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"How do you know God didn't start the universe and blow it up?":

Connecting Classroom Talk and Controversy to Scientific Literacy

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"How do you know God didn't start the universe and blow it up?": Using Classroom Talk and Controversy to Support Scientific Literacy

by

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Thesis

Presented to the Faculty of the Graduate School

of the University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

Master of Arts

The University of Texas at Austin

May 2014

"How do you know God didn't start the universe and blow it up?":

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The University of Texas at Austin, 2014

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This study investigated the participant structure and content of discourse in five high-school science classrooms and their connection to scientifically literate practices for talking, reasoning, and evaluating claims. Through a detailed exploration of the way teachers introduced classes to the topic of evolution, I was able to examine how teachers used language to build a social framework for participation, examined the opportunities and challenges stemming from their various approaches, and explored how the structure and content of classroom talk contributed to framing science. This study used techniques from interactional sociolinguistics and conversational analysis to examine videos of interaction in five secondary biology classrooms on the day teachers introduced their students to lessons focused on the topic of evolution. Implications of this study focus on how teacher's discourse moves could open or close a discussion to student knowledge contributions, and emphasize how open discussions offer both challenges and opportunities to teachers wishing to facilitate scientifically literate discourse practices in their classroom.

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CHAPTER 1

Introduction

I have been interested in scientific literacy since I worked as a teacher and community organizer for community-based literacy programs. A few years into my work, it struck me that there were myriad programs for so many overlapping literacies across the lifespan: many people I worked with recognized the need for programs in speaking and reading, financial literacy, numeracy, and even health literacy. However, my community had little talk of any need for scientific literacy, despite the growing presence in American popular culture of advocates for "scientific literacy," the frequent news reports about Texas curriculum wars, studies claiming the American public lacked fundamental knowledge about science, and endless concerns over whether the U.S. educational system was producing enough science, technology, engineering and math (STEM) graduates.

This project approaches the problem of teaching students to do science as a literacy issue. As others have observed, John Dewey's claim is as meaningful as ever: "Contemporary civilization rests so largely upon applied science that no one can really understand it who does not grasp something of the scientific methods and results that underlie it" (cited in Anelli, 2011). There are many ways to approach researching science instruction that prepares students to work in different specialized fields, but scientific literacy is not simply for those who make a living as biologists, chemists, or engineers. Scientific literacy is important for all individuals, and all deserve to have the foundational concepts and processes they need to make sense of scientific information, investigate questions, and make decisions in their daily lives. All of us deserve to understand what questions the scientific method can and cannot answer, to experience wonder at the natural world, and to enjoy watching the limits of science push forward into the endless mysteries of our world.

Purpose of the Study

Researchers have long recognized that although students are "talking science," they are learning something about doing science and being scientists(Lemke, 1990; Gee, 2012). A large and growing body of interdisciplinary research in science education, literacy studies, and applied linguistics has promoted making the structure of talk, instructional activities, and evaluation in the science classroom connect students to the way science is done in the "real world" in order to deeply engage them with discipline-specific practices of speaking, thinking, and reasoning (Engle & Conant, 2002; Radinsky et al., 2010; Ford, 2012).

There have also been studies that reaffirm the value of controversy in the science classroom. Many have offered ways to minimize students' emotional distress while promoting "constructive controversy," "intellectual discussions," or other activities and strategies designed to facilitate conceptual change (Jensen & Finley, 1996; Johnson & Johnson, 2009; Oliviera et al., 2009; Walsh & Blakely, 2014).

This study attempted to further connect these lines of thinking about teaching in science classrooms with research in sociolinguistics and literacy in order to contribute to an understanding of how situated instances of classroom interaction can create opportunities for learning. The overarching goal of this project was to contribute to the literature on classroom discourse surrounding controversial topics in science classrooms in the hope that researchers, teachers, and supporters of science education can better recognize and adapt to challenges posed by those moments when there is a mismatch between the science curriculum, the teacher's goals for a class, and the way students are making sense of what is happening in the classroom.

Problem Statement

This study draws on Gee's (2014) distinction between the "little d" instances of discourse (everyday language used by individuals) and the "big D" Discourses of ideologies and social practices in a culture that connect with language and provide context. The persistent conflict between scientific Discourse and other powerful Discourses in American culture continues to challenge teachers as they seek to encourage student participation, maintain the social environment of their classrooms, and facilitate mastery of science curriculum content. Recently there has been renewed emphasis on the importance of STEM education and the training of students to be future participants in advancing science and technology, showing how scientific progress often easily converges with cultural, economic, and political interests. Yet there is also a long history of scientific findings that contradict powerful Discourses in American culture.

Although much attention has been given to institutional pressures on teachers and approaches to facilitating student discussion of controversial topics, less research has focused on providing a detailed analysis of the way students are positioned toward scientific Discourse and how this influences epistemic authority and the process of sense-making in classroom interaction surrounding contemporary scientific theories.

This qualitative study began from the assumption that what Erickson (1996) called "scenes of immediate interaction" (p. 303) during discussion in science classrooms can represent the way various teachers attempt to position their students towards the process of making sense of scientific findings, "doing" science in the real world, and evaluating knowledge claims in the midst of larger Discourses. Using techniques from interactional sociolinguistics and conversational analysis, this study offers a detailed description of the language used by science teachers and provides an interpretation of how this language connects to scientific Discourse and to conferring value on student knowledge contributions.

Research Questions

This study aimed to investigate how various science teachers addressed challenges that arose from the contentious nature of scientific Discourse:

1. How does the language teachers use position students towards evaluating knowledge claims during discussion, and who or what is recognized as a knowledgable contributor?
2. How are teachers facilitating and responding to the structure of talk surrounding controversial topics?
3. How do they ultimately frame scientific Discourse as classes begin lessons on the topic of evolution by natural selection?

CHAPTER 2

Literature Review

This section begins by offering a theoretical frame for this study's investigation of classroom talk, and explores the way that language used during classroom discussion connects with the process of making and evaluating knowledge claims. After a brief examination of the way researchers have characterized what it means to be science-literate, the section concludes by exploring the connections researchers have made between discourse practices and contemporary science education.

Theoretical Framework: Taking a Stance in Conversation

Language is embedded in socialization, and in educational settings it is deeply intertwined with the process of learning (Ochs, 1986; Schallert & Martin, 2003). This study explored language in the classroom, beginning with the assumption that everyday language-in-use (discourse) mutually constitutes what Gee (2014) called the "Big D" Discourse of ideologies and social practices that characterize groups of people within a culture: whenever we use language we are always saying something, doing something, and forming an identity in the world.

A focus on the social side of talk emphasizes how individuals are strategic and active when they encode and interpret the meaning of utterances. Speakers consider their audience and attempt to get their listeners to take a perspective, feel or behave in a certain way. For their part, listeners must work to interpret the situated meaning of the speaker's words, then design and communicate their response. In this process, interlocutors must produce and interpret language by drawing on explicit knowledge (about the topic, interlocutors, and other contextual features) as well as implicit knowledge about what will likely be seen as relevant, informative, or persuasive (Grice, 1975; Gumperz, 1982; Johnstone 2008). A person talking is always *someone doing something,* and human intentions are central to an interpretation of speech (Bloom, 2002; Gee, 2012). In light of this, language can never be truly neutral – to speak is to take a stance as the words we use invite others to take a perspective on the world (Bruner, 1986).

Stance, or footing in Goffman's (1981) terms is the position a speaker takes towards discourse as they interact with others, aligning themselves relative to others involved in a discussion. In any communicative event, interlocutors draw on salient frames of reference to interpret each other's speech, and speakers work to shift the conversational frame using a variety of cues. During the process of interaction, footing can shift from moment to moment, reframing the discussion as a casual chat, a contentious debate, a serious talk, etc. Footing offers an opportunity to influence the direction of conversation as it simultaneously represents one's identity and values. The act of taking a position creates social pressure as speakers are often acutely aware of the way larger Discourses are represented through talk (Hartman, 2006).

When a student in a classroom makes a statement like, "Darwin established all species alive descended from a common ancestor," he or she is taking a position as a knowledgeable contributor among the other students and the teacher while also making a claim about the nature of reality. In doing so, the student is inviting others in the classroom to take their own footing, aligning themselves in response. Their utterance has created context for responses that follow.

If the student's teacher were to respond, "That's correct," she is positioning herself as a knowledgeable person with the authority to ratify the student's claim, and contributing to a participant framework where there is consensus with the student who authored the position. Yet, if another student were to say, "My 8th grade biology teacher told us that common ancestry has not actually been established," they would be taking their own footing in opposition to the original student's claim, animating their 8th grade teacher as the source of this position, and shifting the participant framework to a classroom debate.

Goffman (1974) also asserted that frames, as ways of organizing interaction, help define our experiences and shape the overall meaning we attribute to speech. The primary frame of a classroom setting puts great power in the talk of teachers and the way they facilitate their students' interaction. Examining classroom talk, moment-by-moment, allows us to explore how teachers and students shape and renew the context for interpretation as they make sense of claims about the world.

How is knowledge given power through classroom talk?

This study set out to examine authority and language in two senses: first, in the sense of controlling the flow and participant structure for discussion, and second, in the sense of being authoritative, certain, or fluent in making a claim during that discussion. How do these different kinds of power connect to discourse in the science classroom?

