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Secondary science students' beliefs about class discussions: a case study comparing and contrasting academic tracks

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ABSTRACT

The dialogue that occurs in science classrooms has been the subject of research for many decades. Most studies have focused on the actual discourse that occurs and the role of the teacher in guiding the discourse. This case study explored the neglected perspective of secondary science students and their beliefs about their role in class discussions. The study participants ($N = 45$) were students in one of the three differentially tracked chemistry classes taught by the same teacher. Findings about the differences that exist among students from different academic tracks are reported. While it seems that epistemological beliefs focusing on content are common for the students in this study, the students' social framing in the different tracks is important to consider when teachers attempt to transition to more dialogic forms of discourse. Some key findings of this study are (a) students' beliefs that science is a body of facts to be learned influenced the factors they deemed important for whole-class discussion, (b) students from the lower-level track who typically were associated with lower socioeconomic status were more likely to view their role as passive, and (c) students' comfort level with the members of the class seemed to influence their decisions to participate in class discussions.

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Introduction

Recent reform efforts such as the Next Generation Science Standards (NGSS Lead States, 2013) in the United States as well as recent standards and/or curricula in numerous European countries (Science Teacher Education Advanced Methods [S-TEAM], 2010) include a focus on rich classroom discourse in which students negotiate meaning. Particularly for secondary science classrooms, these reform-based initiatives suggest significant changes in the teaching of science, which are often teacher-directed (Alozie, Moje, & Krajcik, 2010). The abilities of secondary science students to clarify their thinking and justify their positions through discourse are essential elements of science practices that should be fostered during instruction (National Research Council, 2012). In the past, some curricula designed to provide opportunities for students to engage actively in science practices have been associated with significant gains in science achievement (Geier et al., 2008; Marx et al.,

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2004; McNeill, Pimentel, & Strauss, 2013; White & Frederiksen, 1998), while other studies have suggested modest to negligible differences (Pine et al., 2006; Schneider, Krajcik, Marx, & Soloway, 2002). A main reason for the inconsistent results is the variability in teachers' approaches to student discussions (Johnson, Kahle, & Fargo, 2007; Klahr & Li, 2005; Klahr & Nigam, 2004). Even when curricula are written to support more active forms of student participation about scientific concepts, the type of discussions that occur remains authoritative and teacher-directed in nature (Alozie et al., 2010; McNeill & Pimentel, 2010; Puntambekar, Stylianou, & Goldstein, 2007).

A number of previous studies, particularly in the area of argumentation, have focused on the role of the teacher in supporting rich classroom discourse. Teachers' questioning strategies (Martin & Hand, 2009; McNeill & Pimentel, 2010) as well as other pedagogical practices such as prompting justification and encouraging evaluation (Simon, Erduran, & Osborne, 2006) can help support student discourse in which students build on and critique the ideas of their peers. Although the role of the teacher is essential, students also play a key part in classroom discourse communities (Berland, 2011). Students may be hesitant or resistant to participate in student-directed classroom discussions for a variety of reasons. For example, in a study of secondary science classrooms, even when there were opportunities for student-directed discussions, students voiced opposition to this form of discourse, potentially because of concerns about their peers and the difficulty of the task (Pimentel & McNeill, 2013). In addition, Furtak and Ruiz-Primo (2008) found that middle school science students were more likely to reveal their divergent thinking in writing than during class discussions. This difference was due to the students' belief that teachers were interested in evaluating answers rather than exploring thinking during talk. Students' belief that teachers are only interested in the right answer has been documented in other studies as well (Jiménez-Aleixandre, Rodriguez, & Duschl, 2000; Mercer & Littleton, 2007).

Shanahan and Nieswandt (2011) suggest that students possess a relatively clear understanding of their role during lessons. This role is generally associated with being well behaved. While this may be true, students' beliefs about engaging in discussions seem to be more complex and worth exploring. Given that science discussions occur in dynamic social contexts, students' beliefs about their role in the discussions may reinforce teacher-centered dialogue even when teachers try to use new reform-based approaches.

Because students are essential contributors to the interactions that take place in class discussions, this study serves to broaden the theories that currently focus predominantly on teacher moves and beliefs. This study therefore investigates the questions:

(a) What features of whole-class discussions do secondary students in different tracks believe are important?
(b) What do secondary students in different tracks believe is their role and the teacher's role during science class discussions?
(c) What factors influence students' decisions about participating in whole-class discussions during science lessons?

Theoretical background

Sociocultural theory was used as the foundation for this study. Of particular importance is the notion that learning occurs first in the social plane with the use of cultural tools such as language before it is internalised (Vygotsky, 1978). As the content specialist, the teacher's role is therefore to provide guided opportunities for students to exceed their present level of understanding or knowledge (Scott, 1998). The value of any activity that is done in the classroom is mediated by the meaning that is made by the students through the interthinking that occurs during discussions associated with that activity (Mortimer & Scott, 2003). Although the teacher does hold the role of discipline master within the context of the classroom, she cannot simply transfer meaning and understandings about science onto students. The teacher's role is to provide opportunities for students to engage in scientific practice so that they not only construct scientific knowledge, but also begin the process of enculturation into scientific discourse (Gee, 1989). Scientific practice in this sense transcends simply doing an activity. Emphasis on the act of doing the activity instead of the understanding that is achieved from discussing the meaning of the practice is misplaced (Mortimer & Scott, 2003). Science learning is more than simply manipulating objects or learning facts. It requires that students engage with scientific language and meanings. However, the question remains about the extent to which students possess similar beliefs of science class discussions.

