EXAMINING THE EFFECTS OF TEACHING ASSISTANTS' RESPONSIVENESS THROUGH TALK MOVES ON STUDENT EXPLANATORY RIGOR IN AN UNDERGRADUATE BIOLOGY LABORATORY COURSE

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ABSTRACT

EXAMINING THE EFFECTS OF TEACHING ASSISTANTS' RESPONSIVENESS THROUGH TALK MOVES ON STUDENT EXPLANATORY RIGOR IN AN UNDERGRADUATE BIOLOGY LABORATORY COURSE

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The purpose of this study was to examine the ways that teaching assistants (TAs) enact talk moves in the classroom and how those enactments may change over time. Further, the TAs responsiveness to student ideas was examined in an attempt to understand how TA responsiveness impacts the rigor of student discourse. Tracking talk move patterns in TAs across time in addition to examining relationships between TA responsiveness and student explanatory rigor during an elicitation discussion has not been previously studied at the post-secondary level. A mixed-methods approach was employed to collect both quantitative and qualitative data through coded and statistical analysis of classroom transcripts taken in an introductory biology laboratory course at a large research university in the United States. Results from the study show that there were not statistically significant trends in TA talk move patterns across the semesters under investigation, suggesting need for restructured TA pedagogical training. Results from the study also demonstrate a clear, statistically significant relationship between TA responsiveness, as determined by talk moves and the explanatory rigor of student contributions. Specifically, high rigor contributions can only be achieved when coupled with ambitious instructor responsiveness. Further results indicate the importance of TA language use when pressing students for explanations, the TA patterns in moving student talk from low to high rigor, and specific talk moves that contribute to the highest student explanatory rigor. Implications of this study will be of interest to postsecondary science educators, researchers, and professional development creators who work to reform and improve science education.

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CHAPTER 1

INTRODUCTION

Background

High quality science learning involves students collaboratively learning how and why natural phenomena occur, and teaching to support this vision includes instruction that is responsive to students' ideas. Because student thinking plays a critical role in educators' daily work, eliciting student thinking as resources for learning becomes crucial for productive sense making. Educators often use pedagogical tools such as talk moves to direct classroom conversations toward and sometimes away from student learning. However, using student ideas as resources is a challenge for both novice and veteran educators, alike. Teaching assistants are undergraduate and graduate students charged with educating college students across a variety of education levels. While these teaching assistants are largely responsible for much of the introductory curriculum at larger universities, they are often given little pedagogical training prior to their assignments. There is a lack of research focused on teaching assistants' pedagogical skills, especially when examining how their teaching strategies change over time. In a multiple semester long investigation of teaching assistants talk move habits in an undergraduate biology laboratory course, we identified which talk moves teaching assistants utilized in response to student ideas and how those talk moves changed over multiple enactments of the same course over multiple semesters. Additionally, we investigated the link between teaching assistants' responsiveness to student ideas and how it affected the rigor of student talk. The results of this study speak to the design of teaching assistant specific pedagogical courses to improve overall pedagogical strategies. It should be noted that nearly all of the previous research with which this project was built on was conducted in K-12 settings. Throughout this literature review, the majority of our sources provide research examples from a population different than our interest. However, because of the dearth in this work being done in post-secondary contexts, the translation of K-12 research literature to higher education seems appropriate.

Statement of the Problem

Orchestrating effective student discussion is difficult for most educators, especially teaching assistants (TAs) who have little to no pedagogical training and yet are asked to teach a multitude of university undergraduates in science (Gardner & Jones, 2011). Further, to support explanatory talk in the classroom, educators need a foundation of core practices to draw upon (Grinath & Southerland, 2018). For those TAs that use discourse practices such as talk moves, it is unknown as to which moves TAs tend to use, nor how TAs use these talk moves for productive classroom discussion and for the elicitation of science ideas. There are no studies exploring TAs' use of talk moves over identical lessons and multiple semesters. Given the understanding that many educators teach the same lessons multiple times per day, as well as teach the same courses across multiple years, it is important to investigate how and if teaching practices evolve. Further, in response to these talk moves, it is not clear how student discourse rigor is influenced by the TAs' responsiveness. There is much evidence supporting the claim that classroom rigor cannot be maintained without educator responsiveness, but such a relationship has yet to be studied in the university science classroom (Thompson et al., 2016). Therefore, it is important to better understand how a TA's use of talk moves influence the rigor of student discussions.

Theoretical Framework

The theory of social constructivism, developed from Lev Vygotsky's sociocultural theory, drives this thesis (Vygotsky, 1978). Vygotsky's sociocultural theory explains how individuals learn and suggests that when students participate in collaborative learning efforts, students then share their individual experiences and prior knowledge with each other. Jaramillo (1996) states that "social experience shapes the ways of thinking and interpreting the world" (p. 135). This philosophy paves the way for the theory of social constructivism, which is not a singular isolated theory, but rather a continuum of theories surrounding individuals' understanding of the world. Prior experiences, beliefs, and understandings develop an individual's perspective of life, and because each individual has unique experiences, each conception of the world is also unique. Therefore, new knowledge is constantly constructed and framed within the context of existing ideas (Jaramillo, 1996). Social constructivism integrates Vygotsky's sociocultural theory in order to posit that students are better able to construct knowledge, comprehend new information, and advance understandings when collaboratively interacting with their peers. Therefore, when taking a social constructivist perspective on teaching, providing students the opportunities to share and make their experiences public with fellow classmates becomes an essential aspect of whole-class learning. When students are able to share their unique perspectives, more opportunities arise for problem solving and sensemaking compared to when students are working in isolation.

Ambitious science teaching (AST) characterizes a coherent and accessible vision for K-12 of how highly effective science instruction can affect how students learn about science, particularly by building on the diversity of student experiences for sense making and progressive knowledge building (Windschitl et al., 2018). One of the primary goals the AST framework seeks to promote is teaching science in ways to help students refine their thinking about the natural world (Ambitious Science Teaching, 2014). Eliciting student ideas as a basis for instruction is necessary to promote rigorous scientific understanding in the classroom. Michaels and O'Connor (2012) provide a definition of eliciting discussions as directed conversations with goals to "uncover students' prior experience or knowledge about a phenomenon or topic, provide insight into their thinking, and pique students' interest in new learning" (p. 3). This practice recognizes the social nature of science and how prior experiences, cultural understandings, and individual exposure influence how students act and form their initial ideas about a phenomenon (Longino, 1990). This is one of the major tenets in all of educational research, and extensive research has supported the principle that prior knowledge has influence on response to instruction and knowledge building (Bransford et al., 2000; Cook & Ausubel, 1970; Gage, 2009). These prior forms of knowledge can be stitched together from stories in the media, conversations with family, prior instruction and education, and everyday observations (Windschitl et al., 2018).

Each of these prior experiences can be considered individual resources because they have the potential to guide and support learning. The language regarding how resources influence science learning can be attributed to growing literature on how science learning happens outside of formal schooling, suggesting a student agency component in learning (National Research Council, 2009). Maskiewicz and Winters (2012) postulate that resources can be concrete, phenomenon-specific intuitions and experiences that form scientific theories in the classroom context. Others suggest student resources are epistemic and thought to support the ability for students to contribute to activities in generating knowledge (e.g., analogy work, argumentation, modeling) which can then guide classroom inquiry activity (Hammer & Elby, 2012; Louca et al., 2004; May et al., 2006). Maskiewicz and Winters (2012) propose the terms "resources" be used rather than “expertise”, “knowledge”, “beliefs”, “skills”, or “conceptions”, in order to stress that students’ contributions are built from fragmented and context-sensitive ideas that can be used to build scientific knowledge within the correct framework and instructional guidance. It is important to note that these student resources are not just for teachers to use, but for their peers to use as well. However, in order for the classroom community to use individual resources, thinking has to be made visible to others, and educators must properly implement the AST practice of eliciting student ideas (Danish & Enyedy, 2007; Linn & Hsi, 2000; Radinsky et al., 2010). While some of these resources can be useful in guiding student learning, some may be problematic. Current literature suggests that if educators do not take the time to understand the resources students bring to the classroom, students will continue to use their resources to form science knowledge (Windschitl et al., 2018). It seems logical then for educators to cultivate the eliciting practice in order to reveal students’ existing ideas and their ways of reasoning about scientific phenomena (Ambitious Science Teaching, 2014). AST implores the importance of using the practice of eliciting student ideas to not only ground the educator in recognizing what students know, but also to tailor classroom instruction around these preconceived resources that students present. In the constructivist conceptual framework, individual student resources become valuable components in classroom conversations, especially considering the collaboration of multiple student resources can dramatically advance the construction of individual knowledge and the reformation of world views.