As teachers present their students with the foundational knowledge of a discipline, they also aim to help the students develop their reasoning within that discipline, preparing students to make and evaluate new knowledge claims. Research into naturally occurring classroom discourse has documented patterns of interaction between teachers and students and their relationship to who has power to control the direction and content of classroom conversations, with direct implications for how students engage in knowledge-building (Mehan, 1985; O'Connor & Michaels, 1996; Krussel, Edwards, & Springer, 2004; Kamberlis & Wehunt, 2012; Smart & Marshall, 2013).

Although the connection between power and language is often thought of in the critical sense with an eye towards how large-scale ideologies surface and are reinvented via talk, classroom researchers have also foregrounded the micro-exchange of power in classroom language that occurs as speakers do things like allocate control of "the floor," establish group norms for discussion, and support or reject knowledge claims. The speakers, structure, and content of classroom talk guide students as they construct the meaning of scientific concepts, helping to build a foundation for their future engagement with science (Duit & Treagust, 2003).

Countless factors direct the course of a discussion, but one of the easiest to observe is who gets to speak. Competent speakers rely on cues that signal whose turn it is to talk: these include timing responses to fit the cadence of discussion, shifting tone and volume, and adjusting posture or gaze to show attention (Sacks et al., 1974). People signal that they want to speak through a wide-range of techniques that include the nonverbal, like raising one's hand or lifting the chin, and the verbal, like interrupting and latching responses. For children, part of learning to do school involves learning how to "make bids" for the floor and hold it once one has gotten a turn to talk (Erickson, 2004).

Once a speaker has the floor, he or she has an opportunity to contribute his or her own understanding and to influence the negotiation of meaning in the classroom. In a classroom discussion, students will design their responses in light of ideas about what is appropriate according to norms for the setting and group (Bakhtin 1986). Taking the floor is an opportunity to showcase one's skill at enacting the group's discourse patterns while also reshaping them. It affords a chance at recreating the context for interpretation of what is said and how it is said.

No matter how a class is structured, much authority in the classroom rests with the teacher (Oyler, 1996). An authoritative claim to knowledge and control over the participant structure are sometimes both implicit in one structure, as in the I-R-E response pattern in which a teacher asks a known-answer question, opens a brief slot for the student to respond, then immediately evaluates the quality of the student's answer (Mehan, 1979). Authoritative discourse patterns like I-R-E, that focus students' attention on just one meaning are often a feature of science instruction; these patterns are often in tension with more dialogic discourse patterns like asking genuine questions, encouraging student contributions, and replacing the "evaluation" of student responses with "feedback" that encourages elaboration or clarification (Scott, Mortimer, & Aguiar, 2006).

Not all knowledge claims are authoritative: speakers make use of hedges, qualifications, and markers of uncertainty in order to participate in conversation even though they are not entirely sure of the contribution they are making. Linguistic markers of uncertainty do not only arise from cognitive factors such as confusion about meaning or doubt regarding the truth value of claims, because uncertainty can also arise from social and affective factors (Jordan et al., 2012). However, although it is difficult to draw conclusions about the source of uncertainty, there are many ways to locate it in speech. Regardless of its source, expressions of uncertainty serve an important purpose, as authoritative claims open the speaker to being proven wrong (Touri, 2013) and more importantly, can lead to premature conclusion of what could otherwise be a rewarding exploration of ideas (Bruner, 1986; Townsend & Pace, 2005). Expressions of uncertainty help teachers encourage learners to make contributions, and offer "wiggle room" to students as they figure out how to make claims within a given discipline and learn the way claims are given value.

Via revoicing, a teacher can lend authority to a student's uncertain contribution in class discussion. O'Connor and Michaels (1993) demonstrated how revoicing is a powerful tool that teachers can use to coordinate various task structures, position students within a participant framework, and socialize students into ways of thinking and talking about content. By revoicing a student's words, a teacher can amplify the student's contribution, position the student in opposition to another, or reformulate the contribution in a way that models fluent practices within the discipline. Other shifts in the participant framework that lend power to a students' utterance include those instances when students align themselves in agreement with a statement, when a student's words are taken up and repeated during the conversation, and when the teacher looks to the student to ratify his or her reformulation of an utterance.

Discipline-Specific Discourse and Scientific Literacy

In light of the complex social and cultural context for every discussion, the language teachers use has power to position students as "doers" of science who avoid premature closure in their evaluation of knowledge claims, participate in the process of scientific reasoning, and make sense of scientific concepts (Crawford, 2005; Kuhn et al., 2008; Ford, 2008).

The concept of scientific literacy is often traced back to the early 20th century, but recently it has been developed away from a prescriptive list of facts and has become more complex, as has the concept of literacy itself (Anelli, 2011). Researchers have expanded the definition of literacy beyond the narrower concept of proficiency in reading and writing, and have asserted that learners have multiple literacies – ways of using language and symbols to make meaning in different contexts. O'Connor and Michaels (1993) summarized the shift to this broader view in their assertion that "literacy acquisition within a particular context involves taking on a set of purposes, values, thinking practices, and ways of reading with text" (p. 318). While students are learning curriculum content, which can be viewed as a conscious, explicit process, they are also engaging in the largely implicit process of literacy acquisition that is tied to a particular field of study (Gee, 2012).

The ability to speak, listen, read and write in a way that reflects the values and thinking practices of a culture is tied to success in any discipline, as every field has its own discipline-specific discourse practices. Engle and Conant (2002) used the term *productive disciplinary engagement* to refer to classroom discussions and activities that deeply connect with a discipline's Discourse and its discourse practices.

Literate practice in scientific fields relies on learning the foundational knowledge and conventional processes required to make and evaluate authoritative claims. The United States' National Science Education Standards (1996) described scientific literacy in a way that emphasized its functional value in daily life:

> Scientific literacy means that a person can ask, find, or determine answers to questions derived from curiosity about everyday experiences. It means that a person has the ability to describe, explain, and predict natural phenomena. Scientific literacy entails being able to read with understanding articles about science in the popular press and to engage in social conversation about the validity of the conclusions. Scientific literacy implies that a person can identify scientific issues underlying national and local decisions and express positions that are scientifically and technologically informed. A literate citizen should be able to evaluate the quality of scientific information on the basis of its source and the methods used to generate it. Scientific literacy also implies the capacity to pose

and evaluate arguments based on evidence and to apply conclusions from such arguments appropriately.

Teachers aiming to cultivate scientific literacy in their classrooms encounter numerous challenges that include difficulties with classroom management, institutional pressures and constraints, and topics that are "controversial" in the larger culture. For example, the theory of evolution is not the first scientific theory to prompt controversy and conflict, and it will certainly not be the last.

As Lemke (1990) examined, the participant structure of a classroom environment itself, where teachers are in authority and students are not always recognized as knowledgeable contributors, can interact with conflict that results from different levels of proficiency with the particular ways of talking and thinking that characterize science. Classroom controversy does not always stem from direct opposition to scientific theories raised by students who have accepted competing theories about the way the universe began, how species came to exist, or whether the Earth's climate is warming. Sometimes conflict can arise from students not yet being fluent in the discipline-specific discourse practices that are implicit knowledge for science teachers.

Of course, those doing and teaching science have long contended with competing Discourses. Scientific theories continue to come into conflict with the aims of business interests, religious traditions, and other political groups (Moore, 2005). In addition to the conflict that arises from culture wars surrounding contemporary scientific theories in the public sphere, classroom disagreement can develop from the nature of science as a method that privileges evidence for probable theories over the assertion of absolute truths.

Researchers have described how scientific Discourse is characterized by adherence to a defined method for evaluating the value of claims about the nature of reality, an emphasis on the provision of empirical evidence to support claims, and a social process of evaluation when new claims arise (Ford, 2012). In this sense, controversy is a defining feature of the discourse practices of scientists working in the world. Conflict helps attract attention to scientific problems, helps to clarify various positions taken on the methodology and purpose of research programs, and refines scientific theories of how the world works (Apple, 2009).

Although the nature of science rejects making absolutist claims, controversy about the theory of evolution itself is decidedly not a feature of scientific Discourse. Rather scientists continue to seek out and debate evidence that contributes to various facets of this overarching theory of how life changes over time. A 2009 survey by The Pew Research Center found that 97% of scientists (defined as members of the American Association for Advancement of Science, including researchers and teachers) agreed that "Humans and other living things have evolved over time," and 87% thought this process was "due to natural processes such as natural selection." In contrast, 61% and 32% of the general public surveyed agreed with these respective positions.

Not only is there a divide between the general American public and those who work in fields that rely on the scientific method, but it is possible that Americans believe scientists to be more divided than they really are on topics that spark controversy in the larger culture. Although 60% of the American general public surveyed said that "scientists generally agree that humans have evolved over time," 28% thought that scientists were divided on the issue, saying that "scientists generally do not agree that humans have evolved over time." The American public's division surrounding the concept of human evolution has persisted in subsequent surveys (The Pew Research Center, 2013).

In Pew's 2009 survey, majorities of scientists rated television coverage (83%) and news coverage (63%) of scientific issues as "only fair" or "poor," highlighting a persistent problem with the way scientific claims are communicated to the public in mass media (Park, 2000). Of course, the Discourse of a field cannot be reduced to opinion polls but these results do lend insight into how scientists perceive a divide between the way scientists and the American public evaluate claims and have access to scientific information.