Lave and Wenger suggest that a significant problem with the use of language in education is the approach to teaching known as knowledge transmission (1991). They say that 'the conflict stems from the fact that there is a difference between talking *about* a practice from outside and talking from *within* it' (p. 107). Because science, as a domain, has evolved a technical and highly structured form of language that serves as a resource for what Halliday termed 'meaning potential' (1995/2006, p. 8), learning to make meaning of the abstract and generalised concepts in science is inextricably linked to being able to interact with the language that defines the field. Being educated in science is therefore being able to use language as a tool to approach phenomena with new perspectives, find new ways to interpret ideas and to problem solve (Mercer & Littleton, 2007). These definitions suggest an active role of the student. While the teacher can provide opportunities for students to engage in dialectic conversations about science, students must agree to participate in any form of discussion that occurs (Lemke, 1990).

Discourse in science classrooms

Although recent research and reform efforts advocate for rich discourse in which students play an active role, science classrooms have traditionally been more teacher-directed. Lemke's (1990) seminal work describing talk in science classrooms brought to light the limited opportunities students have to actively engage in discussions during lessons. Although students are typically encouraged to participate, rigid organisational structures can greatly influence the types of student responses that are deemed acceptable. This can often result in triadic discourse, or IRE, in which the teacher initiates (I), the student responds (R), and the teacher evaluates (E) (Cazden, 1988; Mehan, 1979). These types of IRE discussions result in limited student interaction or reasoning in which students support or refute the ideas of their peers (McNeill & Pimentel, 2010). Unfortunately, the teacher continues to be the driver during most discourse in science classrooms (Duschl & Osborne, 2002).

In contrast, student-directed discourse, such as argumentation, can provide students with opportunities to reason and develop new meanings as they engage in debate and consider counter arguments (Osborne, 2010). High-quality collaborative argumentation discussions include students providing multiple different ideas as well as questioning and critiquing those ideas (Evagorou & Osborne, 2013; Sampson & Clark, 2011). Argumentation lessons can help support classroom discourse that enables student engagement in talking science in which students co-construct understandings of natural phenomena (Jiménez-Aleixandre et al., 2000). In addition to work focused on argumentation, research on classroom discourse has highlighted a number of different frameworks such as 'accountable talk' (Michaels, O'Connor, & Resnick, 2008), 'responsive teaching' (Hammer, Goldberg, & Fargason, 2012), and the 'communicative approach' (Mortimer & Scott, 2003) all of which share a common focus on supporting greater student-directed discourse in science classrooms.

Communicative approach of discussions

The conceptual framework used to guide the analysis of this study was Mortimer and Scott's (2003) idea of the communicative approach of discussions. The communicative approach refers to the overall relationship that occurs between the teacher and the students during the discussion. Mortimer and Scott (2003) present two dimensions to consider classroom discourse: interactive/non-interactive and dialogic/authoritative. Both dimensions exist on a continuum and coexist within discussions (see Figure 1). Although the approach is defined as a continuum (Mortimer & Scott, 2003), there are features associated with each extreme which help to characterise them. The first dimension focuses on interactive versus non-interactive talk. Interactive talk occurs when more than one person is participating in the discussion while non-interactive talk excludes student participation. The second dimension focuses on dialogic versus authoritative talk. A typical IRE class discussion in which the teacher focuses solely on assessing student understanding of scientific content and explanations by soliciting student participation would be considered an interactive, authoritative approach (Example 1).

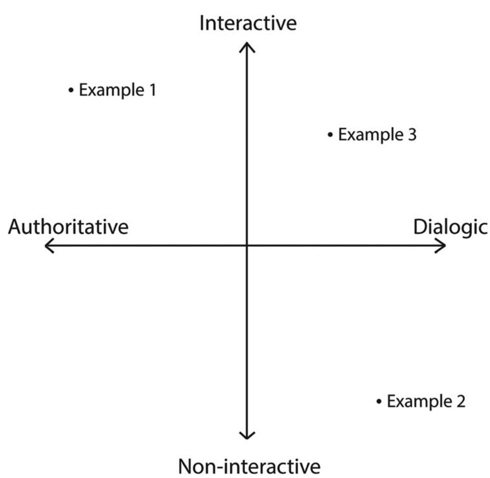

Figure 1. Two-dimensional representation of communicative approach framework (Mortimer & Scott, 2003).

Authoritative approaches to talk are associated with teacher-dominated contributions which rigidly steer discussions within clear content boundaries. A pure lecture, which is non-interactive, can be considered dialogic, however, if the teacher presents multiple viewpoints on a topic (Example 2). Dialogic approaches are characterised by greater co-participation between teacher and students with multiple ideas being considered during the discussions (Scott, Mortimer, & Aguiar, 2006). A discussion that is geared towards developing student meaning making by opening the conversation to include students' understandings and ideas can be considered both interactive and dialogic (Scott, 1998). This case appears as Example 3 in the figure. The extent to which students are allowed to participate or alternative viewpoints are allowed moves discussions within these two dimensions.

Student beliefs

Dialogic interactions during science talk require the co-participation of students with the teacher; however, limited research exists on students' beliefs about classroom discussions. We draw on work from Chinn and Samarapungavan (2009), defining a belief as a conceptual structure that is perceived to be true or correct. In a study of high school students' beliefs about discourse and argumentation, Kaya and colleagues (2012) found that most students indicated that they participate in scientific discourse and that most students thought that argumentation was used in science lessons. In addition, the majority of students indicated positive attitudes towards argumentation. However, other research has investigated students' beliefs about classroom discourse in relation to their participation in classroom discourse and found limited participation. For example, while studying the discourse patterns in high school English classes Alpert (1987, 1991) found that students were more likely to resist teacher solicitations for them to participate in discussions as opposed to other activities such as reading and homework. He also concluded that when teachers used more dialogic forms of talk in which they were responsive to student ideas that students were less likely to resist talk. Similar resistance has been described in science classes with students being less motivated to discuss their ideas in class because of their belief that the teacher is looking for the 'right answer' (Furtak & Ruiz-Primo, 2008).