Moving toward a social constructivist approach from an individual construction of knowledge approach is supported throughout education literature. Hodson and Hodson (1998) emphasize that when individual learning is prioritized, student learning can be isolated, and their ideas can be reinforced regardless of if they are scientifically correct. Further, because each individual student has unique resources to be used in the classroom, to support individual construction of knowledge ignores the importance and utility of the social setting for learning (Driver et al., 1994). Vygotsky notes that “individuals interact with one another in social situations to socially negotiate meaning” and, thus, a student’s development “cannot be understood by a study of the individual; we must also examine the external social world” (Jaramillo, 1996, p. 136). The classroom ought to be considered an egalitarian setting, and therefore the curricula should seek to facilitate connections between students. The center of productive forms of classroom talk integrates discourse between students. Because of this, student ideas as resources become prime components in not only supporting an open classroom, but also in constructing knowledge, only when educators recognize the important role these resources take in pedagogy.

Social constructivism has played a critical role in a variety of research fields ranging from mobile technology learning to physics and mathematics education (Hammer, 2000; Nesher, 2015; Thinley et al., 2014). Science education, however, has much to learn from her sibling fields of academic study, and social constructivism has numerous applications. Fleer and Robbins (2003) suggest that “teaching should take account of…present conceptions” while using students’ rich and complex ideas to create common meaning and understanding of science ideas (p. 418). Levin et al. (2009) support that learning science “involves learning to attend to - and to assess – ideas and reasoning” (p. 143). Responsive teaching, or teaching in which educators take up students’ thinking and focus on student ideas in their moment-to-moment interactions, becomes a critical component in recognizing student ideas as valuable resources. Because eliciting student ideas in the classroom seeks to uncover such complex student resources, responsive teaching and classroom discourse become embedded in constructivism.

Purpose of the Study

The purpose of this study was to examine the ways that teaching assistants (TAs) enact talk moves in the classroom and how those enactments may change over time and how the responsiveness of TAs influence student rigor. In the study, six introductory biology lab TAs enacted an instructional activity, eliciting student ideas, in which they presented students with a phenomenon and elicited the students' initial ideas about possible scientific explanations for that phenomenon. In doing so, the TAs drew upon specific talk moves to meet the goals of rigor and responsiveness in their teaching. The TAs enacted the same instructional activities multiple times for different class sections across multiple semesters. To examine these enactments over time, and to better understand how TAs' responsiveness elicits student ideas, a longitudinal multiple case study approach will be employed. Videos of individual TA enactments were transcribed and coded for talk moves in order to see patterns across time. Talk moves were coded using previously described metrics based on the talk moves described in the ambitious science teaching framework (Grinath & Southerland, 2018; Windschitl et al., 2012). The TAs' responsiveness to student ideas, determined by the previous mentioned framework, was examined in an attempt to understand how TA responsiveness impacts the rigor of student discourse. The results of the study are relevant for scholars and preparers of TAs at the post-secondary education level and for all educators engaged in repeat teaching.

Research Questions

The questions that guide our research are as follows:

1. What are the talk moves that TAs utilize to elicit and respond to student ideas while teaching an undergraduate biology laboratory course and how do those talk moves change over multiple enactments?

2. How does the responsiveness of the TAs affect the rigor of student discourse?

Significance of the Study

This research has implications not only for further educational needs for TAs at the undergraduate level, but also for post-secondary education contexts where an instructor has multiple sections of the same class each day. By better understanding the talk moves that TAs tend to lean on more heavily, and how those practices may change over time while repeating classroom discussions, better TA and other educator training can be designed, utilized, and taught to both novice and experienced TAs.

Organization of the Study

In the following chapters, we frame our work within the context of current research and literature in post-secondary education. We outline our research context and methods, describe our findings, and we discuss the significance of this work for educators at all levels.

In chapter 2, we review the overarching framework of ambitious science teaching and describe in detail the importance of eliciting student thinking in science instruction in a way that helps drive curriculum and the learning process. Then, we discuss many of the challenges educators face when eliciting student ideas, and we share mostly K-12 classroom evidence of educators struggling to use student ideas as classroom learning resources. Next, we discuss the importance of classroom discourse in building scientific knowledge, and we share research supporting that classroom talk plays an essential role in providing opportunities for students to learn from one another. We then discuss the role pedagogical tools known as talk moves play in supporting the sense making and scaffolded discussions in the classroom to promote deep understanding of complex concepts and robust reasoning. Then we define rigor and responsiveness in the context of this thesis and examine the relationship between instructor responsiveness and the rigor of science discourse and work. Finally, we investigate the lacking research focused on teaching assistants’ discourse patterns, and we highlight a gap in science education literature.

In chapter 3, we describe our research methodology, including the context in which the research was conducted and the participant selection criteria. It is here where we also describe our coding schema and methods of case study and longitudinal analysis.

In chapter 4, we present findings for both research questions. We use a mixed methods approach to display our findings in both qualitative and qualitative manners. We discuss longitudinal data findings, patterns of TA talk moves, and the associations between rigor and responsiveness. Chapter 4 is also where we dissect several classroom elicitation discussion transcripts to demonstrate some of the patterns and findings related to our research questions.

In chapter 5, we discuss the findings in depth to make meaning from the results. We discuss the lack of pattern in TA talk moves over multiple enactments and why that is concerning for educators dedicating classroom time to teaching ambitious science principles. We also discuss the specific talk moves used for each rigor level and why the responsiveness of TAs directly influences the rigor of classroom talk. In chapter 5, we will also address a discovered talk move pattern that assists moving students from initial low rigor responses to high rigor responses.

In chapter 6, we conclude the thesis by finalizing the most important findings and how these findings can assist educators at all levels in better implementing responsive talk moves that encourage high rigor among students. We also address limitations, implications, and future directions for ambitious science teaching talk move research.

CHAPTER 2

REVIEW OF LITERATURE

Ambitious Science Teaching

Ambitious science teaching (AST) characterizes a coherent and accessible vision of how highly effective science instruction can affect how students learn about science, particularly by building on the diversity of student experiences for sense making and progressive knowledge building (Windschitl et al., 2018). Windschitl and colleagues (2018) describe the goal of AST as the following:

> The goal of AST is to help students of all backgrounds to deeply understand fundamental science ideas, participate in the practices of science, solve authentic problems together, and learn how to continue learning on their own. The kind of teaching required to achieve these goals is adaptive to students' needs and thinking, and maintains rigorous standards for participation and performance by everyone in the classroom. More importantly, the practical ideas that make up this vision have been tested in a wide range of classrooms, and they continue to evolve as teachers use them. (p. 3)

Recently, science education has been introduced to this framework for ambitious instruction (Windschitl et al., 2012), but the notion of ambitious education originates from math and English curriculum. AST heavily focuses on allowing all students to participate in challenging science, while simultaneously making science compelling to diverse learners and providing opportunities for students to demonstrate what they learn. It should be noted that the AST framework was designed and is often researched only in K-12 education, and few studies extend the AST framework in post-secondary contexts. The framework, provided by Windschitl and his colleagues (Thompson et al., 2013; Windschitl et al., 2012) introduces four core practice components:

1. Designing instruction around big ideas,
2. eliciting student ideas to adapt instruction,
3. supporting ongoing changes in students' thinking by using authentic investigations in an effort to move initial ideas to scientific ideas, and
4. drawing together evidence-based explanations.

The research presented in this thesis will focus on the second core practice for AST: eliciting student ideas to adapt instruction. However, in an effort to give a concise understanding of the other three practice components, I will provide brief explanations of each practice.

The first core practice set is planning for engagement with big science ideas. Because not every science idea in a curriculum is worth teaching, it is important to frame science ideas into a coherent "big picture" for learners. Windschitl et al. (2012) define big ideas as "substantive relationships between concepts in the form of scientific models that help learners understand, explain, and predict a variety of important phenomena in the natural world" (p. 888). Big ideas are far more robust than traditional curricular topics, as big ideas seek to provide deeper and more comprehensive scientific understanding that can be linked across multiple curricular topics (Nersessian, 2009). It is also critical to recognize that a big idea is not simply an event, but rather a relationship between a natural phenomenon and the underlying causal explanation (Windschitl et al., 2018). Therefore, big ideas will provide an underpinning throughout weeks of instruction, and the causal explanations will provide student opportunities to design and use genuine scientific investigations.