It is also important to note that although the process of scientific inquiry unites various fields, "science" is not monolithic. Chemists do not talk or behave like biologists, just as psychologists have different conventions for their speech and literature than neuroscientists. Scientists working in each field have their own discipline-specific discourse practices – those significant and salient words, knowledge, actions, and context that bind them as members of a group with a common culture. Nonetheless, a set of core discourse practices are shared across scientific fields that are rooted in collective values such as empiricism, induction, and replication. These practices are central to what it means to be scientifically literate, and are themselves more important than the knowledge of any given theory or finding. After all, whereas the scientific method remains relatively consistent, the evaluation of new findings changes with developments in instrumentation and theoretical orientation.

Teaching Students to "Do Science" in the Midst of Competing Discourses

Although teachers aim to engage students with a science curriculum that makes the Discourse of science relevant and meaningful, connecting science to the real world sometimes means addressing the Discourses around scientific theories that students grapple with outside the classroom. Although teachers can explain to students that the scientific method is only one way of knowing, they cannot expect students to leave conflicting epistemologies outside the classroom door. How are teachers guiding students as they develop their identities as scientists, and how are they coping with challenges that arise along the way?

Science instruction has long emphasized both teaching students the history of scientific discovery while having students engage in observation and hands-on experimentation as a way of learning how science is done. Researchers have promoted science lessons that focus on collaborative problem solving and open-ended activities as a way of helping students engage in a process of inquiry during science lessons (Radinsky et al., 2010) and have highlighted the importance of the teacher in facilitating this kind of instruction (Kelly & Brown, 2003).

Inquiry-based environments encourage students to contribute knowledge claims to the discussion and reason through the evaluation of claims made by the self and others. They are characterized by such features as group projects, discussion, and teacher questions that are open, focus on supporting student understanding, and encourage elaboration instead of providing evaluation (Morge, 2005; Chin, 2007; Lustick, 2010). Researchers have highlighted that teachers who facilitate a symmetrical participant structure (positioning themselves as a "co-inquirer") are especially supportive of students' inquiry-based learning in the science classroom (Tabak & Baumgartner 2004). Building on this line of work, researchers have connected teacher questions to students' cognitive level of engagement with science instruction and highlighted the need for greater emphasis on questions that promote higher-order thinking instead of questions that seek brief factual responses (Smart & Marshall, 2012).

Science teachers aim to help students develop an understanding of science content and to prepare them to engage with science-related information throughout their lives, yet may not know how to safely handle controversial discussion topics without misrepresenting scientific

Discourse or discouraging student participation (Sandoval & Daniszewski, 2004; Hermann, 2008; Hess, 2009). As teachers seek to help their students make sense of scientific foundations and findings, challenges arise from both macro institutional and political Discourses and from the nature of local, personal interaction (Erickson, 2004).

Teachers and researchers have asserted that for classrooms to truly engage students in the process of talking, reasoning, and making sense of concepts, they must be low risk, equitable environments (Joseph & Schiller, 2010). Nonetheless, many have stressed the importance of dissenting opinions and argument as a characteristic of scientific development that can be mirrored in the classroom (Driver, Newton, & Osborne, 2000; Kelly, Crawford, & Green, 2001). Conceptual change can include a "warm" emotional process, and students' emotional involvement in a classroom topic may be a necessary aspect of knowledge revision (Mason, Gava, & Boldrin 2008). Although researchers have promoted the intellectual benefits of "constructive controversy," Johnson and Johnson (2009) offer a review of the many reasons why educators have a negative view of conflict in educational settings, including that conflict can threaten social relationships, give rise to negative emotions, impede effective teaching, and is not the best use of limited classroom time.

Because many teachers introducing evolution seek to minimize distressing their students with threats to their personal beliefs and prioritize social facets of the discussion like politeness over student mastery of content, researchers have also promoted reframing evolution in the classroom as an "intellectual discussion" that minimizes attention to social factors and emotional involvement in debate (Oliviera et al., 2009). Hermann (2008) reviewed how instructional approaches that emphasize evidence for the theory of evolution are linked to greater student understanding of the theory of evolution itself, asserted the value of positioning the theory of evolution within sociohistorical context, and suggested that instructional approaches using "procedural neutrality" to encourage student contributions can help students develop their understanding of the nature of science.

Conclusion

In summary, how teachers use language expresses stance and positions themselves and their students in relation to a topic, in a participant framework that reflects and reconstitutes cultural values, norms, knowledge, and authority (Goffman, 1981; O'Connor & Michaels, 1996). The Discourse of science presents unique challenges to teachers who aim to cultivate scientific literacy while facilitating an equitable participant framework in their classrooms. Ultimately, when science teachers engage their students with the topic of evolution, their local classroom language-in-use reconstructs larger cultural and historical Discourses surrounding science, shaping the way students negotiate the meaning of scientific claims (Ford, 2012).

Although researchers have offered many frameworks, strategies, and resources for teachers to encourage productive disciplinary engagement with scientific Discourse, and whereas some have focused specifically on how teachers cope with the challenges posed by classroom controversy, there has been little work that focuses on connecting these two lines of research in science education. A detailed examination of local patterns of interaction surrounding controversial topics can contribute to the literature by highlighting how the many lines of thinking about discourse in science classrooms complement each other, and enhance our understanding of how situated instances of classroom interaction create opportunities for learning.

How do participant frameworks, teacher and student positions, and the process of making claims in science classrooms contribute to framing scientific Discourse and ultimately position students towards evaluating claims regarding controversial topics? Although any sample of talk cannot yield generalizations about how individuals will behave in other contexts, it can provide a powerful resource for ontogenetic examination of local interactions that reconstitute Discourses surrounding science and ultimately reshape what it means to be scientifically literate.

CHAPTER 3

Method of Inquiry

The overarching goal of this project was to provide a detailed exploration of the way meaning is constructed in secondary science classrooms as a way of offering insight into how teachers' framing of "controversial" topics can influence the flow of discussion through the language they use – and more importantly, how discipline-specific discourse can be emphasized or obscured during these discussions. In this section, I address the methodological issues associated with the study and introduce my positionality as a researcher. I describe the participants and context of this study, and I review the methods of data collection and analysis that I used.

Methodological Issues

In an ideal study of this topic, I would have drawn on a greater variety of information about how these teachers viewed their roles, institutional pressures, and curriculum demands when they approached this topic, and sought to connect the practices of these teachers with their students' understanding of topics addressed as part of the science curriculum. I also would have preferred to engage in member-checking with the teachers described here so that they could give their insight into what was happening in their classrooms, which they certainly "know best". Yet because data were not originally collected for the purposes of this study but instead were capitalized on as an opportunity to investigate my research questions, this project cannot be used to make broad generalizations about whether certain teachers are more effective at cultivating scientific literacy in their classrooms. However, analysis of their talk can give us a picture of the way scientific Discourse was framed, which can then be compared and connected to the ways of thinking, speaking, and reasoning that researchers have associated with scientific literacy.

Instead of seeking broad generalizations, the goal of this project was to build on research into the various ways classroom talk creates a framework around the literate practices of a discipline, and to show how this process is currently playing out in classrooms. I see this study as a limited examination of select episodes in these teachers' classrooms, with talk surrounding one particular topic, evolution, on one particular class day. Nonetheless, I believe that any selection of classroom talk can be a valuable object of reflection for researchers and teachers, and any instance of science classroom discussion is an opportunity to empower scientifically literate learners.

Positionality

As any study is open to charges of bias by the researcher, it is important for me to be transparent about my position towards the data and analysis presented here (Merriam et al., 2001). Science teaching can be framed many ways, but I framed it as a literacy issue for this study because my background is in literacy instruction and my research interests center on the psycholinguistic processes involved in literacy and learning.

I personally take the view that evolution and other theories that have been built through the scientific method should be privileged in science classrooms, even if this excludes ways of reading, talking, and thinking that students have learned in other contexts. Students have a right to science education that is contemporary, evidence-based, and free of any obligation to accommodate competing theories not based in the scientific method. Still, I regard as scientism the assertion that the scientific method is the best way of knowing in all contexts, and I do not think that scientism (as a value-laden, ideological stance) is helpful when trying to cultivate literate practices in science learners.

All of the teachers in this study agreed to participate in a larger study of their teaching practices, which in my view implies that they care about contributing to our understanding of effective teaching and classroom environments enough to undergo "scrutiny" willingly by researchers. I have not personally met any of these teachers, and although I have watched many videos of their teaching, I do not presume that my interpretation would necessarily mirror how teachers or students made sense of their discussions. Therefore I was careful to design this study in a way that would not make a value judgment of these teacher's language or instructional approaches, and deliberately tried to minimize my assumptions about whose talk was "better" or "worse."

Data Collection and Procedures

Data for this study were originally collected as part of a larger, multi-year study investigating the relationship between autonomy-supportive classroom practices and student motivation in high school science classrooms. The larger, multi-year study involved videotaping participating science classes for every class over one six-week period. I reviewed all available videos of classes held by 12 biology teachers from Spring 2013 through Spring 2014, and selected for inclusion those videos of class days where the teacher told their class that they would be starting a lesson on the topic of evolution, resulting in a total sample of five videos. For each video, I began by watching it all the way through once, then watched it again and took notes on the flow of the lesson and classroom activities.