The main focus of this study on student beliefs is on how students are framing the talk that occurs in the class. By framing, we mean 'the set of expectations an individual has about the situation in which she finds herself that affects what she notices and how she thinks to act' (Hammer, Elby, Scherr, & Redish, 2005, p. 98). This study investigates social and epistemological framing. The social level is defined as who the students expect to talk and interact with during class discussions, while the epistemological level is defined as what types of knowledge are valued and used during the discussion (Hammer et al., 2005). In an authoritative, teacher-centered class discussion in which a teacher is focusing on content knowledge, the implied social frame is that student contributions will flow to the teacher and a response from the teacher will occur and the epistemological frame will focus on the scientific point of view only.

Given that context plays such an important role in beliefs, this study also investigated students' beliefs across different ability groupings or tracked classes. Research has produced mixed results regarding the impact of tracking on student learning. A recent study suggested that the placement of students into various ability grouping may have little impact on variables at the social level when controlling for cognitive ability, gender, and socioeconomic status, but the authors note that due to the low reliabilities of the scale, very limited assertions could be made (Vogl & Preckel, 2014). Another study comparing tracking among countries suggested that while tracking could have positive effects on student learning, the benefits of tracking were negated by peer effects. No effect of tracking on student science achievement was also reported when background factors such as cognitive ability and socioeconomic status were considered (Slavin, 1990), but this could be confounded by the fact that students of similar socioeconomic status are typically tracked into the same classes (Oakes, 1990). Consequently, although researchers have investigated tracking, there is little consensus. However, considering the importance of context and classroom community in supporting rich discourse (Berland, 2011), we felt that tracking was an important consideration as we investigated students' beliefs about classroom discussion.

Methods

Context of the study

A case study approach was used to address the research questions because of its instrumental value in better understanding the interplay between the participants' beliefs and the interactions taking place during the class discussions (Stake, 2000). Specifically, we focused on one secondary chemistry teacher, whose pseudonym will be Ms. Romac, and 45 of her high school students. Ms. Romac was a 50-year-old chemistry teacher with eight years of teaching experience. She came into teaching as a second career after having worked in several positions that made use of her Bachelor of Science degree in Chemistry. Before teaching, she worked as a chemist and quality control specialist in some chemical companies and she also worked as a laboratory manager in a university research facility. After staying at home to raise her children, she entered a teacher certification programme and became a teacher. Ms. Romac was chosen as a participant because of her interest in exploring talk within her classes and also because her class schedule included three different academically levelled classes: 11th–12th-grade honours chemistry II, 10th-grade college preparatory chemistry, and 10th-grade general chemistry. Students were placed in each level as a result of previous achievement in science classes and teacher recommendation. Parents were given the ability to override the teacher recommendation for placement, however overrides were uncommon.

Of the 21 students in the elective honours chemistry II class, all but one student participated in the study. Compared to the other classes, the participants from honours chemistry II had a much lower percentage of females, but had the greatest ethnic diversity. Furthermore, a higher percentage of the students in this class reported that they had immediate family members involved in a science-related career (45%). Lastly 90% of the students in this class had at least one parent with a post-secondary degree (see Table 1).

There were 27 students enrolled in college preparatory (C.P.) Grade 10 chemistry and 14 participated in the study. In this required class, each gender was similarly represented. All of the participants in this class identified themselves as European/White. Only two students (14%) reported that they had an immediate family member involved in a science-related career. Lastly, 72% of the students participating in the study from this class reported that at least one parent had a post-secondary degree (see Table 1).

Of the 19 students in the general chemistry class, 11 participated in the study. Like C. P. Chemistry, gender representation in this required course was approximately equal. One student identified himself as Hispanic while all others identified themselves as European/White. Only one student (9%) reported that they had an immediate family member involved in a science-related career. Lastly, two students (18%) reported that at least one parent had attained a post-secondary degree (see Table 1).

The teacher and students participating in this study were members of a high school community in a suburban area located in the Northeastern Region of the United States. The total enrollment was approximately 1100 students with 93% identifying themselves as White.

Study design

To address the research questions, we collected three data sources: student questionnaire, video recordings of three lessons in each classroom, and semi-structured student interviews. The specific mapping of research questions to data source is explained in the data analyses section.

All student participants completed a questionnaire prior to the recording of any lessons or interviews. The student questionnaire consisted of three parts: the Dialogic/Authoritative Likert Scale items, open response questions, and background information (see Supplemental Online Materials for complete questionnaire). The Dialogic/Authoritative section included 13 items that described elements of authoritative (e.g. Teacher focuses on science point of view at all times) and dialogic (e.g. Students talk directly to each other) discourse as outlined in Scott et al. (2006). Students were asked to rate each item in terms of how important each feature was for effective science talk during whole-class discussions. The four-point rating scale included the following choices: extremely important, very important, somewhat important, and not at all. The five open response questions focused on: (a) the purpose of whole-class discussions, (b) factors students believed contributed to their willingness to participate in class discussions, (c) the teacher's role in whole-class discussions, (d) student's roles in whole-class discussions, and (e) the value students placed on this approach for learning science. Background information

Table 1. Descriptive statistics of student characteristics by class.

	Chemistry II	C. P. Chemistry	General chemistry
Total participants	20	14	11
Gender			
Females	25%	57%	55%
Males	75%	43%	45%
Ethnicity			
European/White	60%	100%	91%
African American	5%	0%	0%
Hispanic	0%	0%	9%
Other	35%	0%	0%
Member of immediate family involved in science-related career			
No	55%	86%	91%
Yes	45%	14%	9%
Highest level of education – parents			
High school diploma	10%	28%	82%
Associate or bachelor degree	60%	36%	18%
Masters degree or doctorate	30%	36%	0%

included the specification of gender, ethnicity, family involvement in science-related careers, and highest level of education attained by the parents.

Three lessons in each class were observed and video recorded. These lessons were selected in consultation with the teacher, because she designed them specifically to support student discussion. One video camera was positioned in the front of the classroom facing the students. When possible, lessons that focused on the same content across tracks were recorded in order to facilitate comparisons.

