STEM School Discourse Patterns

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Specialized STEM high schools, which report higher than average numbers of graduates pursuing STEM careers (Subotnik, Tai, Rickoff & Almarode, 2010), are among the beneficiaries of resources allocated to increase the capacity of the United States to prepare a qualified scientific workforce equal to predicted demand (Augustine, 2005; Carnevale, Smith, & Strohl, 2010). Prior research indicates a wide range of potential reasons for these outcomes, including selective student admissions processes (Peters-Burton, Lynch, Behrend, & Means, 2014). However, despite billions of dollars of government funding for these specialized schools (United States Government Accountability Office [GAO], 2005), research examining STEM school practices, differentiating features, and their effectiveness is scant. Despite promising preliminary findings regarding the learning outcomes and interest in pursuing STEM careers associated with specialized STEM schools (e.g., Subotnik et al., 2010), the extent to which these forms of attainment are generalizable or attributable to mechanisms other than selective admissions processes is unclear (GAO, 2005; Tofel-Grehl & Callahan, 2014).

Prior research has not documented the instructional practice, culture, or discourse in STEM schools (but see Tofel-Grehl & Callahan, 2014 for an initial investigation of STEM school culture). Therefore, it is unclear what, if any, guidance could be provided to policymakers and practitioners about the essential, valuable, or unique aspects of educational culture and classroom practice in STEM schools. As instruction and classroom dynamics are critical variables in student outcomes (e.g., Erduran & Rudolph, 2007; Ritchie & Tobin, 2001; Sandoval, 2005), one promising path to understanding the uniqueness within and across STEM schools lies in the study of classroom discourse. Specific pedagogical practices might differentiate the instruction in these specialized schools from one another and from non-specialized American schools. For example, teachers' use of effective questions in classroom discussion is associated with higher levels of student achievement (Schoen, Cebulla, Finn, & Fi, 2003). The current study examines classroom interactions between and among teachers and students from a diverse sample of STEM schools through the lens of discourse analysis.

Tofel-Grehl & Callahan (2014) observed that the cultures in specialized STEM schools manifest through the empowerment of students to engage collegially with each other and with teachers in pursuit of enhanced understanding. This included a shared sense of purpose and priority, as well as a right on the part of students to steer classroom discussion and activity. Students' empowered role in the classroom may have value as both a motivator and a means of enhancing learning. Active student participation in classroom discussions that are focused on deepening understanding of scientific concepts is important to the development of scientific reasoning and argumentation, as these skills require "the opportunity to consider plural theoretical accounts and the opportunity to construct and evaluate arguments relating ideas and their evidence" (Duschl & Osborne, 2002, p. 52). However, the trend in STEM schools' classrooms to foster a shared sense of purpose and highly engaged discourse differs from the observed discursive norms of many American high schools (Lemke, 1990; Scott, Mortimer, & Aguiar, 2006). Thus, it may serve as a key differentiating feature of these schools from their non-specialized counterparts.

Discourse in Science Instruction

Patterns of classroom participation typically fall into one of two major discursive structures for describing classroom engagement—the authoritative and the dialogic. To refer to discourse as authoritative implies a relational power structure in which one participant retains absolute power or authority over the exchange. This power is based both on position within the social structure as well as the knowledge differences between participants. The authority gives knowledge, information, or confirmation of 'correctness' in addition to access to participate. Within an authoritative classroom setting, the teacher predominately possesses this role of authority. The centrality of the teacher and the authority of the teacher drive classroom discussion while furthering a singular theory or idea (Scott et al., 2006).

Dialogic engagement, on the other hand, provides opportunities to explore differing perspectives, theories, and opinions. Dialogic participants also engage in the process of developing their own solutions or explanations. Within this structured dynamic, participants engage in discourse on equal footing, with no single figure holding authority over others. Within a classroom setting, dialogic engagement involves both teachers and students engaging in the asking and answering of questions (Scott et al., 2006). Additionally students engage in the development and examination of solutions with their fellow students. In learning environments that foster dialogic engagement, the teacher often acts as a moderator and facilitator, rather than a knowledge giver (Driver et al., 2000). In this environment, the types of questions framed by teachers and, in turn, by their students drive classroom discourse and are essential tools for both assessing the emerging understandings of students and fostering the attainment of students' learning goals (Cazden, 2001; Chin, 2007; Simon, Erduran, & Osborne, 2006). However, consistent with the low prevalence of dialogic classroom discourse (Lemke, 1990; Scott et al., 2006), Banilower, Smith, Weiss, and Pasley (2006) found in a national sample of classrooms that only 14% of all lessons entailed rigorous intellectual discussion, and they identified teacher use of questions as one of the weakest aspects of instruction.