The third time I watched a video, I began to transcribe talk. My transcription aimed to preserve the content of speech verbatim as well as instances of filler (sounds like "um," "uh," etc.) and pause. Because this study aimed to examine the discourse surrounding the *introduction* of evolution as a classroom topic, I only transcribed in detail those segments of video that met specific criteria for topic introduction. A segment was transcribed starting from when the teacher opened class and explicitly stated his or her purpose to address evolution as a new topic (e.g., "Today we're going to watch a video on natural selection") or posed a question to the class about their background knowledge on evolution (e.g., "So, question now – What do we know about Charles Darwin"). Only the discussion prior to the start of actual classroom activities was transcribed. That is, I stopped transcribing as soon as the period of topic introduction ended and once structured, content-focused activity had begun (such as students taking notes, watching a video, or working in small groups).

Participants and Context

To protect the confidentiality and privacy of teachers and students in this study, the teachers were each given a number to distinguish them, and all students were given letters in place of names. The participants in this study were five high school biology classes within a large (~85,000 student) urban school district in central Texas. The district serves students from all socioeconomic levels and backgrounds. The district reports that their student population is 60% Hispanic, 24% non-Hispanic white, 9% black, and 3% Asian/Pacific Islander. In order to provide context for the episodes examined in this project, this section provides brief thumbnail sketches of the teachers, their typical class day (as viewed in a collection of videos taken over one six-week period), and the particular lesson that became the focus of my analysis.

Teacher 1's class – thumbnail sketch

Teacher 1 was a middle-aged Caucasian woman who was teaching a 9th grade Pre-AP Biology class. On a typical class day, Teacher 1 would have a brief lecture followed by group discussion, and then students would begin a group project or continue work on a project begun in a previous class. During the class session examined for this project, Teacher 1's lesson was centered on Darwin's theory of evolution by natural selection and how this theory built upon previous work by Darwin's predecessors. The actual lesson began with a quiz over the assigned reading, followed by discussion and a group project.

Teacher 2's class – thumbnail sketch

Teacher 2 was a middle-aged Caucasian man who was teaching a 9th-grade Biology class. On a typical class day, Teacher 2 would have students watch a video, read an article, or read a textbook chapter about their topic while working individually to fill out worksheets designed to check their comprehension. The class session examined for this project was a typical class day, and was centered on the topic of evolution by natural selection. Teacher 2 began the class by attending to classroom business, then showed a one-hour video while students followed along, filling out a worksheet. The last segment of the class gave time for students to work on a homework assignment (reading an article about species change and answering comprehension questions) or to catch up on other assignments due by the end of the grading period.

Teacher 3's class – thumbnail sketch

Teacher 3 was a middle-aged Caucasian woman who was teaching 9th grade Biology. On a typical class day, Teacher 3 would have a class discussion, followed by a brief lecture in which students completed fill-in-the-blank notes. Then students would work on a group project due at the end of class. On the day of class examined for this project, the class turned from their topic of Mendelian genetics to the topic of evolution by natural selection. Teacher 3 attended to classroom business, then showed students a brief video clip. This was followed by a review of the ideas in the video clip, then a group activity.

Teacher 4's class – thumbnail sketch

Teacher 4 was a young Caucasian woman who was teaching a 9th-grade Pre-AP Biology class. Teacher 4 tended to vary class activities between lecture, discussion, and pair or group projects. Every other Friday Teacher 4 would hold a discussion of "science in the news," during which students could present notes they had written about scientific findings they had seen in the press. In the class session examined, the day's topic was evolution by natural selection, and had been preceded by a curriculum unit on genetics. First, students did a warm up activity filling out a punnet square. Afterward, the teacher attended to classroom business, held a discussion of "science in the news," then had students ask questions about their upcoming test and review worksheets. Then, the students worked on a group project visiting learning stations in the classroom.

Teacher 5's class – thumbnail sketch

Teacher 5 was a young Caucasian woman who was teaching a 9th grade Pre-AP Biology class. On a typical class day, Teacher 5's students would take notes during a lecture on the day's topic before participating in a group project. The class day examined for Teacher 5 focused on the topic of evolution and the phylogenetic tree. Teacher 5 began class by addressing classroom business, then showed a short video clip. Students then individually wrote down their thoughts on the video before sharing their ideas with a partner. Teacher 5 then held a class discussion, which was followed by an activity wherein students moved around the room marking claims about evolutionary theory as "true" or "false" with sticky notes and writing how certain they were on a scale of 0-100%. Then, students took notes during a lecture on the day's topic.

Data Analysis

Discourse analysis has a long history of contributing to our knowledge about cultivating literate practices in classrooms. Because of my interest in analyzing the situated meaning of smaller, local discursive events naturally arising within "big D" Discourse, a qualitative approach was best suited to constructing a rich description of language use by particular people in a particular time, place, and political culture (Gee, 2014; Miles, Huberman, & Saldaña, 2014).

The coding scheme for this study was initially developed in a workshop with peers and a faculty member specializing in discourse analysis. The transcribed classroom talk was initially reviewed for knowledge claims about science in the world: I specifically looked for descriptive statements about scientists, the scientific method and processes of doing science, the cultural/historical context surrounding science, and statements about contemporary scientific theories and findings. In case it would be useful during later analysis, I noted whether a claim about science showed markers of uncertainty such as filler. Then, I went through the transcripts and highlighted any statements that explicitly referred to controversy about scientific theories and findings.

For a second round of analysis, the transcripts were reviewed for the ways teachers and students positioned themselves relative to each other and the statements being made via such techniques as open questions, known-answer questions, revoicing, repetition, problem-posing, elaboration, contradiction, and agreement. During this stage of analysis, I noted who held the floor at any given time and whether speakers had gotten control of the floor through verbal means (like interruption and latching) or though nonverbal communication (like hand-raising).

The coded transcripts were then reviewed to examine where knowledge was located during the discussion, focused on answering the central question of who or what had epistemic authority during classroom talk and how this authority was conferred. Ultimately, this formed the foundation for a thematic analysis of how features of the teachers' language positioned students towards claims being made, created challenges and opportunities for the negotiation of meaning, and ultimately contributed to framing scientific Discourse.

Assuring Trustworthiness of the Study

As I examined how the language used by science teachers positioned their students toward contemporary scientific theories and explored how their discussions connected with a representation of scientific Discourse, I drew heavily on existing research and modeled my analysis after well-established techniques in discourse analysis. The development of this study benefitted from the guidance of two senior researchers with expertise in the study of discourse practices. In three different sessions, I asked peers to review samples of the data and analyze it, recorded their observations, and discussed the differences and similarities in our interpretations. Throughout the process of analyzing this data, I relied on debriefing and peer scrutiny as ways to enhance the trustworthiness of this project (Miles, Huberman, & Saldaña 2014).

CHAPTER 4

Results

This section will explore in detail the three themes that emerged from analyzing the classroom videos. The first theme suggests that repetition of student contributions was a key feature of teachers' language that could either amplify or obscure student contributions to classroom discussions. The second theme focuses on how teachers who did invite student contributions opened up space for the discussion of cultural controversy surrounding scientific theories, which in turn offered an opportunity for these teachers to take a stance and explicitly position students towards scientific Discourse. The third theme centers on how classroom language, turn-taking, making knowledge claims, and positioning all ultimately contributed to framing scientific Discourse in the five classrooms.

Theme 1: The Complicated Role of Repetition and Revoicing

Often teachers used revoicing and repetition to amplify students' speech, recognizing them as contributors and encouraging further conversation. Teacher 1 used repetition to allow a casual tone into discussion as opposed to dismissing a student's contribution as less than serious:

> ***Teacher 1:*** (Leaning against desk at front of room) So, question now – What do we know about Charles Darwin?
>
> ***Various students:*** He's a dude
> He invented
> His name
>
> ***Teacher 1:*** He's a dude? I suppose he might've been.
>
> ***C:*** (raising hand) I know! Kind of.
>
> ***Teacher 1:*** What do you know about him, *C*?
>
> ***C:*** (reading from book) Um, Okay. He was an English, well, wait. (Quieter) Uh, naturalist, he established that all species have, um, descended from time common

(inaudible)

Teacher 1: (walking towards student) He did what?

C: Never mind (laughs) I kind of got a rough gist of it after I think about it.

Teacher 1: He was an English dude.

C: He was, he was a, I read that he was a naturalist.

Teacher 1: A naturalist, you're right, he was. A naturalist is somebody who studies (waves hand in open gesture at class)

Many students: Nature

In this section, *C* attempts to relinquish the floor, claiming she has "a rough gist" and withdrawing from an attempt to position herself as a knowing contributor. The teacher responds by repeating and slightly elaborating a different student's previous contribution, saying Charles Darwin was an "English dude" – thus positioning students as valuable contributors, keeping the floor open, and offering *C* an opportunity to expand on the minimal description of Darwin that the class has established so far. *C* then decides to take up a knowledgeable position, allude to a source, and more loudly state her contribution that Darwin was a "naturalist." Teacher 1 affirms this contribution, offers the phrasing for a definition, then prompts the class to finish constructing her definition, positioning them as knowers.

In order to guide students through building a shared account of how Darwin developed the theory of evolution by natural selection, Teacher 1 relied heavily on students volunteering their prior knowledge and repeated their statements ("…we're gonna start with Darwin and as *D* said, he did spend a lot of time in the Galapagos"; "As *N* said earlier, he, Darwin, saw lots of variation between the organisms just based on what islands they lived on").

