in this study develops common knowledge on the concepts of forms and transformation of energy.

International Science Classroom Discourse Studies

Analyzing discursive interactions during classroom discourse between high school students and their teachers in Brazil, Scott et al. (2006) observed that minimal shifting occurs between communicative approaches and that there was minimal dialogic teaching. Scott et al. (2006) reasoned that the problematic issues related to communicative approaches in science classrooms arise because teachers perceive their job to be providing information from a scientific perspective. Scott et al. (2006) suggested that teachers need to have insights into the everyday language conventions that students are likely to bring to their learning environment. They also pointed out that a combination of authoritative and dialogic discourse tools are particularly helpful in developing students' conceptual understanding of science concepts.

In their work on types of teacher questions and the development of argument structure during a lesson on ecology taught in a New England high school science classroom, McNeill and Pimentel (2009) indicated that more open-ended questions increased percentages of student talk, the use of evidence and reasoning to support claims, and dialogic interactions among students. McNeill and Pimentel (2009) have used a combination of Toulmin's (2003) argument pattern, a scheme for dialogic interactions, and Blosser's (1973) classification scheme for analyzing teacher questions to examine patterns of classroom discourse and the role of the teacher in promoting argumentation. Furthermore, McNeil and Pimentel (2009) argued that when questions with multiple answers are explored, interaction shifts from monologic to dialogic. The same authors emphasized that first establishing common knowledge within a monologic format and then introducing dialogic activities is key in an inquiry unit to prepare students to engage in dialogue and argumentation strategies. In this type of interaction, McNeil and Pimentel (2009) have pointed out that the emphasis should be placed on (a) teaching students social and discursive skills that lead to productive dialogue and (b) identifying effective discussion starters in the curriculum that help students make connections beyond the classroom. Because dialogic interactions among teachers and students rely on evidence and reasoning to support claims, McNeill and Pimentel (2009) have emphasized the importance of providing teacher support for students who struggle with this type of argumentation in science.

Aguiar, Mortimer, & Scott (2010) used Brazilian high school classroom episodes from different teaching sequences involving innovative teaching approaches to examine students' wonderment questions based on discourse between the teacher and students. These authors found that interactive discourse between the teacher and students influenced the teacher's explanatory structures and ongoing classroom discourse. Subsequently, Aguiar et al. have argued that there is a need for professional development that shows teachers how to deal with students' questions and how to take into account the role and purposes of all individuals during student-led argumentation and debates.

Mercer (2008) used data from a primary school in the United Kingdom to examine how the passage of time is embodied in classroom talk. He used transcribed discourse from a series of events and dialogue between a teacher and students as well as among students to discuss the processes and the challenges associated with conducting a temporal analysis. A temporal analysis describes the process by which classroom discourse is used to represent past shared experience and carry ideas forward from one occasion to another to achieve learning outcomes. Using temporal considerations of a dialogic approach, Lehesvuori et al. (2013) described a study in which high school students in central Finland experienced science lessons on the topic of energy in which the teaching sequences used by the teacher involved different communication structures that facilitated parallel visualization. A sociocultural discourse analysis was used with the teaching sequences and encompassed both historical and dynamic aspects at the episodic level of teacher-student exchanges. Conceptual change literature suggests that lessons should explore or elicit students' conceptions and address these conceptions in ways that will cause students to shift their thinking to adopt scientific explanations (e.g., Duit & Treagust, 1998; Ebenezer, J., Chacko, S., Kaya, O. N., Koya, S. K., & Ebenezer, D. L., 2010).

Within the same conceptual change inquiry lesson sequences, students might be set for argumentative discourse (Driver, Newton, & Osborne, 1994; Erduran, Simon, & Osborne, 2004). Lesson sequences that use scientific inquiry standards also advocate argumentation (NRC, 1996). One such curriculum design is the Investigating and Questioning Our World Through Science and Technology (IQWST) curriculum (Krajcik, McNeill, & Reiser, 2008). The IQWST curriculum is designed to provide teachers with tools/materials to help students learn science by engaging students in inquiry processes. These processes allow students to take an active role in their own learning and reflect on the ways in which knowledge is constructed within various scientific communities (Fogelman, McNeill, & Krajcik, 2011). Krajcik and Sutherland (2010) have proposed argumentation as an essential component of scientific discourse and of fostering inquiry in the classroom. Argumentative discourse, based on solving open-ended or ill-structured socio-scientific problems (Zeidler, Sadler, Simmons, & Howes, 2005) can also take on the character of argumentation—i.e., claim, evidence, reasoning, and explanation (McNeill & Pimentel, 2009). These authors have suggested that it is the role of the teacher through dialogic interactions to promote argumentation that employs a traditional argument structure. It is critical for teachers to provide students with opportunities to talk about science, to practice supporting their ideas with evidence, and to make arguments indicating why evidence supports one conclusion more than another (Krajcik & Sutherland, 2010).