The second core practice is eliciting student ideas to adapt instruction. The goal of this practice is to elicit what students know about a puzzling event related to a critical scientific idea and then to analyze students' ways of engaging with that event to adapt further instruction (Windschitl et al., 2012). If the main objective as a science teacher is to change and challenge students' thinking over time, then teachers must know what the students understand about science ideas. Numerous studies have supported the notion that allowing students to participate in initial conversations while referring to their own experiences and ideas greatly influences their intellectual engagement and overall learning (Magnusson & Palincsar, 2005; Rosebery et al., 2010; Windschitl et al., 2012). Teachers need to select a rich scenario with which students interact and this scenario selection requires planning for student conversations. An eliciting lesson begins with framing, which leads the students into a conversation about the reasons for investigating a particular set of ideas. This helps students put the activity into a meaningful context before it begins, and it makes explicit the kinds of participation expected from them. Planning for a rich task to go along with a selected phenomenon can reveal a range of student thinking and understanding about the big idea previously mentioned (Windschitl et al., 2012). Teachers then elicit observations from students about the phenomenon, and encourage students to discuss and share their initial causal hypotheses about the phenomenon. Depending on the context of the scenario, students might be encouraged to construct a model of the phenomena, relating it to the driving question. Modeling is the process by which scientists demonstrate and share their ideas about the natural world. They collaboratively make changes to these representations over periods of time when new evidence and understandings emerge (Windschitl et al., 2018). This practice is important in that it not only allows students' ideas to be made public and for students to work with their preconceptions to form scientific understandings, but it also acts as a tool for teachers to synthesize what students currently know and what they need to know. This allows educators to adapt and shape further instruction.

The third core practice is supporting ongoing changes in students' thinking by using authentic investigations in an effort to move initial ideas to scientific ideas. In light of a specific phenomenon under investigation, this practice uses students' initial theories and ideas to build scientific content knowledge by merging previous knowledge with classroom literature and investigation (Windschitl et al., 2012). Conceptual science knowledge emphasizes students constructing and critiquing theories and models, justifying positions and scientific claims, and generally explaining ideas to other classmates (Rosebery et al., 1992). After features of the big idea are shared to the class, the teacher encourages students to examine the unobservable events, processes, and dynamics in order to better understand the big idea. The students then work together with their own experiences and investigations to postulate theories and ideas regarding the shared phenomenon (Windschitl et al., 2018). The practice of supporting ongoing changes in students' thinking is metacognitive and an intentional examination of one's ideas, as the practice demands student interaction in a way that allows students to make sense of other's experiences and views. This form of collective science work has been associated with deep conceptual science understanding and the patterns observed in science phenomena (Mercer, 2008; Minstrell & Kraus, 2005; Rojas-Drummond & Mercer, 2003). This practice also involves shifting the social language students use associated with science ideas to more academic language, which supports students' thinking and understanding of foundational science language, and therefore, science ideas (Scott & Mortimer, 2005).

The final core practice of AST is using and establishing evidence-based explanations. AST establishes new experiences, additional language, and new ideas throughout the course of a science lesson; however, simply amassing scientific knowledge is not the goal of AST. Instead, students should be able to develop more robust understandings by incorporating the ideas and pieces of evidence from a multitude of classroom activities and conversations (Windschitl et al., 2018). By pulling together evidence from a plethora of classroom events, students advance their current explanations and scientific models. Therein lies the goal of this fourth practice: to assist the construction of evidence-based explanations for a specific phenomenon regarding a science unit. There is overwhelming evidence supporting the tenet that a more coherent understanding of science ideas is formed when students use evidence-based explanations to discuss science ideas as opposed to reproducing textbook explanations (Smith et al., 2000). Hausmann et al. (2009) states that using "prompts designed to focus on problem-solving steps led to a sustained level of engagement with the examples" (p. 2626). Thus, the complex interaction between prior knowledge, cognitive processing, and changes to the learner's ability to comprehend science ideas is enhanced when students use evidence-based explanations in science. Further, when teachers encourage rigorous discourse regarding a science phenomenon in the K-12 classroom, students are more proficient in referencing evidence and using it to support explanatory claims (Colley & Windschitl, 2016).

AST outlines a powerful and useful framework for science teaching to ensure equity and rigor for students from all backgrounds and experiences. AST frames this thesis given that the core practice of eliciting student thinking is central to methods and questions this project aims at answering. While AST practices are being used in schools and districts across the world, little evidence exists in which the AST framework is implemented in college classrooms. Eliciting student ideas is a fundamental practice in order to investigate classroom discourse and talk moves. It should be noted that the literature reviewed in this thesis leans heavily on work done in

K-12 education, primarily because of the lack of post-secondary studies and the multitude of K-12 reports. While some of the literature sources used in this literature review do directly relate to post-secondary education, much of the K-12 work will be used to forecast similar science education experiences in the post-secondary setting.

Challenges to Eliciting Student Ideas

Eliciting student ideas through the use of talk moves will not, alone, ensure rigor. Simply knowing that productive classroom talk is important is not enough to guarantee that it happens. Similarly, requiring educators to use evidence-based discussion and argument does not spontaneously create a rigorous classroom environment (Michaels & O'Connor, 2015). For educators and researchers alike, it has been a goal to tackle the challenges of helping educators improve skills in facilitating discussion in order for students to lead classroom discourse with explanations, justified claims, and evidence. However, despite the ever-growing research knowledge and professional development strategies, the majority of science teachers at the K-12 level continue to use teacher-led group talk centered around IRE patterns (Michaels & O'Connor, 2015). These teacher-led dialogues are predominately void of any reasoning and evidence-based discussions in the science classrooms, and professional developments often only result in modest changes for teachers (Billings & Fitzgerald, 2002). These modest changes do not seem to last, as teachers may move away from IRE patterns temporarily, but do not consistently take on the more deeply transformative practices and sequences correlated with robust discussion (Alvermann et al., 1990; Alvermann & Hayes, 1989; Kucan, 2009).

One of the major examples demonstrating the challenges educators face in eliciting student ideas and engaging their students in higher order thinking comes from Corcoran and Gerry (2011). Observations from 55 elementary, 37 middle school, and 29 high school science classrooms were evaluated using rubrics aligned with reform-based teaching. Fewer than one third of observations contained any type of higher order thinking. While the classroom lessons seemed well organized, Corcoran and Gerry (2011) suggested that the students were disengaged and that didacticism dominated the instruction. Studies have begun to demonstrate that teachers struggle with integrating and embedding talk tools within complex instruction (O'Connor & Michaels, 2019). While teachers may use talk moves often in K-12 contexts, they struggle applying these tools in well-structured and coherent instructional situations. Further, teachers face the challenge of developing an understanding as to what is worth talking about within a science conversation and how to use student contributions in ways that push the curriculum forward while supporting student inclusion. Once ideas are elicited, what do teachers *do* with these ideas? Eliciting student ideas encourages classroom conversation and discourse as a driving influence in the learning process for students in the classroom; however, many teachers never experienced this style of education while they were learning. Thus, teachers tend to recite the talk moves in K-12 contexts rather than use them for reasoning purposes while eliciting student ideas (O'Connor & Michaels, 2019). Many of the shifts currently being made in new teaching standards require teachers to realign their deeply entrenched talk patterns, which can be an enormous challenge and one that often cannot be fixed through simply learning about the theory of talk moves to elicit ideas.

Getting students to share their ideas in the classroom continues to prove difficult for educators. Because this thesis is focused on the responsiveness of students and instructors alike, understanding the difficulties to eliciting student ideas is fundamental for learning how to overcome such obstacles. Eliciting student ideas encourages discourse as one of the primary learning mechanisms, and such discourse is of particular interest in this thesis as we investigate how teaching assistants elicit and respond to student ideas over time and how such responsiveness influences the discourse rigor.

Role of Classroom Discourse

According to constructivist theories of science education, one of the key learning products is building on student resources as tools for learning. Because students come to the classroom with a variety of diverse understandings and experiences, it is important for educators to explore their students' existing resources to direct and build new science knowledge (Posner et al., 1982; Treagust & Duit, 2008). Therefore, classroom talk plays an essential role in providing opportunities for students to learn from one another as well as for educators to determine student resources while leading them towards science understanding. There are clear connections between classroom talk, specifically student's opportunities to dialogically reason with classmates, and student growth in complex forms of understanding (Windschitl et al., 2012). There is growing evidence that the science classroom should be treated similarly to the science community, in terms of encouraging and allowing educator mediated student discourse. With active science dialogue, these classrooms work as a community to produce sophisticated forms of knowledge and activity, ultimately creating a more stimulating learning environment compared to student memorization and reproduction of learning material (Engle, 2012; Minstrell & Kraus, 2005). Productive classroom discourse not only provides a more robust knowledge of complex science ideas, but it also provides students with the opportunity to engage in the authentic practices of the science discipline such as argumentation.