For each of the three lessons, the researcher selected two students from each class to be interviewed in order to elaborate on the themes that emerged from the survey. One student from each class lesson was chosen because he or she contributed with more frequency or more elaborately to the discussion (frequent talker); while another was chosen because he or she tended not to participate in the class discussion (infrequent talker). The selection of these students was based on information that had been provided by the teacher as well as data from the video-recorded lessons. The interviews took place within one week of the lesson. Eisenhardt (2002) suggests that between 4 and 10 cases is formidable for developing theory to maximise the complexity in a way that is manageable. In this case there were 18 student participants whose interview responses were considered using two lenses: (a) three groups of six students representing different academically tracked levels and (b) two groups of nine students representing the active participants vs. those students who did not frequently participate.

Selected students participated in semi-structured interviews which lasted between 20 and 30 minutes each. These interviews included questions about a video clip from the lesson and also questions based on the student's responses to the questionnaire (see Supplemental Online Materials for the complete interview protocol). During the semi-structured interviews, each student viewed clips from his or her specific class. The video clips served as a source for stimulated recall by the student and provided specific contexts for the interview questions (Calderhead, 1981). For each lesson, 1–2 video clips were chosen. These clips were between an average of 2–5 minutes long. Clips were chosen according to how representative they were of the overall discussion that took place throughout the entire lesson or if they represented a unique event. For example, if the lesson was mostly authoritative in teacher approach, the clips for that class would predominantly reflect that approach. If a lesson had both authoritative and dialogic approaches, balanced throughout, two clips for the lesson were chosen for the interview. In some instances, video clips were chosen because they highlighted a discursive interaction that was unique and it served as a source of reflection for the student being interviewed. The interview questions asked students to comment on various aspects of the discussion that was taking place in the clip. For example, students were asked to comment on their feelings about the type of discussion that was taking place, the impact of that discussion on their learning, ways in which they wish the discussion could have been different, and influences on their decision to participate or not. After this, the students were asked to clarify some of the responses they had made in the class questionnaire. For example, one student responded that he believed students should only talk in class if they are called on by the teacher. The student was asked to clarify this response.

Data analyses

Data analyses were conducted using both holistic and categorising strategies directly informed by the research questions (Rossman & Rallis, 2003). The initial analyses of each data source were conducted independently. Data from the various sources were then triangulated to determine common themes as well as present inconsistencies that served to further elucidate the research questions (Patton, 2002). Themes which appeared to be most prevalent, meaning that they appeared most often across data sources and participants, were then presented in the description of the case study (Rossman & Rallis, 2003). We next describe this analysis process specifically for each of the three research questions.

Research question a. To address the first research question investigating the important features of whole-class discussion, student survey responses to the dialogic and authoritative approach items were analysed. Initially, the authors expected that the survey items would converge to produce two separate scales: Dialogic Beliefs and Authoritative Beliefs. We hypothesised that students who gave high importance to dialogic approach items would prefer more student-directed discussions; while students who gave high importance to authoritative approach items would prefer more teacher-centered discussions. However, this was not the case. When we conducted a principal component factor analysis, items from the two different scales loaded together suggesting that students valued elements from both scales. Furthermore, the reliabilities of the scales were low. Consequently, items were analysed independently to look for trends in students' responses to individual items.

Students' Likert-scale responses for each item were used to form two groups of students. Those students rating the feature as not at all important or somewhat important were combined into one group which considered the factor to be of minimal importance. Those students rating the factor as very important or extremely important were placed in another group which considered the factor to be of high importance. Chi-Square Goodness of Fit tests and Test of Independence tests, including cross tabulations by class for each individual item, were then performed. The intention was to determine if a significant difference existed among the three different tracks of the chemistry classes with respect to each item representing either a dialogic or authoritative approach to discussion (Shavelson, 1996). This was to explore whether there were trends in the different tracks' views of discussion. Those items that showed no significant difference in responses when classes were compared were aggregated and ranked according to the percentage of all students who expressed a high level of importance to that item from all the classes in the study.

The coding of one open-ended survey item (Question 1) and a portion of the interviews (Questions 1, 2, 5, and 6) were then used to elucidate why significant differences may have occurred for some items and not for others. The open response questions and interview transcripts were analysed thematically using open coding by one author only (Strauss & Corbin, 1990). Specifically, the prevalence of common statements related to the purpose of whole-class discussions, such as to have the teacher guide student thinking, to demonstrate to the teacher what students know, and to learn what the teacher is presenting, was determined and then compared across classes.

Research question b. The second research question focused on understanding students' beliefs about their role and the role of the teacher in whole-class discussions. Students' responses to survey open-ended questions 4 and 5 describing students' beliefs about their role in whole-class discussions were grouped based on similarity and then the incidence of responses in each group were tallied (Miles & Huberman, 1994). For example, as each response to survey question 5 focusing on the students' role in whole-class discussions was read, unique categories representing the response were created. The final scheme consisted of eight basic categories: contribute ideas, participate, elaborate, ask questions, answer questions, learn from others, listen, and learn. Each complete student response could include one or more of these categories. After identifying the categories, student responses were coded for the categories and the number of each code tallied. A similar process was used for question 4. The final categories relating to the teacher's role in whole-class discussions were guide/lead discussion and check student knowledge. The responses for both questions were then disaggregated by class to determine if differences existed among the tracked chemistry classes. Student interview transcripts were also analysed for any responses that addressed the students' or teacher's role in discussions. Relevant quotes were labelled by gender, class, and talker type to determine if any patterns emerged. These were compared to the patterns from the open-ended survey items to question, refine, and elaborate the emerging themes.

Research question c. The third research question focused on factors influencing the students' decisions to participate in whole-class discussions. Students' responses to survey open-ended questions 2 and 3 were grouped by similarity, analysed and tallied in a similar fashion as described above (Miles & Huberman, 1994). Question 2 asked students to explain why they did not participate when they had a question or had something to add, while question 3 asked students to describe when they were most likely to contribute to a whole-class discussion. Responses to each question were listed, categorised, and then compared by class. The main categories that emerged for these two related questions were knowing the right answer, not wanting to disrupt the flow of the discussion, and comfort with the students in the class. In addition, the student interviews based on the video recall (Questions 3, 4, and 7) were analysed for relevant quotes labelled by gender, class, and talker type. Particular attention was given to the ways student were socially and epistemologically framing their participation (Hammer et al., 2005). The responses were then compared. Similar to research question b, these quotes were used to refine the emergent themes from the survey analysis.