Inquiry lessons, whether conceptual change, science, or ill-structured, provide opportunities for students to ask “wonderment questions” (Aguiar et al., 2010, p. 175), which are questions that focus on predictions, explanations, and causes. These wonderment questions are asked when students try to relate new knowledge and existing knowledge in their effort to understand science content. Wonderment questions might arise because of (a) comprehension, (b) prediction, (c) anomaly detection, (d) application, and (e) strategy planning (Chin & Brown, 2002). Based on an analysis of selected science lessons in which students posed many wonderment questions, Aquiar at al. (2010) concluded that such questions influence the teaching of explanatory structures and the development of ongoing classroom discourse. The IQWST curriculum extends student learning experiences beyond the classroom by posing driving questions in much the same way that wonderment questions situate science within issues that are of interest to students and the scientific community. Providing examples of questions and probes that help teachers foster connections between students’ questions and the driving question helps teachers as well as students to establish meaningful discourse (Singer et al., 2000).

The insights of international studies on classroom discourse can be translated to the implementation of Krajcik et al.’s (2008) standards-based IQWST curriculum that incorporates dialogue into classrooms. The researchers mentioned above have provided analytical tools to characterize discursive interactions. Thus, this study analyzes and interprets the discursive interactions that transpire as the teacher in this study develops common knowledge on the topic of energy.

Research Question

The following research question guides this study:

> What is the nature of classroom discourse when one middle school science teacher teaches a class of seventh-grade students a unit on forms and transformation of energy?

The Significance of the Study

This study has world-wide significance for three primary reasons. First, understanding how the teacher in this study conducts whole-class discussions and how she develops students' conceptual understanding on the concepts of forms and transformation of energy to establish common knowledge provides insights into the nature of classroom discourse in the time of world-wide reform. Secondly, because the teacher implements a standards-based science curriculum from a sociocultural perspective of learning, it is important to know whether classroom discourse parallels the IQWST curriculum's intentions, which reflect reform-based curricula in other parts of the world. Thirdly, this study also provides a platform for global researchers on ways of developing common knowledge through classroom discourse. This platform allows teachers and administrators throughout the world to become aware of why and how such dialogue plays out in the reality of a classroom in ways that can transform teaching and learning in more meaningful ways. Finally, the study suggests the use of an analytical tool that assesses classroom discourse is highly valuable to improve teaching and learning everywhere.

Context of the Study

Research Site: The Science and Mathematics Academy

The Science and Mathematics Academy (SMA--pseudonym), a public charter school with students in grades seven and eight, is situated in the heart of a large urban city in a mid-western state. The total school population is 387, with 331 students living in a metropolitan 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 1 was Arab-American. There were 94 boys and 67 girls in seventh grade.

Investigating and Questioning Our World through Science and Technology (IQWST)

At the time of this study, SMA adopted the Investigating and Questioning Our World through Science and Technology (IQWST) curriculum that promotes inquiry. The focus of this study is the Energy unit of the IQWST curriculum. The primary learning goals in the seventh-grade physics unit are to help students to understand that (a) there are different types of energy and that (b) energy can transform from one form to another. Through shared learning goals across units, inquiry processes are repeatedly revisited. The driving question in the unit is the following: “Why do some things stop while others keep going?” To answer this question, the investigations enable students to experience scientific phenomena and processes by allowing them to examine new information; ask new questions; plan experiments; and collect, analyze, and share data. The unit is divided into three learning sets. The first learning set attempts to answer the following question: “What determines how fast or high an object will go?” The first learning set is then divided into four lessons in which students investigate factors that determine the amount of kinetic energy possessed by an object and the connection between elevation and energy. The second learning set attempts to answer the following question: “Why do some things stop?” This learning set is divided into three lessons in which students investigate thermal and sound energy. The third learning set attempts to answer the following question: “Why some things keep going?” This learning set consists of four lessons, which introduce chemical, electrical, and light energy as well as how they can be converted into one another and into other types of energy. The main investigation includes falling objects, a pendulum, a bouncing ball, playground instruments, and springs. Energy conversion diagrams are introduced as a way to represent energy transformations.

Participants

The teacher for the study was selected based on her willingness to participate in the study and she was the head of the science department with the most experience with the IQWST curriculum. 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. The teacher taught 68 students, ages 13-14, in four sections of seventh-grade science class. For this discourse study, we used one section consisting of 18 students. Ninety-six percent of the students were African-American. All participants in this study are referred to by pseudonyms.