While a classroom climate that best mirrors the complex science community appears beneficial in theory, the application is challenging in practice. It takes an educator who is acquainted with the teaching frameworks and their practices to effectively use student talk as a social resource for learning. For novice educators, the practice of using student talk as social resources for learning has proved to be exceptionally challenging and is rarely observed in science classrooms (Roth & Garnier, 2006a). Lemke (1990) suggests that classroom dialogue consisting of reasoning and cross talk between classmates is seldom seen in the traditional K-12 science classroom. Thompson et al. (2013) found that novice secondary teachers were often able to initially engage students in science discourse, by using a demonstration or puzzling phenomenon, but struggled in supporting classroom talk after sharing initial ideas. Further, these teachers were unsure as to what purpose the classroom discussions served, suggesting a need for discourse-based practices to frame patterns and instructional moves to encourage learning.

Inclusive and robust classroom talk in the sciences diverges from the historical design of classroom dynamics, where educators lead classroom instruction, discussion, and activity to passive students (Grinath & Southerland, 2019; Schwarz et al., 2016). Further, traditional K-12 science instruction uses an "Initiation – Response – Evaluation" (IRE) pattern, where a teacher begins a dialogue with a question, waits for a student to respond, and then evaluates that response as either correct or incorrect (Lemke, 1990). This IRE pattern is used until a correct answer is given and provides minimal interactions from the students in the classroom. Lemke (1990) maintains that this type of classroom "dialogue" does almost nothing to encourage conceptual thinking or to engage students in building visible science knowledge. Further, the IRE pattern can discourage student participation and can eliminate discourse altogether. Because IRE puts such an emphasis on the "correct" answers, students may fear incorrect answers, creating a stigma around responding to questions in general. This stigma signals that classroom talk must always arrive at the "correct" answer, consequently excluding the critical role "incorrect" answers attribute to creating a classroom that mirrors the science community such as advancing knowledge, discourse, and considering methods (Grinath & Southerland, 2019; McNeill & Pimentel, 2010).

Opportunities to participate in classroom discourse are fundamental for student learning, and the meaning-making process should always be considered in the context of classroom discourse. Social interactions in the classroom are rarely accompanied by considerations of individual student understandings, yet literature provides theoretical bridges between social activities and individual learning (Southerland et al., 2005). This perspective emphasizes the dual nature of individual and social learning and considers them both necessary facets of the learning process: “learning is a constructive process that occurs while participating in and contributing to the practices of the local community” (Cobb & Yackel, 1996, p. 19). Therefore, using this theoretical framework is critical in understanding the important role of classroom discourse; to have a better understanding of classrooms and learners includes a consideration as to how group construction of meaning influences an individual’s science learning.

It is clear that classroom discourse is essential for student growth in complex forms of understanding, and we also know that novice and experienced teachers both struggle with supporting a classroom environment rich in student talk. For this thesis, understanding the critical role classroom discourse plays in supporting classroom learning is fundamental in studying student learning and the tools teachers can use to support learning. There is no doubt the full spectrum of educators need some direction as to which discourse-based practices are the most effective and the moves necessary for achieving a productive classroom environment.

Talk Moves

It is widely accepted that well-structured talk in the science classroom promotes academic learning, and without student discourse, the construction of science knowledge begins to fade. But simply acknowledging that productive classroom discourse is important, and encouraging educators to engage in talk with their students, is not enough to guarantee that it happens (Michaels & O'Connor, 2015). Therefore, in classroom research on disciplinary teaching and learning, much research has focused on understanding collections of pedagogical moves that educators use in moment-to-moment teaching to work with and publicly share student ideas (Leinhardt & Steele, 2005; Michaels & Connor, 2012). These moves are considered "talk moves" and are defined by Thompson et al. (2016):

> [Talk] moves provide students with opportunities to express and clarify their ideas and for teachers to support students in elaborating ideas, deepening their reasoning, and building norms for classroom talk so that students can routinely engage in these complex forms of social reasoning. (pg. 6)

A variety of K-12 researchers have attempted to identify sets of recurring moves that shift conversation from recitation to reasoning, thus supporting students as they build on their peers' ideas. Because of this, there is a variety of language used in education, specifically science education, to describe talk moves. It, once again, should be noted that most of this research work has been done in K-12 contexts, with a lack of post-secondary research studies interested in talk moves. Most of what our research team used for literature is being translated to the post-secondary context from K-12 work. Michaels and O'Connor (2015) distinguished specific talk moves as *productive* talk moves from their linguistic and interactional value. These productive talk moves go beyond common classroom talk, such as the evaluation move in the IRE sequence, or simply K-12 teachers repeating a students' idea from an implicit evaluative angle. Their findings, coupled with support from other literature, supports the notion that any teacher who succeeds in supporting productive discussion relies on a core set of talk moves, such as ways of eliciting and responding, commenting, and inviting responses (Berland & Reiser, 2009; Kim et al., 2011; Michaels & O'Connor, 2015; Osborne et al., 2004; Wells, 2007).

There are many types of talk moves, some of which aim to acknowledge students' contributions, including *revoicing, recapping, invitations to say more*, *add on*, or *agree/disagree*. Others, described in the ambitious science teaching framework in an effort to elicit student ideas, are considered more ambitious (Grinath & Southerland, 2019; Windschitl et al., 2012). These ambitious talk moves include *probing questions* and *pressing for explanation*. Research supports the principle that a responsive classroom cannot be accomplished without a specialized repertoire of talk moves that educators and students use together. When examining student learning, expert teaching, and knowledge building in science, classrooms are now thought to be communities that can form productive reasoning only when educators and students use careful orchestrations of talk (Engle, 2006; Leinhardt & Steele, 2005; Minstrell & Kraus, 2005; Scott & Mortimer, 2005). Thus, talk moves support the sense making and scaffolded discussions in the classroom, which are thought to be the "primary mechanisms for promoting deep understanding of complex concepts and robust reasoning" (Michaels et al., 2008, p. 284). Talk moves aimed at promoting dialogue that include discourses such as explaining reasoning and peer-to-peer cross talk have been defined in education research literature aimed at K-12 levels of science education (Lemke, 1990; McNeill & Pimentel, 2010; Michaels et al., 2008; Oliveira, 2010).

We know when teachers elicit student ideas using open-ended questions that require student reasoning and explanations, students are more likely to not only participate, but also to explain and reflect on their answers (McNeill & Pimentel, 2010; Oliveira, 2010). When it comes to how instructors use talk moves beyond K-12 education, we find less evidence, suggesting a need for further studies within higher education contexts. Talk moves, therefore, are important pedagogical components to study in higher education, specifically among teaching assistants (TAs), due to the limited TA training prior to teaching a course and the overall lack of research focused on this population. If that limited training focused on responsive and ambitious talk moves, the small changes made by TAs in how they gather and work with student ideas might help institute and sustain higher degrees of explanatory rigor in classrooms (Grinath & Southerland, 2019). While the language around which talk moves are considered *ambitious* or *productive* can differ, it is clear that not all talk moves are equally powerful in moving students toward ideas. However, developing and using a repertoire of talk moves is essential for supporting productive discussion.

Rigor and Responsiveness in Science Classrooms

The environments and expectations of students in a science classroom can vary, and the differences between classrooms can be attributed to the relationship between classroom responsiveness and intellectual rigor. For an educator, responsive teaching can be characterized as teaching in which educators take up students’ thinking and focus on student ideas in their moment-to-moment interactions. Student ideas become valued resources to be used in the learning process. In combination with responsive teaching, educators must also continually do work to support and sustain classroom rigor. Rigor can be characterized as an interaction between learners and those responsible for supporting learning, suggesting that rigor and the quality of teacher support and responsiveness are closely related. Educator responsiveness and rigorous science work, therefore, go hand-in-hand.