Research Questions

Analysis of discursive practices in science classrooms within STEM schools may provide meaningful information about the nature of these classrooms and, potentially, their uniqueness. Full descriptions of current practice can serve as a foundation for exploring the differences in instructional norms within STEM specialized schools and across science classrooms in general.

In the current study, we address the following research questions:

1. What forms of discourse are prevalent in science classrooms in specialized STEM schools?
2. How do teachers drive classroom discourse through the types of questions they ask?
3. How did students' perceptions of their own agency differ based on discursive classroom structures?

Methods

Using a grounded theory approach, we investigated the discourse patterns present in a sample of science classes in specialized STEM high schools. Data across 6 specialized STEM schools, representing a diverse cross-section of school administrative structures and geographic locations within the continental United States, provide the opportunity to analyze these discursive practices. Classroom interactions between teachers and students were examined through an iterative review of observational and interview transcript data and constant comparison of emergent themes across episodes.

Participants

Sampling. Six schools were selected from the nation's more than 350 self-identified STEM schools. Schools were selected for inclusion in the project based on diversity of school model type (fulltime non-residential, fulltime residential, part-time pull-out, university affiliated), geographic region (Northeast, Southeast, Midwest, South, Southwest, Northwest), enrollment size (<300, 300-599, 600-899, 900+), and admissions criteria (selective or open-admission). For a more detailed description of the school site selection process and descriptions of individual sites, see Tofel-Grehl & Callahan, (2014). Schools included in this research ranged from 2-4 year high schools.

A total of 86 discrete classes across STEM disciplines were observed in the 6 participating schools. Approximately 36 total science classes were observed; 6 science classes were selected for detailed discourse analysis. These 6 classes were selected to maximize the variety of schools included, the variety in courses offered, the number of teachers included, and the level of quality of the audio recorded during the observation period. Seeking consistency across sites, whenever possible, researchers observed biology, chemistry, and physics classes at each school. Additional high-level science electives were observed as time allowed. Audio recordings of class sessions were transcribed in order to isolate questioning techniques and discursive dynamics within science classrooms. Seven classes were excluded based on audio quality. The remaining 29 classes represented the final corpus from which one science class was selected randomly from each school (see table 1).

Classes ranged in time from 45 minute s to 90 minutes in length. Approximately 420 minutes of classes created the corpus of data for this analysis. While more than one class

Procedure

At each participating site, focus groups were conducted with separate groups of teachers and students. Administrators were not present during focus groups, but were interviewed separately. Interviews and focus groups were conducted using semi-structured project protocols. All STEM area teachers were invited to participate in focus groups; students were selected for participation by teachers and administrators.

The research team observed as many STEM classes as possible over the course of two-day site visits. Initially, both observers made observations within the same classrooms. Consistency of observations was ensured by comparing and discussing field notes until the observation notes of both team members were in concert. Whenever possible, members of the research team observed classes in all STEM disciplines and collected relevant documents provided by the participating teachers and administrators.

The primary focus of observations was teachers' instructional practices. Research team members checked their observations and interpretations with participants whenever possible. Member checking with student participants was less frequent due to the challenges of scheduling and accessing students multiple times during a visit, but teachers provided consistent feedback regarding observed phenomenon.

Analysis

Consistent with a grounded theory approach, emergent discursive themes were identified from the data (Lincoln & Guba, 1985). Audio recordings of classes, field notes, focus group transcripts, and review of program documents, such as lesson plans, were used as data sources. Analysis of classroom discourse provided insights into the dynamics and structures within specialized STEM school science classrooms.

To address the first research question, classroom discourse was analyzed holistically within the conceptual framework of authoritative versus dialogic discourse patterns. The second research question then focused analysis on the techniques employed by the teachers to influence classroom discourse in the service of their instructional goals. Questioning techniques emerged as a primary discursive tool that differentiated the classrooms observed and served as a meaningful tool through which teachers guided and informed their students. Thus, the coding of the discourse focused on the questions asked by classroom participants (both teachers and students) and the responses to those questions. Analysis addressing the third research question utilized data collected from the five student focus groups to explore how students' perceived their own agency within their science classes compared to other STEM area courses.