Professional Development in IQWST

Along with her colleagues, the teacher participated in a five-day summer ~~institute~~ professional development program conducted by the 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. The sessions did not explicitly focus on classroom discourse because there was the assumption that teachers knew how to facilitate this type of conversation in the classroom.

Methodology

Research Design

This interpretive discourse study adopts notions advocated by Mortimer and Scott (2003). We explore in-depth teacher-students' classroom discourse in the common knowledge development of the concepts of forms and energy transformation of energy. We use an interpretive discourse analytical tool (Mortimer & Scott, 2003) that helps to explain how teachers use discourse to mediate students' conceptual understanding of science concepts. These authors also emphasize the importance of situating classroom discourse within a sociocultural perspective of learning to develop scientific knowledge, support student meaning-making, and maintain a narrative. Mortimer and Scott (2003) characterize patterns of discourse and communicative approaches in their framework that have been successfully used by Lehesvuori et al. (2011, 2013); Scott, Mortimer, and Aguiar, (2006), Viiri and Saari (2006) to enable teachers to help students construct meanings in science classrooms.

Data Collection

Federal regulations require that all research involving human participants must be reviewed and approved by an Institutional Review Board (IRB) before research activities can begin, therefore, IRB guidelines were followed and approval was granted in this study. Approval from participants and school administration was secured. The purpose of the study was shared with the teacher, students and legal guardians. The researcher observed 11 enactments of the four lessons on the concepts of forms and transformation of energy. Each lesson was 55 minutes long. The researcher used integrated circuit (IC) system and videotapes to record the large-group **whole** classroom discussion. The video recordings of teacher-students' discourse were transcribed verbatim. A sampling of student IQWST workbooks that contained activities on the forms and transformation of energy lessons were collected as evidence of the work completed in the classroom. The videotaped lessons occurred over a semester (approximately 5 months). The workbooks were sampled based students' who completed the assignment. The class consisted of 18 students. The lessons were video-recorded daily.

Data Analysis

An interpretive discourse analysis following the notions of Mortimer and Scott (2003) was used to analyze teacher-student classroom discourse transcripts that corresponded to the workbook lessons from the IQWST physics unit. The data analysis involved several steps. First, the researcher identified the details of who said what. The line-number denoted every turn of the conversation. Secondly, each discourse excerpt between the teacher and students was subjected to inductive analysis to identify the types of questions. Thirdly, Mortimer and Scott (2003) were used to determine the patterns of discourse and communicative approaches in the transcribed discourse excerpts. Mortimer and Scott's four criteria were used to discern the communicative approaches (see below). These steps yielded the characteristics of the teacher-students' classroom discourse which constitute the findings. Mortimer and Scott (2003) combined two planes, authoritative/dialogic and interactive/non-interactive, and advanced four communicative approaches:

a. Interactive/dialogic (I/D): Teacher and students consider a range of ideas. If the level of interanimation is high, they pose genuine questions as they explore and work on different points of view. If the level of interanimation is low, the different ideas are merely made available.

b. Noninteractive/dialogic (N/D): Teacher revisits and summarizes different points of view, either simply listing them (low interanimation) or exploring similarities and differences (high interanimation).

c. Interactive/authoritative (I/A): Teacher focuses on one specific point of view and leads students through a question and answer routine with the aim of establishing and consolidating that point of view.

d. Noninteractive/authoritative (N/A): Teacher presents a specific point of view.

Table 1. *Types of Teacher-Posed Questions and Examples*

Question Type	Examples from Excerpts
Fill-in-the-blank (cued)	"When something is moving… it has what kind of energy?" (4.1)
Affirmation	"But you started with the same size, right?" (3.7)
Second-order	"If I am changing the speed, how many things should you change in the experiment?" (2.9)
Descriptive	"How does speed affect what somebody is doing?" (2.9)
Explanatory	"Why do you think most people picked the bus as number one?" (1.4)

Reliability and Validity

Validity and reliability ensure rigor of research (Creswell & Clark, 2017). A complete, open account of the study's method and results justify the validity of this study. The judgment of credibility and trustworthiness then lies with the person reading the narrative. The validity of this research also consists of systematic data analysis, interpretation, and discussion based on Mortimer and Scott's (2003) teacher-student classroom discourse. We provide one interview excerpt as supporting empirical evidence from the data, thus ensuring validity. For member-checking, we e-mailed a draft of the entire article two times to the teacher and required her to read the data presented in the study. In establishing inter-rater reliability, we sent the research claims and the transcripts of teacher-students discussion excerpts to two researchers external to the study to check the fit. The inter-rater-rater reliability is 90% agreement.