Instructor Responsiveness

As the classroom is considered a community of learners, it is important to carefully examine the talk of both students and teachers. K-12 research agrees that teachers' talk mediate increasingly productive forms of student reasoning and activity (Colley & Windschitl, 2016; Engle, 2012; Minstrell & Kraus, 2005; Sfard & McClain, 2002). According to Michaels and Connor (2012), sense making can be considered a form of reasoning, requiring students to act on ideas. These actions include: comparing and contrasting ideas, elaborating on ideas, questioning the coherence of an idea, assessing credibility while using evidence, forming multiple representations of an idea, reconstructing group ideas, and the application of collective ideas to a variety of situations. It is important to note that when students participate in the sense making process, they articulate their actions through the cooperation between their own experiences and that from academic sources, such as a teacher. From a sociocultural framework, students participate in intellectual work on a social plane within the classroom, suggesting that students work with peers in a less organized way to access reasoning, work through uncertainty, and discern how knowledge and evidence adapt over time (Brown & Campione, 1996; Colley & Windschitl, 2016; Scardamalia & Bereiter, 2014). Therefore, an educator that recognizes and subsequently accommodates this classroom dynamic of social sense making will use students' experiences, questions, and ideas to influence and direct sense-making conversations.

Creating a definition for responsiveness is complex, given the multifaceted nature of responsive teaching and the subjectivity it can carry. Pierson (2008) characterizes responsiveness in K-12 settings as the “attempts to understand what another is thinking, displayed in how a conversational partner builds, questions, probes, clarifies, or takes up that which another has said" (p. 25). Pierson extends this definition to include the extent to which teachers “take up” students’ thinking, while simultaneously using those ideas in moment-to-moment interactions. She defined two forms of “high” responsiveness: “High I” responsiveness is demonstrated when a teacher responds to student reasoning to help align it with targeted teaching concepts and ideas. For example, this could be correcting a misconception. “High I” responsiveness puts teacher reasoning on display, whereas “High II” responsiveness puts the student reasoning on display. During episodes of “High II” responsive teaching, a teacher focuses on the students’ meaning and logic, with the intent of understanding it on its own (Levin et al., 2009). Pierson’s study found a strong correlation between “High II” responsiveness and student learning in K-12 contexts.

Thompson et al. (2016) used literature and research analysis of K-12 classroom responsiveness to construct three dimensions critical for responsiveness: building on students' science ideas, encouraging participation and building classroom community, and leveraging students’ lived experiences while building science stories. In order to have a complete picture of responsiveness in the classroom, it is vital to understand a teacher’s synchronized use of all three dimensions (Thompson et al., 2016).

To understand teacher responsiveness to building on students’ science ideas, two primary actions must be considered. The first deals with how to evaluate student ideas when students publicly share their ideas; research examines pedagogical moves teachers can make in the moments of teaching to advance student science ideas (Cohen, 2012; Mercer, 2008; Michaels & Connor, 2012). Moves such as revoicing, add on, agree/disagree, and say more give an opportunity to dissect student’s ideas, giving the classroom a chance to deepen understanding and reasoning. Perhaps an even greater advantage of talk moves is the ability for teacher responsiveness to cultivate the growth of classroom standards that include science discourse as an integral part of the classroom dynamic. A classroom routine that consistently engages in complex forms of social reasoning will result in students with richer scientific understanding (Thompson et al., 2016).

Teacher responsiveness, however, involves more than simply responding to students' scientific ideas. Responsiveness is an essential function of classroom connection building, where the community of students make meaning through linking ideas (Scott & Mortimer, 2005). Educators' responsiveness will directly impact if students use ideas or if classroom discourse is encouraged. Because responsiveness can carry multiple meanings, it is important to note that not all responsiveness necessarily advances the goals of ambitious teaching. For many, responsive teaching may look like showing respect for students' ideas, while letting all students participate in sharing their thoughts. For others, responsive teaching may include being respectful of student contributions or being affirmational in classroom conversations (Ambitious Science Teaching, 2014). While these teaching habits are necessary and appropriate for creating a stimulating class environment, these actions are not considered "responsive" by our definition primarily because there are no instances in which an educator treats a student idea as a resource for the class to use.

Beyond the talk move strategies that an educator employs, the other primary action that must be considered deals with how the classroom discursive culture is upheld. Mercer (2008) claims that a classroom culture emphasizes how language is used for collective student learning. In order for these forms of classroom talk to emerge and encourage student learning, teachers are required to design highly demanding and cognitively rich tasks. Beginning a lesson with highly rigorous and responsive tasks or questions is critical to preserving sense-making conversations for the rest of the lesson or unit. In fact, research continues to demonstrate that responsiveness during highly cognitive activity is a significant predictor of students' opportunities to learn (Jackson et al., 2013; Stein & Lane, 1996).

As previously described, classroom discourse that incorporates students' lived experiences is necessary for meaningful science learning and understanding. It is critical that educator responsiveness supports such discourse in responsive ways that merge student's stories with science stories. Such responsiveness will provide an emphasis on authentic learning contexts allowing new opportunities for students to identify with science (Moje et al., 2004; Paris, 2012; Thompson et al., 2016). In practice, educators often must decide "when to work with and on students' ideas and when to focus on canonical science ideas" (Thompson et al., 2016, p. 3). This can create tension between constructing science understanding and answering questions correctly. While there have been few examples of how educators use responsiveness to engage students in science instructional activities, studies support the notion that when students' experiences are deliberately used to understand science, a multitude of benefits surface. According to Barton and Tan (2009) and Moje et al. (2004), when educators allow students' stories to be revealed, the knowledge-authority roles are reversed, and new science information can be linked to lived experiences. These studies found that teacher responsiveness resulted in an increase in students' science participation and classroom community.

Rigorous Science Work

Rigorous work helps characterize ambitious teaching. It is work that presses learners to extend their current understanding to participate in scientific discourse. Rigor does not simply imply "challenging work", nor is it a set of performance standards expected to be reached (Windschitl & Barton, 2016). Windschitl and Barton (2016) define rigor as "a characteristic of the interactions between learners and those responsible for supporting learning" (p. 1101). With this approach, multiple influences determine rigor including the standards or performances particular to a task, the quality of educator support, and the learner's intellectual activity. In order for work to be considered rigorous, there is dependence on all of these conditions working together (Windschitl & Barton, 2016). As previously described, being initially responsive to students' resources as essential components to the process of doing science is critical for engaging in science discourse. At the same time, such responsiveness is fundamental for establishing and maintaining rigor in the science classroom (Jackson et al., 2013; Windschitl & Barton, 2016). The interconnected nature of responsive teaching and rigorous science work has been analyzed in K-12 contexts, and Thompson et al. (2016) found that explanatory rigor cannot be attained in moments where teachers are unresponsive to student thinking. Conversely, when teachers are responsive to student ideas as resources and partial understandings, simple activities can be transformed into rigorous sense-making opportunities (Grinath & Southerland, 2019; Thompson et al., 2016). A plethora of projects focused on K-12 classrooms support this work, and they all agree that classroom discourse that publicizes students' resources, questions, and reasoning lifts the rigor of learning experiences (Engle, 2006; Michaels & O'Connor, 2012; Scott & Mortimer, 2005; Thompson et al., 2016). These studies support the findings from Windschitl and Barton (2016) concluding that rigorous work is not a single moment or attribute that needs to be "added" to increase the difficulty of science work. While an appropriate goal of a science lesson may be for students to generate knowledge through investigation, in order to sustain explanatory rigor teachers must support such rigor across multiple instructional activities.

Within the context of the science classroom, rigorous talk can take many forms. Much of the literature focuses on rigorous talk as the substantive ways students collaboratively construct scientific explanations, also known as explanatory rigor (Thompson et al., 2016). Rigorous scientific explanations closely resemble scientists' work, given that scientists engage in complex and rigorous reasoning about certain phenomena that extends far beyond simply describing observable patterns. Scientists must posit hypotheses, while working within a framework, by using evidence and judgement regarding science knowledge claims (Duschl, 2008). Classroom dialogue presents several challenges in attempting to differentiate pseudo-rigorous conversations from rigorous conversations. In pseudo-rigorous conversations, students and educators participate in short "clips" of dialogue that heavily rely on facts and vocabulary terms appropriate for that specific topic. This type of conversation differs from rigorous conversations, which may not yet have the accuracy of commonly accepted scientific terminology (Lemke, 1990). Rigorous discourse, then, can be framed as helping students move toward an idea or helping students make progress on ideas, which can be done in a multitude of ways, but requires a responsive teaching environment. According to Palincsar and Magnusson (2001), comparing first-hand student experiences, or resources, with known scientific ideas and concepts is one of the many ways an educator can facilitate student progress on ideas. Through this interaction, students are given the opportunity to develop specific language, helping them see science as both relatable and human, as well as giving them ownership of their ideas.