Coding of authoritative vs. dialogic discourse. Initial coding of the classroom discourse was done on a macro level. Interactions between teachers and students were coded into one of two categories—authoritative or dialogic. Questions asked by teachers were examined in conjunction with the responses they generated to determine the quality of the interaction along a spectrum from highly authoritative to highly dialogic. Authoritative discourse was defined as discursive engagements primarily driven by the teacher in which students' goals are focused on answering direct teacher questions with little evident regard for a larger understanding. For example, in the authoritative exchange shown in Figure 1 from a science class that was coded as highly authoritative, each question asked by the teacher has a specific answer; answers given by the students are evaluated for correctness by the teacher, and at times the teacher answers her own questions. With each back-and-forth exchange between the teacher and the student, the student does not gain independence to offer ideas or his own questions.

In contrast, interactions coded as dialogic show more collaboration and interaction between teacher and student on an intellectual level. The teacher often guides student thinking during these exchanges with probing questions, but does not offer final validity to a student's opinion. Figure 1 includes an example from a physics class that illustrates that contrast.

While the questions asked in the dialogic example serve the larger curricular goals of the teacher, they do not have a concrete "right" answer. There is also more back-and-forth between the teacher and student in the discussion of reasoning with the teacher not presenting himself as the final authority on the validity of the student's answer.

Coding of questions. Questions in the discourse distilled into four specific categories. The first, opening questions, are those designed to open up a line of discussion within a classroom. These questions may or may not have predetermined correct answers; rather they serve the purpose of initiating student conversation and thinking on a topic, introduced new content topics, and tended to promote high levels of student response in terms both the amount of time students spent on response and the

Class Title	Teacher Education	Elective/ Required
Physics	Masters	Required
Honors Physics	PHD	Required
Chemistry	Masters	Required
Optics	PHD	Elective
Environmental Biology and Chemistry	PHD	Elective
Microbiology, Immunology, and Disease	PHD	Elective

Table 1. Discourse Class Descriptors

Authoritative Discourse Example	Dialogic Discourse Example
Teacher: OK, what is our independent variable here? Independent variable. The independent variable? Julian **Julian**: The independent variable? Glucose. **Teacher**: Glucose. OK, so this is our independent variable. OK and our dependent variable is going to be? Monty. **Monty**: I dunno…. Water? **Teacher**: The dependent variable is going to be the amount of water defused. OK how are we going to measure that? OK, because it is data, we need a number. How will we measure that, Tammy? **Tammy:** Umm, in milliliters? **Teacher**: OK, so is that right, initial map of a potato core minus final map, OK and then we can divide by initial times 100%,OK and I'm going to tell you right now, do not take the absolute value. Don't ignore negatives. What is really important when you do that? You need to blot all of the excess liquid off of the potato core with a paper towel? Why is that important? Um, Jack? **Jack:** The excess water on the potatoes will actually change weights, but if we blot them out we get more precise reading on the scope. Teacher: Good. Correct.	**Teacher:** Abby, where shall we put this one kilo mass to make it balance? **Abby:** I said eight inches **Teacher:** And can you explain your logic that you went through to arrive at that? **Abby:** Well I think that it was twice as much weight so it would be half as much distance. **Teacher:** That sounds pretty simple and straightforward. Do you want to come up here and try (on the model)? If I let go of this are you guys confident we will be ok? **Abby:** No. **Teacher:** No? Why not? **Abby:** I am stalling for time to work it out. I was confident when I said it and put it as my answer but looking at it, it doesn't look right. **Teacher:** Show of hands of how many people think it will balance.

Figure 1.

nature of the follow up questions asked. Examples of each category of questioning are found in Figure 1.opening questions include "If I hang this mass at the same distance as that mass, will it work?" and "What is smog?"

Follow-up questions built upon prior student responses or questions and sought to either scaffold a discussion based on student input or facilitate more accurate or detailed responses from students. These questions built upon responses as a matter of sequencing content or sought more information to clarify an answer. Questions coded as follow-up did not include those seeking analysis or justification of reasoning. Examples of follow-up questions include: "So, if you don't think it will balance, where shall we put this one kilo mass to make it balance?" and "When smog occurs, what are some of the causes?"