Results and Discussion

The four activities listed in Table 1 cumulatively characterize several instances of (a) teacher posed questions, (b) teacher-initiated discourse patterns, and (c) teacher preferred communicative approaches. The data reveals four types of teacher-posed questions: (1) cued (Cue) elicitation to prompt students to provide her with correct responses, (2) second-order (SO) to elicit qualitatively different ways of student understanding, (3) descriptive (Des) to obtain information or facts, and (4) explanatory (Exp) to probe students for scientific explanations. Evidence reveals that the teacher adopted three patterns of discourse (IRE: Initiation-Response-Evaluation, IRF: Initiation-Response-Feedback, IRA—Initiation-Response-Affirmation) and combinations of the patterns; and two communicative approaches of the four communicative approaches described in the data analysis section.

Table 2. Classroom discourse on the forms and transformation of energy

Instructional Activities	**Question Types**				**Pattern Form**			**Communicative Approaches**			
	Cue	**SO**	**Des**	**Exp**	**IRE**	**IRF**	**IRA**	**N/A**	**N/D**	**I/A**	**I/D**
Linking Energy with Moving Objects		*3*		*3*						*1*	*3*
Predicting Kinetic Energy Variables	*7*	*3*	*5*	*2*		*1*	*2*			*4*	
Formulating Scientific Explanations on Kinetic Energy Variables	*15*	*9*	*4*	*3*	*3*	*1*	*1*			*2*	
Studying Forms and Transformation of Energy	*17*	*6*	*12*	*1*	*3*		*2*			*4*	
Cumulative	*39*	*21*	*21*	*9*	*6*	*2*	*5*	*0*	*0*	*11*	*3*

Note there were overlaps of questions types. There were several instances of combinations of cued and second-order questions as well as cued and descriptive questions. Combinations of discourse patterns were noted in the dialogue excerpts as follows: 1—IRIRA; 2—IRP (P stands for probe);
3 - IRElIRIRIRER; and 4--IIRRIIRIREIREERIREIRIRERA); sItIRERIREREFIREEIRREREIRRE (s stands for student-initiated question, t stands for teacher response to student question). While

the four excerpts based on all four activities were critically analyzed as represented in Table, we interpret and discuss only one teacher-students' discourse because of the importance of "scientific explanation" and the space it requires.

The students had completed Activity 2.2 (see Figure 1): Kinetic Energy Investigation. They had tabulated their data for analysis and writing their conclusions. The following example is one student's original work. The excerpt below suggests how Cathy helps students formulate scientific explanations.

[Insert Figure 1] See at the end of the paper

Excerpt 1: Teacher-Students' Dialogue Excerpt

1.1 Cathy : Let's look at this conclusion question. How does speed affect kinetic energy? (**Descriptive**) Did you guys figure out that squish is equal to kinetic energy? (**second-order**) (**Cathy starts by giving the answer to the problem)**

1.2 Darryl : Yes. (**IRE)**

1.3 Cathy : You need to write that on the top of that page. On the top of your page, write, "Squish equals kinetic energy." That's what you're measuring. So, somewhere up here, squish equals kinetic energy. As we're doing this conclusion question, you realize that what you were measuring was the amount of energy something had. We just wrote the sentence. As the speed goes up… kinetic energy does what…? **(cued)**

1.4 Darryl : Increases. (**Interactive authoritative)**

1.5 Cathy : Okay. Your evidence is, "When I increased the speed of the can, the Play-Doh squished more. Reasoning is going to be the hard piece. It always is. Talking about reasoning again. I'm going to leave this up for a few minutes. You've got to watch this demo to get it. I squished a little. I squished a lot. Which one took more energy? **(cued)** Watch again… I squish a little. I squish a lot. Which one took more energy? (**cued**) The littler one took more energy. Your reasoning is… Darryl, how could you write that so it makes sense? (**Cued Second-order)** How could you explain that so it makes sense to other people? (**Explanatory Second- order)** Squish a little and squish a lot… how could you explain that as reasoning? (**Explanatory, Cued, Second-order)** You have two things. It takes a lot to squish a lot. It takes a little to squish a little. How could that be tied into reasoning? **(Cued, second-order)**

1.6 Darryl : When you have the small clay and the big clay, it takes more to squish because the mass is smaller**. (Feedback IRF)**