Teacher 1 used revoicing when she took up the idea of scientific theory "pushing" against religious thinking:

Teacher 1: Who remembers why Lozaro Spallanzani and Francisco Redi were not liked by a lot of people?

J: Um, cause when Charles Darwin came up with the theory of evolution a lot of the. Christians thought that he was pushing a little bit, by not believing in, that, um, God created everything.

> ***Teacher 1:*** Okay, so his ideas about evolution. Pushed into the. Christian thinking about where organisms came from, the creation of organisms. (Pause, looks at *J* then turns to *M*). *M* what were you gonna say?

The first thing that stands out about this exchange is that *J*'s response does not actually answer the teacher's question, a point we will return to later. Regardless, the teacher revoices *J*'s statement, reformulating the student's language with the more discipline-appropriate vocabulary of "Where organisms came from, the creation of organisms" but keeping the metaphor of thinking that "pushed" into other thinking. After some extended discussion of religious controversy sparked by scientific theories, the teacher returned to the idea of "pushing" as a way to describe conflict between ways of thinking about the world:

> ***Teacher 1:*** Which I'm not arguing with that or what that means, but at the same time what I'm saying is that throughout the ages you have these scientists who've pushed people's thinking and pushed their anger buttons in the process by espousing ideas and theories that weren't very popular.

By using student-supplied language, the teacher could highlight the value of student contributions, allow students control over the tone of the discussion, and allow student language to frame the claims being made about Darwin, his process of observation, the theory of natural selection, and the history of cultural controversy surrounding many scientific theories.

There was a notable difference between Teacher 1's use of repetition and revoicing to amplify student claims during an extended discussion and the rapid fire repetition of student language that was used by Teacher 3:

> ***Teacher 3:*** All right so those are the three types of selection. So directional it's when in one end is better so if say they decided to put all the food really high, like in the cafeteria all the counters raised up, so who's the only people that could eat the food?
>
> ***Students:*** Me
people with a step stool
tall people
>
> ***Teacher 3:*** The tall people. So tall people would survive, what would happen to the short people?
>
> ***Students:*** They would die

They would starve to death
They would die of starvation

Teacher 3: They would die. Shhh. The tall people, then who would they marry? Who's left?

Students: Tall people

Teacher 3: Other tall people. And what kind of babies would they have

Students: Tall

R: Unless!

Teacher 3: Tall babies. So you'd see over time that whole bell curve will shift so the whole population on average is taller.

Here, Teacher 3 is leading a chain of reasoning about how selection can happen within a population, but only briefly opens space for students to supply words before quickly ratifying one response through repetition. In a way, this is an I-R-E pattern, except the Evaluation comes in the form of the words the teacher takes up and repeats. One student's response that "people with a step stool" could eat food put up high may have been flippant, but tools *are* an adaptation that could help people survive in the situation the teacher described. However, the teacher emphasized the particular trait at the core of her example, "Tall people," and moves on. Teacher 3 also uses this technique to emphasize the idea that short people in the situation described "would die," emphasizing this wording over the more violent but contextually-specific reply that "they would starve to death." The teacher quickly echoes that only "Tall people" survive who will have "tall babies," and arrives at her conclusion about population change without allowing time for student contradiction or discussion.

It is a given that even in open, extended discussions, repetition of "correct" answers will occasionally marginalize other student contibutions. After all, a teacher cannot amplify every student's knowledge claims, and it is not necessarily desirable to do so. However, occasionally students' knowledge claims were obscured in a different way, as a teacher reformulated a student's talk and animated students as the source of positions. It was not always clear whether the student actually agreed with the claims attributed to him or her. An example from Teacher 5's classroom arose when a student volunteered a science topic she saw in the news:

> ***K***: I heard about something where like they saw like, people were like oh my god it's actually real, and then all these religious people were like oh my god it's still not real.
>
> ***Teacher 4***: The big bang theory?
>
> ***K***: Yeah.
>
> ***Teacher 4***: Oh yeah so they found evidence for inflation was the idea that, in order to account for the amount of time, um, that's needed for the expansion of the universe that we have. Cause the universe is 5 billion years old, and we know that from chemical data, isotopes, cause they decay at a certain rate, and so we can calculate for some of the oldest lived isotopes, figure out when the universe should've started, and it's 15 billion years. But the universe is too big to only be 15 billion years old, so they needed something called inflation, which is like when you go to blow up a balloon, nothing happens. And then all of a sudden Poof (hands expand) it like really blows up, that's inflation. So they had that hypothesis but they didn't really have like, backup evidence, data yet to like corroborate that hypothesis, and that's what they figured out. So they found like these background waves that are evidence of inflation. But yeah, that's a good point like if. Um. If you do:n't. really understand the scientific method and like the way that it works then something like evidence, scientific evidence maybe to you is like, (inaudible).

The student had not phrased her comment as a strong assertion. Instead, she described what she had heard about "people" discussing a scientific theory, but did not deeply describe or evaluate the situation. This prompted the teacher to clarify that she was talking about controversy surrounding the Big Bang Theory, and once the student affirms her topic, the teacher launches into an extended explanation of scientists finding evidence to support this theory. The spotlight here is on the teacher's knowledge, as she offers a frame for the situation the student is describing. Then the teacher animates *K* as the source of a position by saying, "But, yeah, that's a good point," and frames the conflict as a result of people who "don't really understand the scientific method" or choose to believe in other kinds of "scientific evidence." Although perhaps this *was* the student's point, her words themselves do not make such an evaluation. She is nonetheless animated as the source of the teacher's claim.

Theme 2: "You're just saying all this because some people don't believe in evolution right?"

Although four of the teachers examined used student contributed knowledge and discussion to some extent while introducing their class to the day's topic of evolution by natural selection, one teacher did not. Instead, Teacher 2 attended to classroom business, telling students what they would be doing, and only briefly introduced natural selection as the topic of a video they would watch that day:

> ***Teacher 2:*** All right a couple of things that we need to get done today, okay. One is, we're going to watch a, uh, video on natural selection, okay. Those are things that are going to help an organism survive in the wild, could be a coloration change, could be they're a little bit faster, could be they blend in a little bit better. All these different things, okay? So. So we have a sheet that we'll fill out when we get there when I give this to you what I need you to do is just read through it so you see what the questions are, what you're looking for when the video starts. Okay? The other thing when we get done with the video, the other thing is we're gonna do, we have an article up here called in the blink of an eye. What we're gonna do is a little sheet at the end only eight questions shouldn't take you that long, use it, help you with the test. This 'll be turned in. Okay? The video sheet and this one.

There was no discussion in this class, and no mention of "controversy." Instead, once the teacher introduced the topic, he began the video (a popular science television program that reviewed types of selection by examining animal adaptations to their environments) and students quietly filled out their worksheets.

Teacher 3 also did not have any discussion of "controversy" in her class – although she alluded to it at one point during their activity, in which students took notes on a slide presentation:

> ***Teacher 3:*** So evolution occurs when there is a change in the allele frequency. That's it guys. That's what evolution is, a change in allele frequency of a population. Not so exciting and controversial, as we said.
>
> ***Student:*** I think it's exciting. I think it's very whimsical
>
> ***Student:*** That's not a word.
>
> ***Student:*** It is a word! Whimsical is a word.
>
> ***Student:*** No it's not.
>
> ***Student:*** Look it up!
>
> ***Teacher:*** So evolution is a change in allele frequency, remember that. There are four ways that

allele frequency can change in a population, here they are, write them down.

However, this brief mention of controversy was much later in the lesson than the introductory period that is the focus of this analysis. It is included here only because it is of interest that there appears to have been some past discussion of evolution as "exciting and controversial" at one point in this class's history. We cannot know if this class had already sorted through some of the ideas about scientific Discourse (as observed in other classes) during discussion, and this study simply did not capture it on video.

As previously examined, Teacher 3's introduction of the lesson consisted of leading students through a chain of reasoning after she had showed a brief video clip about types of selection. Their exchange continued from this discussion of directional selection:

> ***Teacher 3:*** Other tall people. And what kind of babies would they have
>
> ***Students:*** Tall
>
> ***R:*** Unless!
>
> ***Teacher 3:*** Tall babies. So you'd see over time that whole bell curve will shift so the whole population on average is taller.
>
> ***R:*** But what if, couldn't some babies be shorter if, uh
>
> ***Teacher:*** But over time. This is over hundreds of years, the genes are slowly shifting and there's more tall alleles in the population so more people are ta:ll. All right? (pause) Um so we say that intelligence is actually polygenic so you have…

R attempts to interrupt the chain of reasoning that the class is following, and starts to pose a problem: "Couldn't some babies be shorter if…" However, he's interrupted by the teacher who emphasizes the point she is making, extending her pronounciation of the trait "ta:ll" in contradiction to *R*'s contribution. The floor was not open to discussing any conflicting line of reasoning; instead, the focus remained on learning about the definition of directional selection.