Analysis and justification questions provided students with an opportunity to justify and more deeply explain the reasoning behind an answer. They also provided teachers entre into back-and-forth dialogue with students and resulted in more inclusive class discussions based on the number of students engaging in the discussion. Student discourse surrounding these questions was peppered with logical connectors such as "because" and "if." Examples of analysis and justification questions include "How did you come up with that answer?" and "What do you think would happen if smog ended up located over a basin such as in Los Angeles or Denver?"

Teacher: Think back 1000 years what happened?
Students all call out: Dinosaurs, Jesus, Ming Dynasty?
Teacher: What was the one big thing?
Emily: The Norman Invasion?
Teacher: Now fast-forward 1000 years. What would you say is the big thing that happened between 1900-2000?"
Jessie: Space?
Matt: World War I?
Evan: World War II?
Jose: The Cold War?
Teacher: All of those are good. But this guy made point that 1000 years from now they will make the point we went to the moon. That is the thing we will be remembered for. When did we first fly? In the 20th century, right? So we first flew this century and we got up in air and then to moon. And that is what we are going to talk about—the Apollo 13 mission. When did we land on the moon?
Evan: 1969
Teacher: The whole point was to get out into space and orbit the earth. Has anyone seen the movie 'The Right Stuff'? When were the first people in space?
Emily: 1959
Teacher: And who was first?
Emily: Urie

Figure 2.

Applied reasoning questions encouraged students to consider alternate possibilities based on different scenarios or to apply prior knowledge in novel ways. Often, as illustrated in Figure 2, these questions forced students to consider hypothetical questions based on specific scenarios. such as: "What might happen if I move the mass on the balance six inches further from the middle?", "How does your answer change if we are on the moon?" and "What impacts would warmer weather patterns have on the movement of smog across that basin?" Applied reasoning questions offer opportunities for teachers and multiple students to engage communally around a question. These questions are highly dialogic, providing multiple opportunities for many individuals to engage around a topic.

Focus group analysis. Student focus group questions regarding students' perceptions of their classroom interactions were used to verify the accuracy of researcher observations. Students were asked general questions regarding their perceptions of their own agency and ownership within classes and more specific follow-up questions regarding what they thought made some classes more effective than others for them. Focus group transcripts were scoured for disconfirming evidence as well; no instances were found where students articulated lack of agency as personally preferred.

Documents collected were examined to determine if questioning techniques or types were written into lesson plans as an instructional practice. No evidence was found of this type of intentionality.

Findings and Discussion

Consistent patterns emerged across STEM school sites within each of the major areas of analysis: (1) authoritative vs. dialogic discourse, (2) teachers' use of questions to drive the discourse, and (3) students' strong sense of agency within classroom settings. First, findings are presented regarding the broad trends observed in authoritative and dialogic discourse across schools and classes. Second, the commonalities in teachers' use of questions as mechanisms for driving that discourse are described. Third, convergent themes from student focus groups supporting students' high levels of perceived agency related to learning are reported.

Trends in Authoritative and Dialogic Classroom Discourse Structure

Common classroom discourse patterns were observed across sites and disciplines. With few exceptions, teachers acted as classroom leaders who drove the content of discussion. While classes differed in the levels of authoritative or dialogic interaction, teachers universally were the authority and controlled the classrooms. Even during classes led by student presentations, the teacher proved the driving force behind questioning and discussion. Additionally, an implicit acceptance of the teacher as the higher authority on content was common to a substantial majority of observed classes. Almost without exception, teachers' answers to student questions were accepted without question.

In classes coded as more authoritative in their discursive structure, three common features were observed. Not surprisingly, the more authoritative the classroom discourse, the more rigidly the teacher adhered to a traditional lecture format. The instructor introduced content and sought little input from students. Teachers evaluated student understanding through rigid, closed-answer questioning using the common Question-Answer-Evaluate linguistic pattern (Lemke, 1990). The majority of questions were asked by teachers, answered by students, and then evaluated for "correctness" by teachers.

This pattern was observed to some degree in all classes, regardless of how dialogic or authoritative the discourse was. However, as classroom discourse and questioning moved more towards the dialogic, reliance on these patterns decreased. Instead, observed discussion patterns showed students were expected to provide more justification for their own answers rather than receiving an evaluation of their answer from the teacher.