1.7 Cathy : But you started with the same size, right? **(Cued, second-order)**

1.8 Carol : Yes.

1.9 Cathy : How could you tie that into reasoning of when you increased the speed of the Play-Doh, it squished more? (**Explanatory, Cued, second-order)** The reasoning is exactly what I said when I did this. The more the play dough squished, the more what does it have? (**Cued, descriptive)**

1.10 Aaron : Mass.

1.11 Cathy : **Not more mass. It's the same mass**. The more… what…? the more it squished, the more… what…? **(Cued, IREIRIRIRER, cued, descriptive)**

1.12 Chris : Kinetic energy…

1.13 Cathy : Chris, say it again, loud and proud… you were right. (**affirmative**)

1.14 Chris : Kinetic energy…

1.15 Cathy : The more kinetic energy it had. Claim, evidence, and reasoning: The claim is yeah, the speed does matter when it comes to kinetic energy… moving energy. When you increase the speed of the can, it's squished more. The more the Play-Doh squished, the more kinetic energy it had. The more I squish it with my fingers, the more energy it takes. It doesn't take a lot to just put my thumbs right in there a little bit. But to squish it takes a lot more energy. How could you answer question number two by looking at question number one? (**cued, second- order**) Read question number two to me please, Mateo.

1.16 Mateo : *How does mass affect the amount of kinetic energy?*

1.17 Cathy : Write that in the same context. Now, the question is… instead of speed, it is mass. How does mass affect kinetic energy? (**cued, descriptive**) Could you just change those words? (**cued, second-order**) How do we know that? (**cued, second-order)** It's the same reasoning?

(Classroom Video, 1-12-10)

Question Types. After students collect their data and record the data in a table in their IQWST workbooks, Cathy continues to post a question for initiating the talk. There are 31 teacher-posed questions, while there is only one student question. While teaching students the concept of reasoning within the scientific explanation triangle, Cathy uses 15 cued questions (e.g., 1.3, 1.5, 1.7, 1.9, 1.11, 1.17), nine second-order questions (e.g., 1.1, 1.5,1.7, 1.9, 1.15, 1.17), four descriptive questions (1.1, 1.9, 1.15, 1.17), and three explanatory questions (e.g., 1.5, 1.9).

Predicting Kinetic Energy Variables

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: Teacher-Students' Dialogue Excerpt

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? (descriptive)

2.4 Tasha: The smaller one…

2.5 Cathy: Why? (cue,explanatory)

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? (cue, second order)

2.10 Avery: One

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

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? (cue. second order, descriptive,)

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? (cue)

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. (second order, descriptive, explanatory)
>
> {Classroom Video, 1-8-10}

Perhaps this is the first-time students have been asked to conduct an investigation with variables. Excerpt 2 reveals that Cathy is again following the IRE pattern of interaction (Mehan, 1979), or triadic dialogue (Lemke, 1990), by constantly asking questions to guide her instruction on scientific investigation. There are 11 teacher-posed questions and no student questions. Cathy asks four types of questions: (a) fill-in-the-blank, requiring one-word answer; (b) second-order; (c) descriptive; and (d) explanatory. Of these types of questions, there are three cue 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). For example, immediately after asking a question, she gives specific instructions to students about how to answer that question (see 2.3). Cathy demonstrates the procedure for the students before allowing students to conduct the investigation (2.13, 2.15). For example, Cathy explains to students how to design and conduct a fair scientific test that enables them 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.

Studying Forms and Transformation of Energy

The lesson on energy transformation is conducted after Cathy takes her students to visit the energy exhibits at the science center. The purpose of this lesson is to explore the topic of conversions of chemical energy into other forms of energy. Cathy guides students to complete a chart that describes various forms of energy, energy conversions, and energy transfers. Students are expected to write an explanation for each conversion. During the discourse, Cathy refers to the giant engine at the science center that illustrates energy conversions, which the students observe. The giant engine is a model of a four-cylinder, four-stroke engine and demonstrates the relationships of the major parts of an engine and how they function together. There is an electric motor that keeps it going at a slow speed. Cathy makes a connection between the concept of energy transfer and conversion and the processes of the giant engine. Excerpt 4 characterizes teacher-student discourse on energy transfer.