In Teacher 1's class, an open discussion of the theory of evolution allowed space for students to offer their own knowledge of the controversy surrounding Darwin's theory. Again, returning to a spot in the discussion previously examined:

> ***Teacher 1:*** Who remembers why Lozaro Spallanzani and Francisco Redi were not liked by a lot of people?
>
> ***J:*** Um, cause when Charles Darwin came up with the theory of evolution a lot of the. Christians thought that he was pushing a little bit, by not believing in, that, um, God created everything.
>
> ***Teacher:*** Okay, so his ideas about evolution. Pushed into the. Christian thinking about where organisms came from, the creation of organisms. *M* what were you gonna say?
>
> ***M:*** I was basically I mean, uh say that religious, um, mostly I think it was like Catholics back in that time, um, since they were very religious, and like how they kicked out the Pilgrims cause they weren't the same religions. They believed that he was just sacriligeous and that if that got out there would be other people turning to this devilish way, so.
>
> ***Teacher:*** You know the interesting thing about it is. that. Most of the established religions of the world have their ideas about where life came from. And it wasn't just Christians, like, Darwin pissed a lot of people off. And you know, if you remember back to the beginning of the year, we talked about Redi and Spalanzanni. Do you remember what theory they refuted with their meat maggot experiment and their boiled gravy experiment? What was that theory?
>
> ***D:*** Spontaneous, um, generation?
>
> ***Teacher:*** Spontaneous generation. So, they made people mad too because what they said was life comes from other life when in reality people used to think. Oh, well, life happens because of god or gods decided they wanted that life to be there so they put it there. Which I'm not arguing with that or what that means, but at the same time what I'm saying is that throughout the ages you have these scientists who've pushed people's thinking and pushed their anger buttons in the process by espousing ideas and theories that weren't very popular.

Teacher 1 is trying to lead students to the idea that Darwin is not the only scientist who provoked cultural controversy by referring to the class's previous knowledge of other scientists. But *J* does not directly answer her question about other scientists. Instead his response identifies controversy as a result of Darwin "not believing… that God created everything" and angering "Christians." By making this claim he is positioning himself as knowledgable, but we can also detect uncertainty in his contribution. Teacher 1 revoices *J*'s contribution, then allows *M* (who raised her hand) to offer her own thoughts.

M aligns herself in agreement with *J*, lending support to his animation of a specific religious group in conflict with the ”sacreligious" and elaborating on a characterization of Darwin's opposition by alluding to historical conflict between religious groups. Teacher 1 responds with an indirect contradiction that offers an alternative characterization of Darwin's opposition, saying "it wasn't just Christians, like Darwin pissed a lot of people off." The teacher seizes her authority as a knower in a move that directs the conversation away from animating one group as Darwin's opposition. Teacher 1 then returns the class to her original question about Redi and Spallanzani, widening the frame of reference for thinking about controversy beyond Darwin alone. She animates a source of opposition to previous scientific findings and explicitly positions herself as someone who is "not arguing with that or what that means," but is instead trying to make a point about how many scientists throughout history have found themselves in conflict with the wider culture.

Just as *J* responded to his teacher's question about other scientists by jumping to the topic of Christian controversy and Darwin, a student in Teacher 5's class did not allow his teacher to proceed unimpeded towards the frame she was building around controversy:

> ***Teacher 5:*** Okay, good. Alright so here is very quickly my disclaimer. I know that this is a uh, what would you call it, controversial topic. Um we are in a science class yes you do have to know um pieces of evidence of common ancestry, you have to know that for your test, um you have to know about the mechanisms that actually cause evolution to work, yes, you do have to know that for your test, okay? Today and next time we're just going to, we're going to look at and talk about like facts, (bringing right fist into open left hand repeatedly) facts that actually exist, okay, that support common ancestry. (Gesturing at screen) This video, it. Sometimes there's a misconception that. We came from apes, no that's, that's not. (Shaking head). We have a common ancestor with them, millions of years ago.
>
> ***Students:*** What is it?
>
> But didn't the video just show
>
> ***Teacher 5:*** But that, no what it's portraying is that there's a change of...
>
> ***Student:*** But
>
> ***Teacher 5:*** Now I'm not going to argue with you and I'm not gonna make you believe whatever it is, you believe whatever you want I am just showing you sheer facts. *D*, yes?
>
> ***D:*** Um, you're just saying all this because like some people don't believe in evolution right?
>
> ***Teacher:*** That's correct *D*. It is a con:troversial topic.
>
> ***D:*** It is so obvious I -
>
> ***Teacher:*** Yeah hey hey hey we're not going to argue about it, okay (extending hand with fingers out, palm facing student). That could go on and on and on forever.

The teacher attempts to position students towards the video with her lengthy "disclaimer" that for the purposes of their class, tests, and activities, "facts that actually exist" support the idea of common ancestry. She makes her claims with few markers of uncertainty. Then the teacher carefully states that it is a misconception that students had an ape ancestor before asserting that humans and apes had a common ancestor.

One student asks, "but didn't the video just show," referring to a clip they had watched from a popular science television program that portrayed humans as having ancestors who resembled apes in many ways. The teacher interrupts this student, rejecting his bid for the floor. Despite the student's attempt to interrupt his teacher again and reclaim the floor the teacher talks over him, and positions him as a source of conflict with whom she is "not going to argue." She references students' beliefs as a possible source of conflict that will not be dealt with in this setting and she positions herself as a knowledgeable authority: "believe whatever it is you believe, whatever you want, I'm just showing you facts."

D asks the teacher, "You're just saying all this because like some people don't believe in evolution right?" The teacher tells him he is correct, repeating and emphasizing her designation of common ancestry as ”a con:troversial topic." But *D* attempts to take a strong stance as knowledgeable in respect to this controversy, saying "It is so obvious I" before his teacher interrupts him and positions him as another person with whom she is "not going to argue."

Evolution itself was not designated as one of the controversial topics in science Discourse during Teacher 5's class, even though the teacher began the class by telling students that the theory of evolution was their focus for the day. Teacher 5 began her class by addressing classroom business, and then opened a regular discussion (held every other Friday) of where students had seen "science in the news." This open discussion format allowed students to raise the topic of controversy over claims being made about the big bang and even a pseudoscience study of same-sex couples:

Teacher 4: …Okay anything else science in the news?

M: Everyone like, uh, last time I went to church uh with my mom everyone was talking about like, uh, some people, like you know, it was like that hasn't happened yet. They were talking about how there's science and there's religion. But like they were arguing about how like, the big bang theory happened and all that, and they were arguing about how like, how do you know God didn't start the universe and blow it up?

Teacher 4: Yeah so that's one of those things, right, that we talked about at the beginning of the year, how like everything we talk about in here, it's all stuff that follows the scientific method. Right, but things like philosophy, religions, faith, those types of things, you can't test them using the scientific method. So really it's not fair to compare the two, um, I know a lot of scientists that have no trouble like merging their faith with science like they don't have an issue doing that. So, um. K?

K: I read something about the man that is at a university, in Nigeria I believe, and he used like different types of experiments to prove that like, gay marriage isn't real, like it wasn't real, like it just wasn't, a thing. And like magnets, with like poles

Teacher 4: with magnets?

K: yeah like, only the opposite, like, types will attract each other, therefore it's not even real and I was just like, what does that, what?

Teacher 4: Yeah, so they would be a case where. that's actually a good example of sometimes there's studies that you read about that didn't follow the scientific method. and you have to be careful about those particular studies.

Although there are many things that could be highlighted about this exchange, it exemplifies a particular finding in the analysis of these classroom conversations: open discussions allowed space for students to raise the issue of cultural controversy surrounding scientific Discourse, which may in itself have made these open discussions a fearful proposition to science teachers. Yet when controversy arose, it offered a powerful opportunity for teachers to take a clear stance, clarify ways of knowing in science, and emphasize how they wanted students to engage with scientific Discourse.

Teacher 4 used this opportunity to explain that for some claims, "you can't test them using the scientific method," and took a stance that echoes Gould's (1997) characterization of Non-Overlapping Magisteria: "So really it's not fair to compare the two, um, I know a lot of scientists have now trouble like merging their faith with science." When a student raises the problem of a study that claimed to be scientific but offered confusing evidence against gay marriage, the teacher seized the opportunity to issue a warning about "studies that you read about that didn't follow the scientific method."

When controversy arose in her classroom, Teacher 5 chose to emphasize that she was presenting "sheer facts," whereas Teacher 1 chose to highlight that science has never been a stranger to cultural controversy, that Darwin "built on other people's ideas," and that " the most widely accepted theory of evolution right now is the one that we're gonna talk about that Darwin came up with about evolution by natural selection." Although it is not the purpose of this paper to evaluate the quality of stances taken by these teachers, the point here is that controversy in the classroom can be treated as an opportunity to clarify the ways of knowing and doing in science Discourse, instead of as something to be minimized or avoided.

Theme 3: Positioning Students Towards Scientific Discourse: Science as Product or Process

In this section, I will review each of the teachers in turn, supplying a broad interpretation of how the participant framework build through classroom talk and the stances taken by teachers ultimately combined to frame scientific Discourse as the class began a lesson on the theory of evolution.

Teacher 1

Teacher 1 began her lesson with a discussion by asking students a question centered on collective prior knowledge: "What do we know about Charles Darwin?" Her discourse moves, including open questions, revoicing, and repetition of student language, facilitated a participant framework in which students were positioned as knowledgeable contributors. Students collaborated in building a description of who Charles Darwin was and how he formulated his theory.

The teacher initated discussion of controversy over scientific theories when she claimed that Darwin was "not liked very well by a lot of people" and connected their talk about Darwin to two scientists the class had previously studied: "Who remembers why Lozaro Spallanzani and Francisco Redi were not liked by a lot of people?" In response, students were quick to animate "Christians" and "Catholics" as the source of opposition to Darwin. The teacher partially rejected this characterization before other students could lend additional support to it, saying "It wasn't just Christians, Darwin pissed a lot of people off." Then she repeated her question about Spallanzani and Redi, trying to return to a broader historical frame for controversy in science.