Within more authoritative classrooms, teachers were observed to spend less time answering student questions. When asked, teachers offered cursory answers at best, and, many times within these classrooms, students' questions were observed to go unanswered. When queried about this, focus group teachers stated an expectation that students would learn on their own and answer their own questions. As one teacher stated in response to a question about teaching in a highly authoritative way "I don't have time for all their questions. They can learn that on their own time."

A third feature common to more authoritatively discursive classroom was the frequency with which students spoke. In authoritative classrooms, students spoke far less often and for far less time than students in more dialogic environments. Rather than participating in the talk of the classroom, students were observed taking copious notes in most cases. The discourse of the classroom was teacher dominated and the student role appeared to be noting what the teacher said for later review. Several students within these more authoritative environments were also observed with voice recorders making audio recordings of classroom lectures.

In classes observed to be more dialogic, two common features became clear. First, no single common class format was observed. While lecture was seen in more dialogic classes, alternate formats of class were also observed. Specifically, dialogic classrooms presented more time for students to work in small groups before reconvening the class to begin a lecture. Dialogic classes often opened with activities such as a "pair and share" in which the teacher might pose a question for common discussion and then allow students time to discuss within small groups or pairs before engaging in a large class wide discussion. While content was still predominantly introduced by teachers, students possessed greater autonomy in opening class sessions with issues of interest or confusion to them. A second common feature of classrooms analyzed to be more dialogic in nature was the apparent value placed on student opinions and ideas. Students within these classrooms were often observed to be more willing to engage in back-and-forth exchanges with teachers and offered their own opinions and reasoning to discussion.

Students within these classes readily contributed and appeared at ease doing so. They often responded to teacher questions with questions of their own. Similarly, their teachers often probed student responses with requests for evidence of reasoning. Students were expected to provide their own justification or perspective for an answer. Additionally, several teachers within more dialogic classrooms openly voiced the positive value they placed on student responses and input. One teacher stated, "We cannot have a discussion without you all" when his class seemed to be offering less complete answers than he sought.

Trends in Teachers' Use of Question Types to Drive Discourse

In general, across classrooms and disciplines, teachers used different types of questions to achieve different goals within their classes. Opening questions were observed to serve a dual purpose in starting classes. Teachers used opening questions to focus student attention on the content of the day as well as to ascertain student understanding at the onset of a lesson. Follow up questions were observed to extend discussions and draw out more elaborated answers from students along a specific content line. Teachers often used these questions to determine student understanding and seek additional information. Using combinations of opening and follow up questions, teachers were able to retain strong control over the discourse of their classes. The nature of the questions led students down more closed and rigid discussion paths. An example of such a moment of questioning was observed within a physics class (see figure 2).

In this way the teacher used his questions to both key students into the coming topic in its historic context as well as explore their prior knowledge regarding the topic.

Follow up questions often were used for the purpose of aiding students in walking through the proper procedures for solving a problem or completing a lab. Additionally, teachers used follow up questions to further answer or provide additional information needed to elucidate content. For example in a calculus class with the instructional aim of introducing tangents the following exchange was observed (see Figure 3).

Teacher: Do you remember the formula for finding the slope of a line?
Student: No.
Teacher: Y sub2 minus Ysub1 over x sub 2 minus x sub1. If I asked you to do that you could do that right?
Student: Yes
Teacher: Quickly give me the slope of y=2/3x -4
Student: 2/3
Teacher: From there we are moving into difference quotients. What does difference mathematically mean? What operation?
Student: Subtract.
Teacher: And quotient means?
Student: Divide.
Teacher: Correct. So this quotient (pointing at board) is the quotient of the differences.

Figure 3.

The use of questions for explicating procedural processes was particularly characteristic of laboratory settings. In labs, science teachers asked more follow-up questions to check student understanding about using specific pieces of equipment. Often teachers would ask questions like "are there any questions on how to do this?" or "do we read fluid levels from the top or the bottom of the meniscus?" as way to ensure that all students followed the same procedural approaches.