The relationship between educator responsiveness and rigorous science work pertains to this study given that we seek to understand how the responsive of TAs affect the rigor of student discourse. Because literature has demonstrated that discourse rigor cannot be maintained nor sustained in the absence of responsive teaching at the K-12 level, it is therefore critical that TAs take up students' thinking and focus on student ideas during their instruction in post-secondary contexts. While the link between rigor and responsiveness has clearly been demonstrated and supported, this literature will provide a foundation in our thesis investigating a not-yet studied population of TAs in the post-secondary classroom setting.

Investigating Teaching Assistants' Discourse

In education literature, especially science education research, there is a lack of knowledge in the longitudinal work that educators do. We are unsure as to how teaching practices may or may not change over time, and if they do change, the driving reasons for such changes are unknown. This inquiry is of interest when studying TAs, as these instructors typically teach similar classes over several semesters, but without much pedagogical training. When educators use and experiment with new discursive practices in their classrooms, researchers face the task of tracking discourse patterns of whole-class dialog or components of an ambitious classroom (Colley & Windschitl, 2020). While Colley and Windschitl (2020) developed and used a visual "barcode" representation to recognize and inquire about supportive conditions occurring with higher rigor science talk, there is still no research that has investigated how TA talk moves change over the course of multiple classroom or activity enactments. The barcodes and similar representations may be beneficial for educators and researchers to visualize what is happening in the classroom across time, but distinct talk moves and how they advance or minimize classroom rigor remains unseen (Colley & Windschitl, 2020).

In one of the few research studies investigating TA responsiveness to student ideas, the researchers suggest that TAs need practice and preparation to notice and engage with students' reasoning (Hill et al., 2018). This study investigated how TAs attended and responded to students' written lab reports in an introductory biology course. The results showed that TAs were primarily cognizant of specific writing styles, and there was evidence that a TA's understanding of the purpose of the laboratory course and assessment influenced their attention to student ideas.

This study also found that TAs could shift their attention from style to reasoning in response to some moment-to-moment contextual cues (Hill et al., 2018). TAs' attention to reasoning is sensitive to context, shown in this study, when TAs' attention is attracted by novel ideas and influenced by features of the context of their lesson. While this paper fails to discuss or offer longitudinal suggestions for the same lesson across multiple iterations, it offers a unique insight into the limited research using the TA population of instructors.

In another one of the few studies investigating TA responsiveness, Grinath and Southerland (2019) investigated how different TA talk moves supported explanatory rigor for undergraduate biology students. The study was designed in hopes of better understanding how TA moves are related to instances of highly rigorous scientific discourse in the biology classroom. While the study fails to discuss or introduce a longitudinal discussion of TA talk moves, it does conclude that the most important aspect of TA talk for sustaining highly rigorous student explanatory discourse was the TAs' responses to student contributions while addressing the TA's initiating questions. Therefore, both the eliciting question offered by a TA coupled with a TA's response to the initial question are both foundational for the most explanatory rigor (Grinath & Southerland, 2019).

There is limited research focused on TAs, yet TAs are tasked with the challenge of instructing college aged students. While limited, the research that does exist suggests that TAs need substantial work and training when it comes to using and engaging with student reasoning. TA talk moves and TA responsiveness to student contributions have been shown to be a critical factor in sustaining a rigorous science classroom, and this thesis aims at further understanding the relationship between the two in a cohort of university TAs.

Summary

The AST framework aims at teaching science in a new way that enables students to improve their thinking about the natural world, and eliciting student ideas rests at the core of ambitious instruction. Elicitation discussions in the science classroom allow the opportunity for educators to uncover students' prior knowledge about a topic, which can be used to direct whole classroom learning. Eliciting students' ideas supports the social nature of science outlined in the theoretical framework within which this thesis is founded. Prior experiences, cultural understandings, and general exposures dramatically influence how students act and form initial ideas about a phenomenon. The practice of eliciting student ideas is one many educators across education levels agree is essential for classroom learning; however, evidence demonstrates that the majority of classrooms do not use student ideas as resources. Traditional IRE patterns of learning continue to exist and rigorous classroom conversations are seldom witnessed. Classroom discourse and conversations are essential in order to form complex scientific understandings, and much research supports the notion that without discourse and the communal sense making process, rigorous science knowledge ceases to exist. However, simply acknowledging that productive classroom discourse is important does not promise it will happen. Educators must use specialized pedagogical moves that shape and direct the moment-to-moment conversations in the classroom. These talk moves give students the chance to express and refine their science ideas, while simultaneously allowing educators to support student ideas and press for reasoning. There are a collection of talk moves that tend to drive classrooms toward more ambitious learning, and there are others that are far more conservative. An educator's talk moves, coupled with responsiveness, both help dictate overall classroom rigor. When an educator is responsive to their students' ideas, they take up their thinking and focus on student ideas as means to steer whole classroom learning. Research continues to support the claim that without educator responsiveness, classroom rigor cannot be maintained at any level of education. There is almost no research aimed at understanding the longitudinal work that teachers do. We are unsure as to how teaching practices, talk moves, and patterns change over time. This is especially true for TAs in higher education and post-secondary contexts. For TAs, evidence suggests that these educators need substantial work and training to use, and engage with, student ideas. Therefore, the questions that guide our research are as follows:

1. What are the talk moves that TAs utilize to elicit and respond to student ideas while teaching an undergraduate biology laboratory course and how do those talk moves change over multiple enactments?
2. How does the responsiveness of the TAs affect the rigor of student discourse?

CHAPTER 3

METHODS

Research Design

A longitudinal multiple case study utilizing a convergent mixed methods design was used in order to explore the patterns of TA talk moves across multiple semesters as well as to describe the relationship between the TAs responsiveness to student ideas and the rigor of student discourse during elicitation discussions. The convergent mixed methods design was a “single-phase approach” where “a researcher collects both quantitative and qualitative data, analyzes them separately, and then compares the result” in order to see if the findings confirm or disconfirm each other (Creswell & Creswell, 2018, p. 217). This methodology builds from the historic concept of the multimethod, multitrait principle from Campbell and Fiske (1959), who believed some research questions, specifically in psychology, could only be best understood by gathering multiple forms of data. The quantitative component of the study consisted of using TA talk move data, across 3 consecutive semesters, to explore patterns and statistical significance. The quantitative component also included using statistical tests on moment-to-moment transcript data to find relationships between talk move category and student rigor level within each case study. The qualitative component of the study consists of describing talk patterns found at each level of student rigor responses. The convergent mixed methods design methodology, used in tandem with case studies, allowed us to examine how the responsiveness of the TAs to student ideas, determined by talk move category, affects the rigor of student discourse during elicitation conversations, and how those patterns may change across three semesters.

For this study, a single case was defined as all of the enactments from a single TA. There were 18 enactments in total, as 6 TAs enacted the same elicitation discussion over 3 semesters.

Our intent was to better address how the TAs’ talk moves and responsiveness influenced classroom rigor among students, an area of research yet to be explored, while simultaneously adding to the body of literature targeted at understanding pedagogical changes teachers make over time. This study focused on the multiple lab sections TAs taught across at least 3 semesters because TAs are assigned and expected to teach many different courses during their time at a university or college. Because TAs often have little pedagogical training, it was especially important for us to study how ambitious science practices were used within the context of the same course over multiple semesters.

Participants

Participant Selection

All TA participants gave their informed consent before their inclusion in this study. Each participant selected met the criteria that the TA taught at least 3 different consecutive semesters. Because the research question seeks to provide insight into how talk moves change over a period of longitudinal teaching, it was crucial that selected TAs had multiple teaching semesters. Of the 21 TAs in the general biology laboratory program, 6 met the sampling criteria. Each TA was responsible for two lab sections of 24 students, and each lab met one time each week for 12 laboratory investigations during a single semester. In this study, each TA had three cases of interest, totaling 18 cases in all. The boundaries of a case were defined by the first semester and lab section a TA was responsible for teaching, the final semester and lab section a TA was responsible for teaching, and a random semester and lab section between the first and final. Table 1 demonstrates the semester and section selected for each of the three cases per TA. Four of the six TAs listed medical school as their post-graduation plans, and two of the six TAs listed graduate school as their post-graduation plans. Four of the six TAs self-identified their gender as male and two of the six self-identified as female. The criteria for case selection and boundary were based on the available data and the targeted longitudinal research question.

Table 1

Selected Semesters for Analysis

TA	Case 1	Case 2	Case 3
Fred	Fall, 2nd class	Spring, 2nd class	Spring, 2nd class
Paul	Fall, 2nd class	Fall, 1st class	Spring, 2nd class
Sally	Spring, 2nd class	Fall, 2nd class	Spring, 2nd class
Scott	Fall, 1st class	Spring, 2nd class	Fall, 2nd class
Tracy	Fall, 2nd class	Fall, 2nd class	Spring, 1st class
Vince	Fall, 1st class	Fall, 1st class	Spring, 2nd class

Note. TA: teaching assistant.