The teacher took a neutral stance towards other ways of knowing, but also used this stance-taking as an opportunity to position the theory of evolution a scientific Discourse and position students toward their task:

> ***Teacher 1:*** So, they made people mad too because what they said was life comes from other life when in reality people used to think. Oh, well, life happens because of god or gods decided they wanted that life to be there so they put it there. Which I'm not arguing with that or what that means, but at the same time what I'm saying is that throughout the ages you have these scientists who've pushed people's thinking and pushed their anger buttons in the process by espousing ideas and theories that weren't very popular. So we're gonna talk about Darwin's theory and what it was. What I want you to remember through this process is that. If you find that, that the things we're talking about push your anger buttons with respect to your religion. That's okay. Because all we're really supposed to learn about in here is what the currently held theories are in science. And the most widely accepted theory of evolution right now is the one that we're gonna talk about that Darwin came up with about evolution by natural selection. So what I'm gonna do here is we're gonna explore what his ideas were and why he came up with the ideas he came up with.

The teacher has done multiple things with this segment of talk. She has highlighted that scientists work within a Discourse that has a long history and has often run into opposing Discourses. She positions herself as neutral towards religious thinking and its meaning. Then, she validates the positions, emotional reactions, and other ways of knowing that belong to students "with respect to your religion" while also positioning them as vulnerable in a discussion that may "push your anger buttons." She positions the class towards natural selection as the "most widely accepted theory of evolution right now," but does not make any assertions of its truth value. Instead she frames their instructional activities as an examination of how scientists reason their way towards "ideas," regardless of truth value.

By encouraging students to build on collective knowledge when introducing the topic, highlighting science as a field with historical context, and emphasizing a neutral, intellectual position towards evolution as a "widely accepted theory," this teacher has built a complex frame around scientific Discourse. A relatively open classroom discussion engaged students in "talking science" as a social process of meaning-making, and the teacher has emphasized conflict around and within scientific Discourse by discussion religious opposition to theories and refraining from making any bold claims about the truth value of Darwin's theory.

Teacher 2

In contrast to the other teachers examined here, Teacher 2 did not have any student talk in the time leading up to the day's activities. Instead, he attended to classroom business, and framed the students' lesson on evolution as part of that classroom business.

> ***Teacher 2:*** All right a couple of things that we need to get done today, okay. One is… we're going to watch a, uh, video on natural selection, okay. Those are things that are going to help an organism survive in the wild, could be a coloration change, could be they're a little bit faster, could be they blend in a little bit better. All these different things, okay? So. So we have a sheet that we'll fill out when we get there when I give this to you what I need you to do is just read through it so you see what the questions are, what you're looking for when the video starts. Okay? The other thing when we get done with the video, the other thing is we're gonna do, we have an article up here called ***. What we're gonna do is a little sheet at the end only eight questions shouldn't take you that long, use it, help you with the test. This'll be turned in. Okay? The video sheet and this one. Now. One other thing. I'm sorry that's 15 questions. Some of you still you were absent or you were slow getting stuff done last time. You've got stuff that you need to take care of and get to us, folks. Grades are in, some of you are way behind already simply because you haven't taken care of your business. Get it taken care of, put your phone up. Questions, comments? It'll take me a minute to get the video up and going. All right, read the questions.
>
> ***Student:*** (approaches teacher, inaudible)
>
> ***Teacher 2:*** Read the questions.

This participant framework stresses that authority over knowledge rests with the teacher and the popular science television program that students are about to watch. The theory of evolution by natural selection is largely instrumental to students filling out their worksheets. Ultimately, this brief interaction frames scientific Discourse as its products, a means for getting through science class, and without internal or external conflict. Despite how Teacher 2 represented a notable contrast from other teachers included here, it would be unfair to compare the teachers within this project. Instead, the way that Teacher 2's brief, authoritative introduction to the day's activities offers a glimpse into how sometimes, for whatever reason (perhaps time constraints, habits, teacher goals, etc), classes frame the Discourse of science in a way that is at odds with the research on scientific literacy.

Teacher 3

In Teacher 3's case, classroom talk emphasized an authoritative command of scientific vocabulary and concepts. The participant structure largely emphasized teacher knowledge, but opened brief slots for students to demonstrate that they were keeping up with a process of reasoning. Below is the transcript of the discussion from the point after a student asked, "But couldn't some babies be shorter?"

> ***Teacher:*** But over time. This is over hundreds of years, the genes are slowly shifting and there's more tall alleles in the population so more people are ta:ll. All right? (pause) Um so we say that intelligence is actually polygenic so you have the really smart people the average people and the not-so-bright people. So say the aliens came and they wanted to study all the average people at [our school] so, they took all the average intelligent people away to go to wherever they're from. Right, so who's left?
>
> ***Students:*** Smart dumb
Smart and the not smart
Smart and stupid
>
> ***Teacher:*** Smart and the not smart. So over time then the bell curve has that big hump in the middle. All the average ones were taken away, so there's a bunch of not smart people, not very many average people, and a bunch of smart people. Okay, it's that disruptive. So you'll have to be able to know that disruptive, what it means and that it has that curve. And finally, let's say there are, Darwin observed finches and they have beaks, and the medium sized beaks are the perfect size to get, to eat these certain berries. The medium sized beaks. The ones that are too long can't quite grab it, the ones that are too short, um aren't strong enough to chew it. So the medium sized beaks are the best, so the long beaked birds and the short beaked birds die off and who's left the

> mediums so the whole bell curve shrinks in, that's stabilizing. Okay? (Pause) So that's what, we're doing evolution next.

As previously examined, here the teacher minimized a student's idea that conflicted with the collective line of reasoning, and knowledge throughout this discussion was largely located in the teacher. The structure of Teacher 3's talk was essentially a lecture. This particular instance of discourse modeled the process of reasoning within a theory or definition, but did not cultivate dialogue, problem-solving, or the other hard work that it takes to reach such a consensus. The teacher has framed scientific Discourse in a way that emphasizes its products – definitions and the concepts they contain – while deemphasizing process or context.

Teacher 4

In Teacher 4's class, the regularly held, open discussion of "science in the news" provided a recurring opportunity to frame scientific Discourse and connect with what students are seeing, hearing, and reading about science in their daily lives. This class was initially included in the analysis because the theory of evolution was the day's topic; surprisingly, evolution was not one of the topics this class designated as "controversial," but their discussion of science in popular media brought up conflict surrounding the Big Bang Theory and even pseudoscience that purported to somehow disprove gay marriage.

Teacher 4 used open questions to prompt discussion, positioned students as knowledgeable contributors, and appeared to have a framework in her classroom that made students feel comfortable challenging her, taking the floor, and occasionally raising taboo topics and clowning. For example:

> ***Teacher 4***: It's from hell creek, what was it? (looking at computer) Hell creek geological formation in Montana and North Dakota, so it's kind of like double meaning, like chicken from hell
>
> ***J:*** What did they name it?
>
> ***Teacher 4***: cause it's crazy

J: What did they name it?

Teacher 4: big but also like it's

J: The uh, cause I read an article that whatever they named it it was like the mythol, the mythologic…al god. of. like, bird from hell.

Teacher 4: Oh! I didn't, I did not read it

J: It's like az- az- aznu- or something, it's, yeah! Yeah anzu.

M: Where's his babies at?

Teacher 4: Very cool. Alright, any (raising hand)

M: Where's his babies at, like the…

Teacher 4: I don't, I don't want to know.

M: are they coming back? (poses like a t-rex/the ancient bird in the picture, makes noise) rarr rarr

Teacher 4: well, so this was just a fossil right, so this doesn't live anymore but the thing I thought was pretty crazy is they show this claw, that they found, like this (scrolls to it) that's a claw from the chicken.

T: Can you imagine if we still had these things running around

Teacher 4: I know!

M: That'd be cool!

T: Right you'd have to carry a gun to school

Teacher 4: Yeah, um, okay.

T: We'd have cubbies when you walked in, and you, whenever you left you're just gonna carry it around

Teacher 4: (nodding) yeah

Y: I forgot my gun at home

Students: Laughter

Teacher 4: Um, anybody else? (raising hand) Science in the news?

As previously examined, when the next two students raised the idea of controversy with the Big Bang theory, the teacher took the opportunity to emphasize what the scientific method could and could not test, and took a stance similar to other teachers in this study by emphasizing "everything we're talking about in here, it's all stuff that follows the scientific method." She also positioned science and religion as two Discourses that need not be in opposition, saying "really it's not fair to compare the two, um, I know a lot of scientists that have no trouble like merging their faith with science like they don't have an issue doing that." She nonetheless warned her students about "studies that didn't follow the scientific method," emphasized features of how scientists reason, and positioned popular media and news as a suspicious source of information about studies while also encouraging students to pay attention to the findings reported there. Ultimately, Teacher 4's practice of opening a lesson with these discussions every other week, and the classroom talk that made up that discussion on this particular day, positioned students as knowledgeable contributors and scientists who were working together to evaluate the claims made around them. The talk examined in Teacher 4's classroom framed science as a group process of critical inquiry based in the scientific method.