Results

In this section, we present our findings from the case study in order of our three research questions. First, we address the elements in whole-class discussions that secondary students believed were important. Next, we consider the differences across the three tracked classes, particularly in relation to the students' role in discussion. Finally, we examine the influences students discussed that impacted their decision to participate in whole-class discussions.

Beliefs about important features of whole-class discussions

This study explored which features students believed were highly important in whole-class discussions. In order to determine trends from the survey items, we combined the responses of students who said a feature was either 'extremely important' or 'very important'. Table 2 presents these results in descending order by the percentage of students who considered the feature important. For all features, with the exception of the last two in the table (designated with an asterisk), the percentage of students' responses denoting the high importance of each feature in whole-class discussions were consistent for all three chemistry classes. Chi-square tests, including cross tabulations considering the possible influence of the students' class on results, suggested that there were no significant differences among classes for each feature, χ^2 (2, $N = 45$), $p > .2$. The last two items in the table will be discussed in the next section. Consequently, this suggests some similarities in terms of what secondary students in different tracks believe is important in whole-classroom discussions.

Interestingly, the students who responded to this survey believed that both dialogic and authoritative features of talk were very important to extremely important for classroom discussions. For example, the top five highly rated items include two dialogic items and three authoritative items. While all students except one believed that it was highly important that teachers were open to a variety of students' points of view, all but three believed that it was also highly important that teachers evaluate and provide feedback on what students were saying. Responses students provided to the open survey questions and during interviews suggest that although students wanted the teacher to be open to different points of view, they themselves were more focused on providing the correct answer to discussions as opposed to contributing alternative points for discussion. For example, most students responded to the open-ended item on the survey that they were least likely to contribute to the discussion: when they felt that they would be wrong (33%); they thought their contribution was irrelevant or unimportant (40%); or their contribution would interrupt the discussion (13%). Alternatively, they would say something in class if: they knew the right answer (49%) or they needed clarification (33%).

During the interviews, most students described science as a discipline of rules and facts or what one honours student called, 'generally accepted answers'. For him, the purpose of whole-class discussions 'should be to clarify what's known', adding that, 'if you want to look into other possibilities, that's fine, but you should know the basics before you start

Table 2. Whole-class discussion features ordered by percentage of students ($N = 45$) who ranked the feature as highly important (very important or extremely important).

Feature categorisation	Item	Number of students (%)
Dialogic	Teacher is open to different points of view	44 (98%)
Authoritative	Teacher evaluates and provides feedback immediately after student contributions	42 (93%)
Dialogic	Teacher and students build on each other's ideas.	41 (91%)
Authoritative	Teacher reshapes and elaborates on students' responses	39 (87%)
Dialogic	Students provide reasoning when they contribute to discussions	38 (84%)
Dialogic	Students initiate new ideas into the discussion.	36 (80%)
Dialogic	Teacher asks students to clarify or elaborate on their responses	30 (67%)
Authoritative	Teacher questions students about content facts and vocabulary	30 (67%)
Authoritative	Teacher rigidly guides the directions of the discussion	29 (64%)
Authoritative	Teacher focuses on the science point of view at all times	20 (44%)
Dialogic	Students contribute personal points of view	*
Authoritative	Students contribute to discussions only when called on by a teacher	*

*Percentage of students' responses differed depending on class.

doing that'. These ideas were echoed by another honours student when she compared science class to her other classes. She thought that in science, 'you can't attach interpretations because you don't have the background to know it so you need those structured classes that take care of all those gaps'. In her case, she believed that open discussions that allowed for student participation could only happen, 'after the chapter was completed … until the information is covered, I don't think discussions are warranted because you don't know enough to have an informed discussion'. Consequently, the secondary students appeared to see science as a body of facts to be learned, which impacted their beliefs about important features of whole-class discussions.

This epistemological framing of class discussions around the clarification of canonical knowledge suggests that items categorised as dialogic, referring to different points of view and ideas, may have been narrowly interpreted by the high school students. In talking about student contributions during interviews, many students mentioned that listening to other students' perspectives and point of views were helpful for learning because other students could sometimes convey the information differently or better than the teacher, thereby helping to fill in their gaps in knowledge. Overall, the points of view that students referred to did not seem like perspectives that were up for debate, rather alternative ways of talking about a common scientific point of view. As one C. P. student put it, 'for certain things, there's not more than one way of looking at it'. Although students wanted to be able to express their understandings of topics, in the end they acknowledged that in class there was a scientific way of understanding the world and they expected that the teacher would monitor and shape that understanding. In this respect, one general-level student expressed her satisfaction with Ms. Romac's approach to talk, saying, 'Chem is kind of like facts. So it's more of getting lectured when we're learning than actually talking back and forth, but she's really good at teaching.' She thought the biggest benefit to having students participate in the discussion was that 'when a student does it, and they understand it and they explain it, it's kind of more my level'. Students' views of science as a set body of rules or facts to be learned and not questioned impacted their interpretation of the authoritative and dialogic features of classroom discussion. They viewed features as important if they could help clarify their own understanding of that body of knowledge, rather than an acknowledgment of the social or discursive elements of science.

Differences in students' beliefs about their role across classes

While it appeared that there were common student beliefs about expectations for talk during whole-class discussions and the teacher's role in that talk, distinctions across the classes were evident when their beliefs about the student's role or social framing in whole-class discussions were considered. Social framing refers to the expectations that students have about how individuals in the class will interact with each other and the teacher (Hammer et al., 2005).