Teaching Assistants

At a large university in the Southeast U.S., 21 TAs in total taught all of the 42 introductory biology laboratory sections, and these 21 TAs were selected from undergraduate biology majors. To qualify for a TA position, an undergraduate biology student must have been considered a junior by credit with a GPA higher than 3.3 in biology and chemistry courses. Further, undergraduate biology students must have completed at least two upper division biology courses. The course administrators interviewed all of the applicants and asked each applicant to come prepared by reading an excerpt about biology education from the *Vision and Change for Undergraduate Biology Education* report (American Association for the Advancement of Science, 2011). During the interviews, applicants were asked to demonstrate how they would implement the recommendations made from the reading as a lab TA if they were to teach a section. Applicants were further asked how they would encourage students to share their unique ideas and experiences in the classroom and how the applicant would know when students were actually learning and understanding the classroom concepts.

Students

The general introductory biology laboratory course included 42 lab sections, each with an average class size of 24 students. All of the students enrolled in the general biology laboratory course during the semesters of the academic years relevant to the study were considered to participate in this study. Information for each of the classroom sections for all 18 enactments can be found in Table 2. All student participants gave their written informed consent before they were included in the study. For most students, the general introductory biology laboratory course was used to fulfill the science lab requirement for the liberal studies curriculum for the university, and the majority of students were not biology students nor did they express plans to pursue biology or other science disciples as a major. Because of this, the population of students used in this study demonstrates and represents a diverse field of motivation and attitude toward biology as a discipline.

Table 2

Student Enrollment per Semester Section

TA	Case 1	Case 2	Case 3
Fred	24 students (11M, 13F)	24 students (6M, 18F)	21 students (13M, 8F)
Paul	24 students (6M, 18F)	24 students (13M, 11F)	17 students (10M, 7F)
Sally	24 students (6M, 18F)	24 students (8M, 16F)	24 students (8M, 16F)

Scott	24 students (7M, 17F)	24 students (8M, 16F)	24 students (7M, 17F)
Tracy	17 students (9M, 8F)	22 students (11M, 11F)	24 students (8M, 16F)
Vince	24 students (11M, 13F)	24 students (3M, 21F)	24 students (7M, 17F)

Note. TA: teaching assistant. M: male, F: female.

Context

University and Course Context

The university context for this study was a large research university in the United States, and the course context was a general introductory biology laboratory course enrolled in by predominately nonscience majors. The university had a diverse student body, with women and minorities representing 57% and 30% of the student population, respectively. There were approximately 1,000 students enrolled in the biology laboratory course each semester, split between approximately 42 individual laboratory sections each semester. Each laboratory section met once per week for a 2 hour class period. The *Framework for K-12 Science Education* (National Research Council, 2012) and the *Vision and Change in Undergraduate Biology Education* report (American Association for the Advancement of Science, 2011) were used to design and focus the core biological concepts for the laboratory curriculum.

Course Curriculum

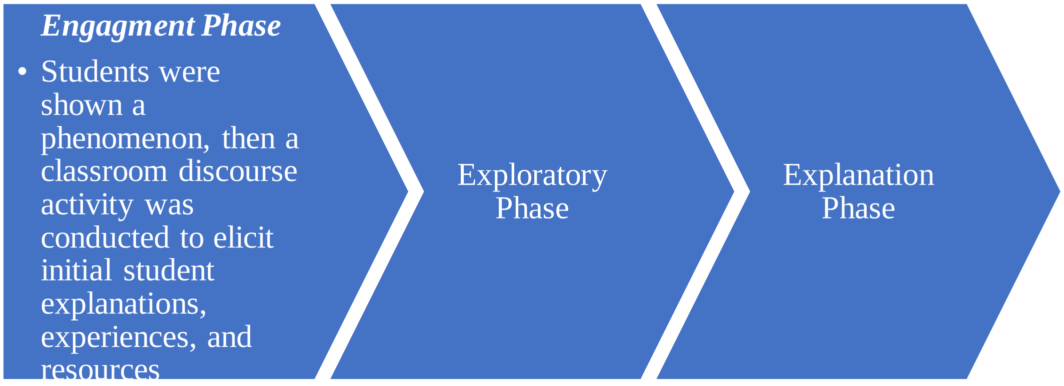
The curriculum for the laboratory course was designed based on 12 different investigations that explored a variety of subfields within introductory biology. Some of these subfields included: animal anatomy, physiology, reproduction and development, ecology of local ecosystems, and evolution (Schultz & Strimaitis, 2016). A complex phenomenon or problem was central to each of the 12 unique investigations, and each week students attempted to better understand such phenomena or problem through a laboratory investigation. During laboratory time, students were constantly posed with guiding questions and were asked to carry out specific investigations in order to attempt to answer or solve a question or problem. Students worked together in small groups to conduct these investigations and propose possible explanations for the complex phenomenon shown at the beginning of each weekly unit. In support of their proposed explanations for such phenomenon, students collected and analyzed data to construct a cohesive scientific argument to answer and support the guiding question.

Course Instruction

The 12 classroom investigations were designed as a modified learning cycle (Bybee et al., 2006). Each laboratory day consisted of multiple components: the engagement phase, exploratory phase, and explanation phase (Figure 1). The engagement phase marked the beginning of each of the laboratory investigations, as TAs engaged students at the beginning of each lab with a phenomenon or problem related to the investigation topic that week.

Figure 1

Three Components of a Laboratory



Note. This thesis deals only with the engagement phase.

Then, the TA facilitated an entire classroom discussion to elicit students' initial explanation, experiences, and resources regarding the phenomenon or problem in question. The engagement phase activities varied from week to week; some weeks videos were used to demonstrate a phenomenon or problem while other weeks the engagement phase involved making connections to past laboratory investigations and/or assignments. While there were three phases used each week to investigate a biology topic, this thesis will deal strictly with the eliciting discussions TAs facilitated at the beginning of the engagement phase. While the other two phases are equally important in science education, they do not pertain to the research questions this thesis aimed to address. The specific laboratory investigation used in this thesis occurred during the week 8 investigation titled "The Trophic Web Lab". All of the 18 enactments came from this investigation, and the data sources for this study came from the classroom videos and transcribed classroom discussions from this specific week.

TA Professional Development and Support

The undergraduate biology TAs in this study had no prior teaching preparation, which was one of the primary reasons behind using them as our sample. After being hired, the TAs enrolled in a weekly teaching professional developing course coupled with the teaching position. The 2.5 hour weekly course met throughout the semester. During these meetings, TAs and administrators modeled that specific week's laboratory content, allowing time to practice responding to students' ideas as they enacted ambitious science pedagogical practices. Allowing the TAs time to model the laboratory also gave them opportunities to understand the mechanics of the investigation and learn opportunities for discussion. While modeling the investigation, the course administrator often explained specific moves, derived from the ambitious science teaching framework (Windschitl et al., 2012) to elicit and respond to student ideas.

In addition to weekly meetings, the TA manual included weekly lesson plans that explicitly outlined the planned events for each phase of each investigation. The lesson plans included suggested timelines for laboratory time and were accompanied by power point slides. These slides acted as guides for implementing each laboratory phase, and they offered questions to probe student thinking and press for explanations as well as explicit areas for the TAs to anticipate what students think, say, and do.

Data Collection

Data sources included transcripts of video recorded elicitation discussions from the Week 8 investigation ("The Trophic Web Lab") for all 6 participants during the 3 chosen semesters across multiple years as described above (Table 1). We created a content log for each video as described by Derry et al. (2010) and identified episodes of talk defined by periods of sustained discussion about one topic where multiple students and speakers can contribute one or more times to the discussion. As previously described, this study focused exclusively on the episode of talk of the entire classroom elicitation discussion. In this specific episode of talk, there were sustained moments of dialogue around the question of how and why a local spring, referred to as "the spring", ecosystem had changed dramatically over the last 20 years. The class was challenged to use a model of energy flow and trophic relationships to brainstorm possible explanations for the specific ecosystem changes in the spring. Table 3 shows the steps and events that took place in the planned engagement phase of the Week 8 investigation. The video clips were recorded using two video cameras fixed to the front and back of the classroom in order to capture each students' response and contribution. We chose to use the Week 8 "Trophic Web Lab" Investigation for the exclusive focus of the analysis because it happened late in each of the semesters in which it was taught, allowing our analysis of TA talk moves and responsiveness to student ideas to benefit from an entire semester of experience with that specific population of students. Further, by Week 8, it was likely that the students and TAs had become desensitized to the presence of the video cameras, allowing for more authentic classroom behavior, from both teachers and students, to be recorded and used for analysis. We created verbatim transcripts of the talk in each of the classroom video recordings to document the words that were spoken and who was speaking (Rapley, 2007). These verbatim transcripts included textual interpretations of overlapped and interrupted speech, acknowledging sounds, and other nuances of group conversations. These transcripts were the basis for the data analysis.