Excerpt 3: Teacher-Students' Dialogue Excerpt

3.1 Cathy : At the science center, they have on the top floor the pistons that move up and down, right? That's what gasoline does with the spark plugs. It pushes your pistons up and down. When something is moving… it has what kind of energy? (cue)

3.2 Sheldon : Kinetic energy.

3.3 Cathy : Kinetic energy… So, when you start exercising, you are doing what? (cue)

3.4 Sheldon : Moving…

3.5 Cathy : Okay, as you start exercising more and more… what happens to your body, Kia?

3.6 Kia : Elastic energy.

3.7 Cathy : Some people in my first hour also had this in there… it's not in the textbook answer. Why would you put elastic energy in there, Kia? Jalen? Think back to that reading about the human body and elastic energy. Henry, what was that connection? Jalen, you said it now. Go ahead and say it now, Jalen. (explanatory)

3.8 Jalen : Your muscles and things in your body are stretching out.

3.9 Cathy : Okay. So your muscles and things in your body are stretching out. I would take either one of those. The third one was the quartz watch. This chemical energy—and this is a tricky one—the chemical energy that's in the battery turns into… what? What do batteries provide? (cue

3.10 Jalen : Energy.

3.11 Anthony : Heat.

3.12 Cathy : Some batteries provide heat, but what type of energy? We haven't talked about this one yet, which is why it's tricky. What kind of energy do batteries provide? (cue

3.13 Darryl : Electric.

3.14 Cathy : So they don't provide sound. They provide…? (cue)

3.15 Darryl : Electric.

3.16 Cathy : Electric energy. When you have a battery… if I were to take a plug and plug it into the wall and not use a battery, what kind of energy am I getting? (cue)

3.17 Mark : Electric energy.

3.18 Cathy : I'm getting electric energy. Just like the battery provides the same type of energy, electric energy, right?

3.19 Mark : Electrical energy.

3.20 Cathy : What does that electrical energy turn into? (cue)

3.21 Tracy : Thermal energy.

3.22 Cathy : It doesn't turn into thermal. So what is it? (cue)

3.23 Tracy : Kinetic energy.

3.24 Cathy : What happens on the watch when the electricity hits the dials on the watch? (descriptive

3.25 Amber : It turns to kinetic energy.

3.26 Cathy : Okay. It turns into kinetic energy. If you said, sound, I would take sound energy. Because sometimes you can hear… like if you put your hand up and you can hear a tick, tick on that type of watch.

3.27 Bridget : Electrical.

3.28 Cathy : Good point! Yep. Electrical… elastic…

3.29 Robert : What's sound energy?

3.30 Cathy : Sound, fireworks… we've talked about fireworks a lot. What do you think is one type of energy that's in there? Jalen? (second order)

3.31 Jalen : Kinetic energy.

3.32 Cathy : There is kinetic energy.

3.33 Bridget : Thermal.

3.34 Cathy : There's definitely also thermal. What comes at the very end of the fireworks? (cue)

3.35 Tasha : Gravitational.

3.36 Cathy : Not gravitational.

3.37 Avery : Chemical.

3.38 Cathy : Not chemical… chemical is in the beginning. There's sound energy. And there's another type of energy that we haven't talked about. How do you know that a firework has been lit?

3.39 Aaron : Smell.

3.40 Cathy : It's not smell. It's not heat. What do you see? (descriptive)

3.41 Michael : Colors.

3.42 Darryl : Light energy…

3.43 Cathy : There is also light energy.

{Video of Classroom Discourse, 3-22-10}

The exchange between Cathy and her students as revealed in Excerpt 3 is a classic example of IRE (3.38-3.43). For example, Cathy is looking for another form of energy in the students' responses and provides clues when the students do not respond as expected. Four major points are evident in the dialogue represented in Excerpt 3: teacher-posed questions, teacher-explanations, teacher responses, and teacher references to past learning.

There are 18 teacher-posed questions, while there is only one student question. Cathy asks five types of questions: (a) 12 cue questions (3.1, 3.3, 3.9, 3.12, 3.14, 3.16, 3.20, 3.22, 3.34), (b) one second-order question (3.30), (c) two descriptive questions (3.24, 3.40), and (d) one explanatory question (3.7). For example, Cathy reminds her students about an exhibit with pistons and elicits their response about the type of energy that is involved when something is "moving," which requires a fill-in-the-blank response (3.1). Cathy affirms the correct answer from Mark as he moves away from the idea that the battery has chemical energy and focuses on the idea that batteries provide electrical energy (3.18). The second-order questions reveal the following: After talking about chemical energy, electrical energy, kinetic energy, and sound energy, Cathy wants to know whether

Jalen will be able to identify the form of energy with respect to the watch (3.30). As a descriptive question, Cathy asks, “What happens on the watch when the electricity hits the dials on the watch?” But students respond with very few words. There is one explanatory or “Why?...” question (3.7). Cathy prompts Jalen to provide an explanation by thinking back to the reading about the human-body and elastic energy.