The students in the classes representing different levels did differ in their responses to two features of whole-class discussions on the survey. As seen in Table 3, all students but one in the general-level class believed it was highly important for students to contribute personal points of view to whole-class discussions. The importance placed on this feature was significantly lower in the other classes with less than half of the Chemistry

II (honours) students stating that contributing personal points of view was an important feature of class discussion. In addition, the Chemistry II students were much less likely than the students in the other classes to state that it was important to contribute to discussions only when called on by a teacher. The differential responses to both of these items can be better understood after considering the beliefs that students shared about their role in whole-class discussions in the open-ended items.

In terms of the student's role in the discussion, there was a distinct difference between the students in the lowest tracked class, General Chemistry, and the other students. While students in the Chemistry II and C. P. Chemistry classes used more active and collaborative language when describing their role, the majority of students in the general class stated that their main role was to listen and learn. No students in the other classes used the word 'listen' in the open response section to describe their role in whole-class discussions. While one student in the honours class wrote that his role was to 'pay attention', most student-role descriptions in both the Chemistry II and C. P. Chemistry classes were active, such as contribute ideas, participate, ask questions, and help others (see Table 4). In this table, only role descriptions suggested by more than one student in the class appear.

Equally noteworthy is the fact that all the answers from the General Chemistry students participating in this study focused on the student's role internally, with no student mentioning social interactions with other students as part of their role in discussions. Even during the interviews with General Chemistry students, only one of six students stated that sharing ideas was part of her role, while four of the students took on a more passive approach. One student stated that his role was 'to listen' and 'take what she [the teacher] says into me'. In the other classes, students included many more active descriptions of their role with three students in each non-general class stating that their role in whole-class discussions was to help others learn or to learn from others. This individual-focused, social framing of the general-level students was also evident in the reasons they had for whole-class discussions. None of the students in the General Chemistry class stated that learning or collaborating with others was a reason for whole-class discussions, while four students in each of the other classes did.

The most active student roles were found in the student responses in the highest tracked class, Chemistry II, to the survey. While contributing ideas was the most common reference, some students also mentioned that they should be expanding or elaborating on what was being said during the discussion as well as evaluating what was being said. In the lesson observations, there was evidence that students in this class did refer back to what other students said either to ask a question or elaborate on the response. Socially, however, these references to other student responses were most often mediated by the

Table 3. Features of whole-class discussions with differential importance among classes.

Item	Class	Minimal importance*	High importance**
Students contribute personal points of view	Chemistry II	12 (60%)	8 (40%)
	C. P. Chem	6 (43%)	8 (57%)
	General Chem	1 (9%)	10 (91%)
Students contribute to discussion only when called on by a teacher	Chemistry II	17 (85%)	3 (15%)
	C. P. Chem	7 (50%)	7 (50%)
	General Chem	5 (45%)	6 (55%)

*Students (percentage) who responded 'not at all important' or 'somewhat important'.
**Students (percentage) who responded 'very important' or 'extremely important'.

Table 4. Students' beliefs about their role in whole-class discussion.

Chemistry II (number of students)	C. P. Chemistry (number of students)	General chemistry (number of students)
Contribute ideas (8)	Contribute ideas/opinions (6)	Listen (5)
Expand/elaborate/evaluate (4)	Participate (5)	Learn (3)
Ask questions (3)	Learn from conversation (3)	
Answer questions (3)	Ask questions (2)	
Learn from others/ Help each other learn (3)	Learn from other/ Help each other learn (3)	
Participate (2)		

teacher and directed towards the teacher. While there is one instance when a student directly asked another, 'Do you mean like the second one? Can you repeat your question?', such an interaction was atypical except in the case of Lesson 3 when the students were teaching the class. Overall, this suggests that there were differences in secondary students' beliefs across the three chemistry tracks with students from the lower-level track typically viewing their role in discussion as passive.

Factors that influence students' decisions to participate in whole-class discussions

In addition to examining differences across tracks, we were interested in whether students' beliefs varied for frequent versus infrequent participants in classroom discussions. Similar to the comparison with tracking, we found that students' social framing of whole-class discussions was important for the frequency of their participation. Student beliefs about the impact of their contributions on others and their own learning, as well as their personalities, seemed to relate to students' willingness to participate in the discussions. Two themes accounting for their approach to talk emerged from the comparative analysis of their responses: (a) Approach to Talk in Relation to Other's Learning and (b) Social Comfort. Although not all students in each talking category (frequent vs. infrequent) included references to every theme, there were similar responses in each group that stood out for each theme.

Approach to talk in relation to learning

Some students explained their tendencies towards discussions in terms of students' learning. Several frequent talkers referred to their contributions to discussions as being beneficial to their own learning as well as the learning of other students; while students who talked infrequently suggested that their contributions were unnecessary or would interfere with the learning of others (see Table 5). For several frequent talkers, the responsibility for learning in class was not focused only on themselves; it included helping other students learn the subject as well. Students who spoke less frequently felt that either it was not their place to help other students understand or that their questions and contributions would be an interruption, rather than a benefit, to their peers.

Students' differential positioning of themselves within the discussion may be due to variations in their perceptions of what is going on. While frequent talkers were more likely to be satisfied with the type of class discussions that took place and characterised them as being open to the inclusion of student ideas and the meanings they were taking from the material being taught, infrequent talkers were more likely to describe

Table 5. Differential beliefs about students' approaches to whole-class discussions by frequent and infrequent talkers in relation to others' learning.