Analytic and justification questions were used by the teachers predominately to provide students with an opportunity to explain their answers and thinking as well as precursors to applied reasoning questions. The fewer questions a teacher asked seeking analysis from students, the fewer instances of abstract thinking by students were observed. When teachers asked questions seeking analysis, justification, or applied reasoning from students, students were observed to spend more time talking within a given class period. Additionally, these types of questions tended to precede group discussions or teachers' opting to have students "pair and share" ideas in smaller settings.

On some occasions, teachers were observed using applied reasoning questions more toward the end of class sessions as a mechanism for foreshadowing upcoming lessons or content. For example, a teacher asked students as a group to discuss potential variables that contribute to acid rain when considering climate, weather patterns, and geography by asking "If we moved this cloud cluster over Denver, with it's mountains and bowl geography, what might happen to the acid rain patterns?" The teacher noted "this will help us in our discussion tomorrow."

Often, reasoning and justification questions led to students asking more questions of each other. When students responded to these questions they were more likely to receive a question from a peer than they were when they responded to the more closed opening or follow up questions. The exchange in Figure 4 illustrates this.

Trends in Discursive Differences Associated with Classroom Characteristics

The STEM school science classes in this sample were predominately characterized by a dialogic approach to discourse. Across class formats ranging from lectures to laboratories, the teachers frequently provided students with opportunities to talk in groups, ask their own questions, and share ideas in pairs and as a whole class. At one

Teacher: So, if smog causes acid rain, what does the acid rain cause to happen?
Student: You mean other than it kills things?
Teacher: Yes. Think about it for a second. What does the acid rain affect?
Carol: Life.
Teacher: Ok, so it affects life. Well how do we decide to deal with the problem?
Eddie: When it affects people?
Josh: Not really.
Teacher: What do you mean, Josh, no?
Josh: It doesn't matter when it affects people. We only deal with problems when politician gets involved and they only care about rich people.
Ashley: That's not true. If it affects lots of people then that can cause people to deal with a problem. But there's lot of other reasons acid rain might not get dealt with. People don't always know about it. You can't just say it's because of money.
Josh: Look at California. There is tons of money there and so everyone dealt with the environmental problems like smog. But now the same thing is happening in New Mexico and no one is passing laws about it.
Teacher: That's an issue of correlation not causation, Josh.

Figure 4.

school, student experts who presented their knowledge on microbiology and immunology led the class. While the frequency of questions posited was lower in this circumstance, the opportunities to ask questions and the types of questions asked remained consistently dialogic. Even in this case, the teacher used her talk time to further engage students in discussing the content and to assist them in acquiring information they needed to answer their own questions. In each instance the teacher sought to engage students in asking questions. She pushed them to identify their concerns or confusion and to ask their own questions (see Figure 5).

In addition observed patterns of discourse included a significant focus on students' reasoning and a demand that students provide evidence of their reasoning. Figure 6 provides one example, recorded during a physics class while the class was reviewing homework.

Students were constantly expected to be active participants in the discussions and lectures that they attended. Passive or instructionally insignificant answers were rarely accepted from students. For example one teacher teaching an environmental sciences class stated "I can't think for you. You are here to think and figure things out. Without you all this class won't work. I need your brains, not just your bodies." This statement reflects the teacher's belief that student ideas drive the class.

Trends in Student Agency Associated with Discursive Structure

Within highly dialogic science classes, students were observed introducing topics of personal interest related to the area of the class. For example, one highly dialogic class focused on immunology closed with a female student asking about current guidelines for immunizing females for HPV; the teacher and students spent several minutes discussing the ethics of the gender-based immunization laws within their state. Female students were vocal and engaged in articulating their personal beliefs surrounding these laws. While not addressing the learning standards of the course, this conversation demonstrated the flexible application of the classroom's dialogic structure. By providing more open opportunities for students to enter classroom discussions without the fear of assessment, the teacher created an engaging environment where students demonstrate active ownership over their learning.

Students also discussed their own sense of agency in the focus groups. Consistently students reported that they felt heard more in some classes. For example when asked what worked best for them in their classes one student replied "I like classroom discussion…. another thing that teachers like to do is that they like to talk to you in class and outside of class, but mainly in class when your whole class is there,

Teacher: Ask the presenters to slow down and restate the long technical terms. You have got to tell them to slow down if that's what you need.
Student: Do lipopolysaccharides have the same things as the others?
Student Presenter: Yes because they are the same type of toxic molecules.
Teacher: Did we ever explain that acronym? Did we use that term? Maybe we should write it?
Teacher: Why do you think phenyl glycine is an example of it?
Student: Because it's only found on prokaryotes?
Teacher: Good, it's only found on the walls of prokaryotes and serves as a flag that says I am foreign? Was that was the panic was about? More questions?