Other behaviors are obvious in Cathy’s classroom. Cathy provides positive responses when her students are correct (3.32, 3.34) and negative responses when they are incorrect, followed by additional prompts and questions to advance their thinking (3.38). For example, Cathy confirms Jalen’s and Bridget’s responses regarding the forms of energy, kinetic and thermal energy, respectively, while continuing to probe for the correct answer. During the discussion about the fireworks, Cathy is looking for another form of energy in the students’ responses because she says “no” to chemical energy although she acknowledges that there is chemical energy in the fireworks.

Cathy references past learning in the context of student experiences at the science center and in the classroom (3.1, 3.7, 3.12, 3.30, 3.38). For example, Cathy prolongs the conversation until the right answer comes forth based on a previous discussion. Later, Cathy does not give Robert a direct answer but uses fireworks as an example of sound energy that was discussed in a previous lesson. She provides a clue to students by asking the following question: “How do you know that a firework has been lit?” Research by Mercer, Dawes, and Staarman (2009) supports Cathy’s attempts to link prior learning to the present. These authors have suggested that this connection provides a way of understanding how participants draw on past text and/or practices to construct present texts and/or implicate future ones; however, Lehesvuori et al. (2013) have acknowledged that developing common knowledge through joint construction or in a meaningful manner takes time.

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. Teachers therefore need to apply less authoritative and more dialogic dialogue to help students construct their own knowledge--in this case, knowledge about the concept of energy. Thus, 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.

Cathy moves her lesson forward with continued questioning. Mercer (1992) argues for the necessity of constant questioning for teachers to monitor students' learning and make their teaching as effective as possible. But the type of question asked counts depending on the purpose of the lesson. Cathy cues her students so that they might come up with the right answers (e.g., 9-10). According to Mercer and Edward (1987, p. 142), the use of cued elicitation to create "common knowledge" is a prevalent practice among teachers, but used more than necessary is a problem. A second-order question such as "How could you explain that so it makes sense to other people?" (5) can guide students' learning and their use of language as a tool for reasoning (Mercer & Howe, 2012) and promote productive discussions (Michaels & O'Connor, 2012). Unlike second-order questions, a descriptive question such as "How does mass affect kinetic energy?" (17) asks for facts of a phenomenon and not its meaning.

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 of the explanatory-type. Asking why questions and ways of explaining by students can involve and promote dialogic interactions between a teacher and students (Scott et al., 2006). Teachers often link prior learning to the present for an explanation that provides a way of understanding how participants draw on past text and practices to construct contemporary books and implicate future ones (Mercer, Dawes, & Staarman, 2009).

Discourse Patterns. Cathy uses IRE, IRF, IRA, and IRElIRIRIRER patterns as she directs her students to formulate scientific explanations by triangulating claims, evidence, and reasoning based on the conclusion question (1) and the IQWST standards. When students mistakenly answer (7, 9), Cathy points out that it is not the constant variable (mass). Cathy keeps probing until she gets the correct answer or the answer she is looking for (e.g., 11). She even goes as far as providing students with the majority of the answers, only allowing for a one-word response (7-10). In other words, Cathy probes until she receives the correct response (11-14). The IRE triad is evident in her evaluative feedback to the students. There is one IRF discourse pattern (5-7). There are two IRA discourse patterns (11-13) in which the teacher states, "Chris, say it again, loud and proud… you were right." There is also a discourse chain indicating IRElIRIRIRER (11).

At times, Cathy asks questions that challenge more than one student to answer. However, the discourse chain should be a bit longer with more R (student response) links, which would give more students the opportunity to offer their explanations. Rather, Cathy's discourse with students reflects repeating and rephrasing. She neither expands upon students' contributions nor allows them to elaborate their answers (Lemke, 1990). To achieve her desired goal, Cathy, like most teachers, maintains control of the content, interactions, and discussion (Edwards & Furlong, 1978; Mishler, 1975). In this control process, Cathy assumes the role of the knower, initiator, and approver of knowledge (Shepard, 2010). Even in long dialogue sequences focusing on a single idea as exemplified in excerpts two and three, the initiation-reply-evaluation pattern dominates (Mehan, 1979).

Communicative Approaches. Cathy repeatedly makes the cultural tools of science available to her students and supports their construction of the ideas through discourse about shared physical events (1.5, 1.9, 1.15, 1.17). However, her communicative approach is interactive/authoritative according to two sequences of talk (1.5, 1.15). She also comes to closure rather quickly when she hears the correct scientific response she wants to hear. This sort of premature closure to the discussion suggests that Cathy carries out a question-answer routine aiming at a specific answer and when it surfaces she establishes it. Mortimer and Scott (2003) classify this closure as interactive/authoritative, and this sort of communicative approach abounds in Cathy's lessons.