Teacher 5

Teacher 5 opened her class's discussion of evolution by having students collaborate in a think-pair-share activity where they responded to an open question. Yet as their discussion unfolded, various challenges to classroom management arose: students began to negotiate meaning around the theory of evolution but were often overwhelmed by conflict and overlapping talk:

> ***Teacher 5:*** You need to be more specific. *D*, yes mam.
> ***D:*** We still have thousands and thousands of different species on this planet because we all evolved from thousands and thousands of different species before. And since we have evolved those species, some of those species don't exist anymore, because we are them? We are just more evolved versions of them if that makes sense.
>
> ***Teacher 5:*** Are we them?
>
> ***Students:*** Loud indecipherable chatter
>
> ***Teacher 5:*** Okay, hold on! Hold on *J*.
>
> ***D:*** We evolved from them!
>
> ***J:*** No we actually did not!
>
> ***Students:*** (Loud indecipherable chatter)
>
> ***Teacher 5:*** Shh! Shh! Shh! *J*, what did I say?
>
> ***J:*** We are not dinosaurs!
>
> ***Teacher 5:*** All right, we're going to stop discussion if we don't raise our hands.

As previously explored, the teacher responded by making moves to position the Discourses of science and religion in opposition to each other, and positioned herself as an authority who did not want any of their struggle to get in the way of "sheer facts" and "facts that actually exist." She emphasized these facts as a means to students succeeding on their test and took a similar stance to the other teachers who emphasized how the science classroom focuses on one particular way of knowing.

Ultimately, even though Teacher 5 attempted to engage students in a collaborative process of reasoning and evaluation, her moves to minimize controversy contributed to framing scientific Discourse in a way that emphasized its products. Teacher 5's experience highlights the well-documented tension that can arise for teachers who want to facilitate a classroom's social framework and position students as knowledgeable, yet find students' contributions emphasizing opposing knowledge and ways of thinking as well as disrupting the smooth functioning of the classroom.

CHAPTER 5

Discussion and Conclusion

In this study, I sought to explore how high school science teachers talk about "controversial" theories in their classrooms and how their language positions students towards the Discourse of science. Using techniques derived from discourse analysis, I examined how five teachers' language contributed to locating knowledge within the classroom, how students were positioned towards the evaluation of claims about contemporary scientific theories, and ultimately how these instances of classroom interaction framed the Discourse of science as students turned their attention to the day's activities learning about the theory of evolution by natural selection.

Discussion of the Findings

Researchers examining classroom talk and science instruction have highlighted the challenges posed to teachers who must attend to the social environment of their classroom while also helping students develop mastery within a specific discipline. In this section, I discuss how this study's findings contribute to an understanding of the way teachers respond to challenges as they work to cultivate scientifically literate discourse practices.

Revoicing as a tool to build structure and content

The teachers in this study used revoicing to control the tone of discussion, encourage and amplify student contributions, and to emphasize students as the source of knowledge claims. One of the greatest surprises to come out of this close examination of classroom talk was the way teachers who took up students' contributions often verged on revoicing, but instead only used repetition. Repetition can amplify the power of a student's words, but it does not always offer them authority over their meaning. Moreover, the distinction between repetition and revoicing is illustrated when repetition of a student's words offer brief evaluation in an I-R-E pattern, denying students true authority over the content and pace of discussions.

Revoicing continues to be a powerful tool for aligning students with classroom content and each other. Yet revoicing can be problematic when teachers animate students as the source of claims without checking with the student. In some cases, the teacher's own reasoning and wording can change the reformulated claim until it loses a clear connection to the student's speech. Would O'Connor and Michaels (1993) recognize such reformulation as revoicing, or is it a different discursive move altogether? Perhaps our definition of revoicing could be expanded to emphasize student's authority over meaning. By taking the extra step of checking with learners about whether the teacher has correctly conveyed their meaning, or by offering students a chance to clarify their claims without teacher input, teachers can make sure they are actually using a powerful technique that has proven its value in classroom settings.

Taking a stance during controversy

Among teachers examined here, openness to student contributions also opened the discussion to conflict and controversy. When controversial topics arose, teachers took an explicit stance in the discussion – Teacher 1 took a stance that recognized how religious students might have valid emotional reactions to content, emphasized how in the science classroom "all we're really supposed to learn about" are theories and findings based in the scientific method, and asserted that evolution is "the most widely accepted" theory. Teacher 3 took a stance that she was presenting "sheer facts" that students would need to complete their coursework, and that therefore she was "not going to argue" with students or their beliefs. Teacher 4 emphasized that science and "philosophy, religions, faith" involved different ways of knowing, and emphasized "the scientific method" and the process of using evidence to corroborate hypotheses about how the world works. Yet in the absence of controversy, Teachers 2 and 3 still implicitly took the stance that scientific concepts in the classrooms were either a means to completing coursework or largely conclusive definitions.

How can teachers prepare for controversy? While Oliviera et al (2009) have emphasized framing controversial topics as an intellectual discussion, they note that there is still division over whether teachers are better off positioning themselves within this discussion as impartial facilators without stance, or if it is better for them to disclose their personal views without necessarily advocating for those views. These findings suggest that teachers who want to use discussion can benefit from prior reflection on how they will communicate a clear position when controversy arises, knowing that students often need little prompting to recognize controversial topics and select features of the warring Discourses behind them. The stance taken by a teacher can emphasize discipline-specific values as opposed to the more general social values of equality, tolerance, and difference of opinion.

Controversy is an opportunity to explicitly emphasize why the scientific method is valued, highlight the understandings that are implicit in current scientific research, model scientific language, and position students as scientists who are reasoning together. Classroom conflicts can become moments when teachers are direct about students regarding epistemological issues and stance alongside the teacher's goals for student participation.

Framing scientific Discourse through the structure and content of talk

These findings illustrate that although science teachers may be united in the stance that the science classroom is a setting which privileges scientific norms for knowledge, reasoning, and talk, there is wide variation in how they build positions upon that stance and ultimately frame scientific Discourse. Conscientious framing matters because the world outside the classroom will undoubtedly present students with competing and often suspicious claims about what science can and cannot do, and what questions the scientific method can and cannot answer.

In the episodes examined here, Teachers 1 and 4 largely framed scientific Discourse as a process of inquiry in sociohistorical context; this framing was supported by how the teachers invited student knowledge contributions in a participant framework that complemented the teacher's claims about science. In the classroom talk of Teachers 2 and 3, closed or highly controlled participant frameworks were accompanied by authoritative discourse that ultimately framed scientific Discourse as a relatively settled series of conclusions. Teacher 5 offered an interesting glimpse into how an open structure does not guarantee that teachers will relate to their students in a symmetrical, dialogic participant framework – instead, the conflict and challenges that result might lead teachers to reassert their authority over the social environment of the classroom. Moreover, teachers using an open participant structure may still emphasize an authoritative view of scientific Discourse, using language which frames science as its products despite an activity structure designed to emphasize process.

Our exploration of a handful of episodes in contemporary science classrooms builds on the work of researchers (e.g., Crawford 2009; Radinsky et al, 2010; Ford, 2012) who have drawn connections between what Oyler (1996) called the "content" and "process" dimensions of authority over meaning-making in classroom discourse, and highlights how these two dimensions can interact during classroom activities surrounding evolution. The structure of talk and the messages sent through that talk are not always in agreement. Structures for student talk which are designed to engender the collaborative negotiation of meaning will not necessarily contribute to framing science as a social process of learning if they are not complemented by the teacher's own stance on scientific topics.

Limitations of the Study

Because this project relied on video data from a larger, unrelated study, it offers a limited understanding of context and lacks the perspective of individuals who participated in these classroom interactions. Every class has a history which undoubtedly influences the participant frameworks, conversations, and shared knowledge going into a particular lesson. I could not check with the teachers and students whose talk was analyzed here to get a deeper understanding of how they interpreted their classroom interaction, nor could I examine how individuals engaged with their personal process of decision-making during conversation.

Because this study focused on the detailed investigation of a few key scenes, the results cannot yield generalizations about effective instructional practices in different contexts. Moreover, this study examined the introduction of evolution, which is only one of many controversial topics that arise in the science classroom. Evolution is largely a problematic topic for students because it comes into conflict with religious Discourse. It's possible that topics which are secular controversies (e.g., global warming) pose their own distinct challenges in educational settings.

Implications for Future Research

Future research in this area can help deepen our understanding of the connections between social structures and knowledge claims in classroom settings, as well as how both contribute to helping students develop their own scientifically literate practices. There are endless possibilities for scientific literacy researchers to continue building connections between the detailed analysis of classroom talk and the constructs and measures developed in research surrounding topics such as instructional practices, teacher preparation, motivation, and academic emotions. Researchers examining classroom talk can expand on our understanding of the contextual features that inform the way students negotiate meaning during classroom discussions of controversial topics.

This study examined only the introductory period of a lesson. Future researchers could examine how participant structures change and shift authority over knowledge claims during different activities from the beginning to the end of the class period. How do these shifts change the overall frame for scientific Discourse, and how does the framing of scientific Discourse connect with student mastery of content?

Contemporary research into how learners position their identities relative to larger Discourses could also expand into the realm of controversial science topics. Which Discourses are most salient to students as they engage in difficult classroom discussions? How might a student's multiple identities – as a learner, a scientist, a church member, a peer – affect the decisions they make about raising their voice and taking a stance in the classroom? Research in classroom discourse can help further illuminate the processes of personal development and social conflict that students experience as they take on scientifically literate discourse practices.

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