Frequent talkers	Infrequent talkers
'I guess personally if I have a question, I'd rather ask it in class and see because I feel like other people probably have the same questions so to ask in class is easier for everyone else too.' 'You don't feel like you're interrupting as much because it is for everyone.' –Chem. II Female #07 'If I've read it somewhere and it's generally accepted to be certain, then I feel like I'm not just going to let people be confused about it.' –Chem. II Male #13 'If you're understanding, you're going to try to help others and learn more yourself.' –C. P. Chem. Male #22 By talking 'we could have other people know how to help them [students who don't understand] out'. – General Chem. #08	'I wasn't asking questions to clarify because … I understand how to do the problems. I feel like if I were to answer all the questions, I'd be taking away from students as they try to learn' 'It's not really my place to tell other people how to do this, because I'm not the teacher.' –General Chem. Male #17 'I don't want to stop the class or I don't want to interrupt a class or stop everybody else from learning.' –C. P. Chem. Male #19 'I don't want to interrupt anyone.' –General Chem. Female #01

the classes as being closed to alternative perspectives and therefore focused on the demonstration of canonical knowledge. The male C. P. student who did not want to interrupt the class (see Table 5) described discussion as 'not really a class discussion … It's like one student or two students just answering questions'. Similar descriptions came from the interviews with two Chemistry II students who infrequently contributed to discussions. One student described his class' discussion as being 'mainly one student and the teacher talking amongst each other … It was like a lecture from someone other than the teacher'. Describing a different lesson, a female Chemistry II student said, 'it's basically just the teacher talking through someone else'. In these cases, the students socially framed the discussion as relatively closed to participation for those students who were not interested in an interactive lecture. By viewing the lessons in this way, infrequent talkers were more likely to perceive the discussion as a means by which students could acquire and demonstrate knowledge of the subject rather than a place to introduce new ideas or ask questions. Since these students were less likely to suggest that their contributions would help others learn as well, this may explain why they considered participating in the discussion as more of an intrusion than an asset to the discussion.

Social comfort

Students' responses to the interviews suggested that the extent to which students feel comfortable interacting with others in the class also plays a role in their approach to participating. Comfort was mentioned not only in terms of familiarity with the students in the class, but also in terms of how students described their own personalities (see Table 6).

As a community of learners, whole-class discussions take place among individuals with different personal characteristics and historical stories with relation to their peers. In Table 6, the General chemistry student, who said that she did not care what others in the class thought of her, was a 12th grader in a class with mostly 10th graders. She believed that a student's readiness to contribute to whole-class discussions was partly a function of a student's 'level of maturity'. Because she was two years older, she did not 'really care because they're all younger than me so I'll do whatever I want'. Her social comfort with the younger students in the class impacted her participation in class discussions.

Table 6. Comfort with contributing to whole-class discussions.

Frequent talkers	Infrequent talkers
'I don't really care what others think.' –General Chem. Female #03 'I'm not really self-conscious.' –Chem. II Male #17 'In this class, I know everyone, so I'm comfortable asking a question.' –General Chem. Male #18 'I barely talk in certain classes, but in my chem. class, we have a good group of kids and I know most of them.' –C. P. Chem. Female #03	'It's just more of a shy thing.' – General Chem. Female #02 'I learn better by listening … I'm kind of shy.' –General Chem. Female #06 'I contributed more in Chem. I, I feel because I better knew the people … When I don't know the people as well in the class, I have a harder time contributing.' –Chem. II, Female #03

Students who frequently talked in class tended to feel less self-conscious about their participation. Although some students referred to their nature or personality as a reason for their willingness to participate, it is noteworthy that some students acknowledged that their approach to talk in class was related to their familiarity with the other students in the class. While a frequent talker referenced in Table 6, a female from C. P. Chemistry, stated that 'I barely talk in certain classes', the infrequent talker in honours Chemistry II acknowledged that she contributed more in a previous chemistry class because 'when I don't know the people as well in the class, I have a harder time contributing'. Both commented that when they are familiar with the students in the class, they are more likely to participate. Given that many students in this study felt a great need to contribute only correct answers because of how they might be perceived by their peers, familiarity with the other students in the class and a sense of community may be important for certain students to feel safe contributing to discussions.

Discussion

Students who participated in this case study believed elements of both dialogic and authoritative approaches were highly important during instruction. Secondary science students have had many years of experience with authoritative approaches to discussions (Baird, Gunstone, Penna, Fensham, & White, 1990; Lemke, 1990) and seem to expect it (Bleicher, Tobin, & McRobbie, 2003). The results of the surveys and interviews suggest, however, that although students want to be able to contribute their ideas about science content, in the end they also want the teacher to guide them to a canonical understanding of science, also known as the science story (Mortimer & Scott, 2003).

Aguiar, Mortimer, and Scott (2010) refer to the importance of considering the students' views and intentions towards participating in science discussions, but their work is the result of observing students' questioning during classes, rather than surveying their beliefs about various elements of talk. By far, students ranked dialogic elements and the teacher's role in setting forth the science story as the most important elements of whole-class discussions. Science students in this study wanted the teacher to guide them towards the scientific way of thinking. Similar alignment between science teachers' tendency towards authoritative discussion and their students' expectations for talk during whole-class discussions has been documented in other studies (Bleicher et al., 2003; McRobbie & Tobin, 1995). Students at the secondary level seek out the guidance of teachers in establishing the scientific point of view, but in the case of the present study, they also wanted the opportunity to engage in the discussion by voicing their understandings and perspectives. This is in line with Aguiar et al. (2010) when they present the dialogic and authoritative dimension of science discussions as being 'complementary forces' (p. 190). Other studies have suggested that dialogic interactions by themselves are not perceived to be valuable school work by students as well as teachers (Anderson, 2000; Russell & Martin, 2007). In the end, at the secondary level, there is an expectation that specific, well-accepted scientific concepts will be clearly established in lessons, not only represented in the objectives that teachers are asked to write for each lesson, but also by the approach to discussions taken by the students. Because of this epistemological framing on the part of both the teachers and students focused on learning the facts of science, shifting away from authoritative discussions is difficult (McRobbie & Tobin, 1995). The persistence of traditional, teacher-centered talk in spite of reform movements is evidence of this. While science education research has continually focused on the teacher's role in shifting discourse, student expectations for whole-class discussions play at least an equal role in maintaining the authoritative focus that is observed during science instruction. In this way, students can take on the roles as 'keepers of the status quo' (Aikenhead, 2000, p. 260).