Activity three as shown in the Table 2 could have set the stage for argumentative discourse (Driver et al., 1994) and the ability to solve open-ended problems through argumentation--e.g., claim, evidence, reasoning, and explanation (McNeill & Pimentel, 2009). Classroom discourse in the context of scientific inquiry depends on the use of data as evidence for explanation and argumentation (Krajcik & Sutherland, 2000). The preferred form of classroom discourse in the IQWST curriculum is a give-and-take exchange of ideas in which classroom discussion is centered on engagement and thoughtfulness (Krajcik et al., 2008). Although Cathy makes some attempt to engage her students in classroom discourse using the give-and-take strategies and pursues lines of questioning by probing her students to discuss their reasoning, she continues to use closed questions that lead to brief, accurate responses from a few students. In some instances, Cathy demonstrates discourse that leads to scientific explanation (e.g., 1.5-1.6), but she heavily cues students to the point that she elicits one-word, correct answers from them (e.g., 1.9-1.12).

According to Kyriacou and Issitt (2008), good learning results when teachers use questions not only to seek right answers but also to elicit reasons and explanations. As seen in 1.5, asking students specifically to provide their evidence and reasoning encourages students to justify their responses and make their thinking visible to the teacher and their peers in the classroom (McNeill & Krajcik, 2012). However, while Cathy attempts to triangulate the scientific explanation with a claim, evidence, and reason, the teacher-student interactions tend to be dominated by the interactive / authoritative communicative approach in which she uses "closed" questions to seek brief, accurate, confirmation answers (Mercer & Howe, 2012). The educative components of the IQWST curriculum include example questions and probes to help teachers understand ways of fostering connections between student wonderment questions and the driving question of the lesson (Singer, Marx, Krajcik, Clay, & Chambers, 2000). These authors advocate the need and importance for teachers to elaborate and reformulate the contributions made to classroom dialogue by students as a way of clarifying earlier statements for the benefit of others and like Mercer (2008) puts it to make connections between the content of students' utterances and the technical terminology of the curriculum.

Implication

Cathy struggles to implement the ideas she had learned during the IQWST professional development, and although she reverts, her attempt to carry out interactive discourse with students by asking questions is commendable. Teachers like Cathy should be encouraged to use "interactive/dialogic communicative approach (Mortimer & Scott, 2003) to check for student conceptual understanding (Alexander, 2004). Lehesvuori et al. (2013) acknowledge that developing common knowledge through joint construction in a meaningful manner takes experience and time. In this sense, teachers need to supplant authoritative with more dialogic interaction to help students construct their knowledge (Aguiar, Mortimer, & Scott, 2010; Mercer & Howe, 2012). The predominant cued questions should be sparse and replaced with questions that encourage students to put main ideas into their own words and press students to elaborate on these ideas. Asking, "How did you know that?" or "Why do you think that?" develops students' understanding (Wolf, Crosson, & Resnick, 2006).

The results of this discourse study reflect only a fraction of a sociocultural perspective of learning advocated by discourse researchers. The reasons might be because professional development is just 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 for implementing standards-based curriculum such as the IQWST.

Even though Cathy participated in professional development focused on how to implement the unit on energy and attempted to engage her students in interactive discourse, this study revealed the need to provide additional professional development on how to develop student understanding and common knowledge using dialogic discourse. It is useful both for teachers and administrators to understand the various classroom discourse tools and how they should be used to develop common knowledge and conceptual understanding of difficult-to-learn science concepts, such as forms and transformation of energy. The tools provided in professional development should include learning how to achieve more in-depth knowledge of the essence of classroom communications through micro-scale, moment-by-moment exploration with teachers (Lehesvuori et al., 2013). Because whole-class instruction is the most common instructional approach (Eshach, 2010), especially in urban classrooms, these tools should encompass strategies to help teachers navigate, mediate, and co-construct knowledge with their students. Professional developers and mentors themselves should use dialogic discourse as they attempt to move teachers toward various discourse patterns and when to use them. It is essential to understand that learning mediated through dialogue happened over time and observed over time with the goal of conceptualizing the interactive cognitive development and education of the teacher (Mercer, 2008).

Administrators and researchers who observe 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, being empathetic with the time needed to create dialogic discourse, teachers who are willing and genuinely trying to implement dialogic discourse need to be supported, monitored in their use of this type of communicative approach, and not left to their discretion during implementation. Follow up from colleagues, administrators, and researchers regarding how teachers are progressing over a specific period should be consistent and a part of job-embedded professional development to ensure that teachers are implementing dialogic discourse where appropriate, particularly as the Next Generation Science Standards (Achieve, 2013) and other reforms are taking root.

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