Figure 5.

Teacher: Here is moon and here it is rotating on its axis, and it takes it 27.3 days per rotation and they want to know the period. And in physics, the period equals the number of seconds, right?
Student: Would you just convert the days into seconds?
Teacher: What do you think? I need a brave volunteer to come up and do it. I need someone who does not know how to do it. Josh? So, come take problem as far as you can. Once you get stuck, you have a room full of people who will help you.
Josh: Ok (works on board).
Teacher: Can you explain what is going through your head as you're doing that?
Josh: I need help first.
Teacher: Ok, that's ok. So they are asking about period. What does period mean?
Josh: I don't think I know it.
Teacher: It's ok to phone a friend.
Student 2: The time it takes to rotate.
Teacher: So do you guys agree with that? So the time it takes to rotate, right? So that 27.3 days is the answer except they want it in seconds so you need to…
Student 3: So they just want us to convert it?
Teacher: You guys do it. Dazzle us with your conversion skills. Make sure you use the school's method.
Student: Ok.
Teacher: You guys ok with what he is doing so far? He is converting it to hours using the school method. Have we got everything in the right place? How do you know you did it right? That is part of the school method right there, going in and canceling out units. That is an essential part of the method. So now we have it at hours. Make sure you cross out the units to make sure you've got them in the right place. Someone with a calculator help us out?
Student 5: 2.4×10^6
Teacher: So 2.3 million. And does that do it for you? So does it match what we did here? It does. So we are right.

Figure 6.

they talk to you. They put an idea out there and step back and then everybody talks…. They like say something back to you and so a lot of teachers, we can debate certain things with them." Students reported believing that teachers not only welcomed student opinions, but welcomed them and contrasted that with their prior experiences in non-specialized schools. Teachers also noted the importance of discussion opportunities to gauge student engagement; representative of the thoughts of many teachers across schools, one teacher remarked "The best conversation that I had with a student was about application. If we are in the real world and that was used. They always ask that and when you can engage a student in that kind of discussion, then they light up about what possibilities are set for this kind of conversation." Both students and teachers commented on a greater ability to engage in classes where the conversations allowed for student input and ownership.

Limitations

Given the qualitative nature of this research, drawing causal conclusions is neither appropriate nor warranted. Furthermore, because of the unique population of STEM schools, generalizations to the larger public is also inappropriate. This work serves as an exploration of the ways in which the questioning techniques and discourse patterns observed in STEM schools manifest themselves in relation to student agency within those classrooms.

Conclusions and Future Directions

STEM schools articulate a culture of valuing reasoning and argumentation (Tofel-Grehl & Callahan, 2014), and the discursive approach associated with developing those skills was observed in science classrooms this sample. The dialogic discursive structures observed in STEM schools' science classes appear to provide students more opportunities to lead discussions and opens the classroom up to better student ownership and agency over learning. These opportunities for high-agency engagement are associated with to increased development of scientific reasoning and argumentation (Driver, et al. 2000; Duschl & Osborne, 2002). As such, the discursive practices of teachers in STEM schools may—especially their use of questioning techniques—may provide added value for students, which could account for their greater likelihood of persisting in the study of STEM disciplines and intentions to join the STEM workforce.

Discourse patterns and disciplinary language are, at their core, situated in a time and space as a possible instructional technique (Lemke, 2000). However, little is understood about the intentionality of teachers in using specific language or questioning techniques to drive learning outcomes or provide critical thinking opportunities. Given that teachers did not actively note in any of their teaching documentation intention toward asking specific types of questions and the types of responses they elicit, one can wonder how much thought and planning occurs to provide students with meaningful classroom discussion. Since language and reasoning development often stems from situated learning models (Gee, 2000;

Lemke 2004), future research focused on intentioned teacher discursive engagement may provide a window into how best to facilitate student thinking engagement in science classrooms. By understanding the ways in which teachers in STEM schools intend their linguistic practices to produce specific outcomes may provide insight into the unique learning environments provided by specialized STEM schools.

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