Students participate less productively in whole-class discussions that are authoritative and focused only on providing correct answers to fact-based questions (Alpert, 1987; Furtak & Ruiz-Primo, 2008; Hutchinson & Hammer, 2010). In both surveys and interviews, many students in this study stated that they were most likely to contribute to discussions when they were certain they could provide the right answer, but this was not true of all students. The manner in which students in this study framed participation in whole-class discussions, both epistemologically and socially, was related to their goals for talking and the level of their science class.

Hutchinson and Hammer (2010) described two epistemological frames that students can take when participating in whole-class discussions: 'the classroom game' and 'making sense of phenomena' (p. 510). In the classroom game, students follow rules that minimise the effort that needs to be expended by focusing on the satisfactory completion of tasks instead of their mastery (Larson, 1995). Students in this study who actively participated in class discussions by asking questions and providing extensions associated with the topic believed that asking questions and participating helped them and others to better understand the scientific concepts. Instead of viewing class discussions as a game where they are demonstrating their knowledge, they were more likely to frame the discussion as place for meaning making. Furthermore, students who participated more productively in discussions had a different perspective on their role in relation to others. They believed that their questions and comments would benefit everyone in the class and that it was their role to help other students in the class learn. Those students who contributed least to discussions were more likely to view their participation in class discussions as interruptions that would get in the way of other students' learning. This difference in students' social framing may play a significant role in the dynamics of whole-class discussions regardless of the strategies that the teacher is using, especially at the secondary level. Shifting class discussion will require that explicit attention is given to shifting students framing of their role.

Social dynamics are constantly at play within high school science classrooms. These dynamics occur on several dimensions, described by Aikenhead (1996) as subcultures. A students' peer subculture and family subculture may be at odds with the school science culture. The lack of alignment among cultures will then influence how students decide to participate in discussions. Students are negotiating their identity and are not necessarily 'free to be whomever they want to be in science' (Shanahan & Nieswandt, 2011, p. 367). In this study, students' willingness to participate more actively in discussions was related to how comfortable they felt either because of personal attributes making them less self-conscious or because they were familiar and felt safe with the members of the class. Shifting class discussions, therefore, requires that teachers address the classroom culture and its interaction with the personal subcultures that students identify with. This will require deliberate and explicit shifts in the epistemological framing of discussions towards being more productive and focusing more on making sense of phenomena as opposed to knowing the right answer (Hutchinson & Hammer, 2010). This would allow students to participate in a way that values thinking and reasoning more than simply facts, thereby making them more apt to take on a scientific identity. One challenge, however, may be how to get students who have been so accustomed to framing science discussions in an authoritative way to buy into a more dialogic, meaning-focused way of talking.

The tracking of students into different groups establishes an additional dynamic that can influence discussions. Differences in students' framing of whole-class discussions, especially as it relates to the students' role, were observed at more than just the individual level. Those students who were tracked into the lowest level course described their role in a more passive and socially isolating way than students in the other levels. While the majority of students in the general class identified themselves as White, placing them in the majority with respect to race, these students were less likely to have a parent with a post-secondary degree. With fewer opportunities to engage in scientific or academic discourse at home (Lee & Luykx, 2007), these students may feel unqualified to participate productively in class discussions. Other researchers have suggested that because of the sociocultural nature of science discourse, participation in discussions by students of non-mainstream backgrounds may include issues of identity appropriation or enculturation (Brown, Reveles, & Kelly, 2005). Aikenhead (1996) explains that when the family and peer subcultures are different or even at odds with the school science subculture, it can be difficult to fully engage students in science lessons. It is not possible from this study to say whether the framing that general-level students took towards whole-class discussions was a result of experiences at home, their previous experiences in science classes, their approach to identity or a combination of all these factors. The stark differences in approaches to talk related to track however is worth further research. It would seem that engaging students of less privileged backgrounds will require more than simply a change in teacher strategies, but also intentional supports that help students to shift their sense of agency in the science classroom and 'help students negotiate their border crossings and cultural conflicts' (Aikenhead, 2001, p. 181). The perceived benefits of isolating students into tracks may be partly due to the reticence of schools to address this cultural aspect of science teaching such that those students whose subcultures align are placed in advanced classes, and those whose subcultures do not align or even conflict are relegated to lower-level tracks.

One of the limitations of this study is that the limited number of students who participated represented a predominantly White student demographic in a suburban area. While there are findings that suggest that students' socioeconomic status may play a role in their approach to talk, these findings are not intended to explain differences in talk that may exist in urban schools where the population of students is more diverse.

Conclusions

Secondary science student's perspectives relating to whole-class discussions are multifaceted and important to consider in efforts to shift the type of talk that occurs in science classrooms. This study found that students' beliefs about science as a body of facts to be learned influenced their approach to whole-class discussion. Furthermore, students from the lower-level track who typically were associated with lower socioeconomic status were more likely to view their role as passive. Lastly, students' comfort level and familiarity with the members of the class seemed to influence their decisions to participate in class discussions.

In attempting to change the dynamics of discussions, it is important that teachers explicitly communicate their expectations to students (Berland & Hammer, 2012) and model the new expectations (Bandura, 1986). Given that students have been taught to frame science discussions authoritatively, teachers will need to be persistent throughout the year in order for students to better understand their role in the different frames that may be used by the teacher during instruction. This may include designing lessons that specifically engage students in more dialogic types of talk as well as incorporating more open questions during whole-class discussions.

Attention must also be given to culture and its role in the dynamics of talk during whole-class discussions. While other researchers have discussed the role of personal identity and diverse cultural backgrounds in mediating student participation in science (Brown et al., 2005; Emdin, 2011), this study suggests that classroom culture and sense of community may also be important in allowing students to feel free to express themselves with their peers. Further research investigating how teachers establish classroom cultures that are more conducive for dialogic talk will broaden our current understanding of how discussions in high school science classes can change.

Disclosure statement

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