Table 3

Events in Planned Engagement Phase of the Week 8 Investigation to Elicit Student Explanations

Eliciting student explanations	Intended steps in planned engagement for Week 8 investigation
Students observe puzzling event	Students have a common experience watching a video about the spring and the food web interactions that take place there
TA elicits hypotheses about "what might be happening"	TA elicits student observations by having students make a food web interaction and asking the question "why is the water dark and murky now" along with information such as "the apple snails have disappeared"
Press for possible explanations	TA presses for possible explanations as to how these apple snails have to do with the murky water and other ecosystem changes

Note. Adapted from Grinath and Southerland (2018). TA: teaching assistant.

Data Analysis

Talk Moves

All transcripts were deidentified so the names of the TAs were not associated with the transcript. TAs were given pseudonyms to further protect their identities. The elicitation discussion episode began when the TA engaged the students with the focal phenomenon of the food web interactions from a video clip showing the spring. The TA showed a video to the classroom showing many of the ecological and trophic interactions at play in the springs. After watching the video, the TA prompted students to use what they saw in the video to group together and draw a trophic food web for the spring. After some time, the TAs invited each of the student groups to share their trophic web interactions. During these explanations, the TAs used opportunities to reinforce student understanding of primary, secondary, tertiary, and quaternary producers and consumers in a specific ecosystem. The TAs also allowed students to add on or remove parts of their trophic food web interactions based on the whole classroom conversation. The TA then introduced the phenomenon explaining that since the video was made the apple snails were no longer in the spring, and that the water was dark and murky. The TA then elicited student ideas as to why these changes were present. Individual student and whole classroom explanations varied, including: pollutant and fertilizer runoff, human interaction, dying animals, climate change, and others.

The episode ended when the TA signaled that the class was moving into the investigation phase of the lesson after the class had applied their initial explanations about why the spring ecosystem had changed dramatically over the last 20 years. For each of the elicitation discussion episodes, the unit of analysis was a turn of talk defined as the words spoken from beginning to the end of a specific student or TA turn at speaking. Each participants' turn of talk began when they speak and ended when another participant began speaking. Each TA and student talk turn was then analyzed using an *a priori* coding framework. The coding framework (Table 4) was adapted from Grinath and Southerland (2018) and was designed using the talk moves described in the ambitious science teaching framework (Windschitl et al., 2012). The talk moves intended to elicit student ideas as described in the ambitious science teaching practices. These talk moves included probing questions to initially elicit student thinking, followed by presses for explanation to extend the initial student thinking. From the *a priori* coding framework adapted from Grinath and Southerland (2018), we also included codes for talk moves that were not specifically outlined and defined within the ambitious science teaching framework. These codes for talk moves reflected some of the most common discursive patterns observed in classrooms from a variety of educational literature (Lemke, 1990; O'Connor & Michaels, 1996; Oliveira, 2010). These talk moves include asking specific questions in order to elicit the anticipated correct answer, and responding to students' contribution by evaluating the correctness of such contribution. Minilectures were also included in the coding framework for when the TAs expanded on student's contributions.

While the coding framework was adapted from previous literature, we decided to leave the framework open for additional codes to emerge specific to the transcripts from the classrooms in this investigation. In addition to the coding framework already discussed, we included talk moves such as distributing participation across students in the classroom and acknowledging student contributions as valuable without remarks of correctness. These two talk moves emerged in many of the classroom videos, but the current coding framework did not initially include them. Therefore, due to their consistent presence in the classroom videos and their importance of use in conversations, we included them in the framework for analysis.

Table 4

Examples of Ambitious, Inclusive, and Conservative TA Talk Moves

Talk Move Category	Specific Moves	Description
Ambitious	Probing question	Broad question with many possible valid responses; *e.g., The water is really dark and murky and there's no more apple snails. So what's something that could be going on?*
	Press for explanations	Move student toward higher cognitive thinking by pressing for meaning; *e.g., So what are just some explanations that you guys talked about in your groups? How's that going to affect everything?*
Inclusive	Distribute participation	Provide opportunity for additional students to contribute to the classroom ideas; *e.g., What else? What are some other ways?*
	Acknowledge contributions	Indicate student contribution holds value without assessing correctness. Often showcasing active listening and encouragement; *e.g., A decrease in algae, okay.*
	Revoice	Repeating student contributions to emphasize part of response, ask for clarification, summarize multiple connections, or connect student ideas to specific science concepts; *e.g., So, we are going to say that makes the water dark. Okay. So increasing fertilizer causes a decrease in the algae. And we're going to say that the fertilizer is enough to kill the algae, the snails eat the algae.*
Conservative	Display question	Teacher requests simple facts, procedure, or definition with one correct answer the TA is expecting; *e.g., So, what are fertilizers known as, for the plants that is?*

	Evaluating correctness	Assessing student contributions are correct or incorrect; *e.g., Energy, that’s right!*
	Minilecture	Respond to student contributions by delivering content in short lecture; *e.g., So all ecosystems are limited by primary producer, which is a really interesting concept because the spring has lost a lot of grass. Grass in the bottom of the spring is slowly receding, a lot of the apple snails that you guys saw. There's some snail shells up front. This is actually a non-native snail, but they're actually... There's none left and it's causing some ecological shifts. Also in the spring that water is getting really murky. It was full of algae.*

Note. TA: teaching assistant. Adapted from Grinath and Southerland (2018). For research question 2, the ambitious and inclusive talk move categories were merged to create one “ambitious” category.

All of the codes for the TA talk moves were then grouped into three categories for research question 1: ambitious, conservative, and inclusive (see Table 4). These groupings follow Grinath and Southerland (2018). These groupings were due to the function each talk move serves. Ambitious talk moves, based on those found in the ambitious science teaching framework and intended to elicit student ideas, include probing questions and pressing for explanation. Conservative talk moves were defined as commonly observed classroom moves that aim to elicit a correct response include display questions, evaluating, and minilectures. Inclusive talk moves were defined as those moves that gave students a voice in the whole classroom discussion include distributing participation, revoicing, and acknowledging contributions. Table 4 shows examples of each of the categories of talk moves and descriptions accompanied with examples from classroom transcripts. Talk moves were assigned to each of the entire TA talk turn. It should be noted that the inclusive and ambitious talk move categories were merged into one “ambitious” category to answer the second research question. The reasoning for this coupling resulted from the specific talk moves themselves in both initial categories doing work with student ideas. The initial “inclusive” talk move category included acknowledging contributions, revoicing, and distributing participation. These moves work with student ideas by making them relevant and “active” in the classroom dialogue while also allowing student ideas to emerge. Allowing student thinking to be introduced in the classroom is one of the major purposes for elicitation discussions, so these initial inclusive moves were combined with the initial ambitious talk moves of pressing for explanations and asking probing questions to make one larger “ambitious” talk move category. This category merging allowed us to examine the relationship between TA responsiveness and student rigor more adequately, while leaving the three categories separate was critical in examining the first research question in how these moves may change over time.

TA Responsiveness and Student Rigor

To examine the qualitative and quantitative component of how the responsiveness of the TAs affected the rigor of student discourse, an *a priori* coding framework adapted from Thompson et al. (2016) was used, which scaled rigor on a 0-4 scale (Table 5). The three categories previously described, combined into two categories for the second research question, that delineated the categories of talk moves, were used to define and describe the responsiveness of the TAs. For TA responsiveness, the categories of talk moves acted as proxies for responsiveness. In this study, the rigor or each student talk turn and the responsiveness of each TA talk turn was used as the unit of analysis, which differ from Thompson et al. (2016) who coded the explanatory rigor of an entire discussion as the unit of analysis. Thompson et al. (2016) was interested in how meaning is socially constructed throughout the entire discussion, while we were interested in each talk turn to provide understanding into how patterns of discourse emerged between conversational turns. Rigor was based on the depth of scientific thinking and talking that occur in the classroom by the students.

Table 5

Different Levels of Student Rigor with Transcript Examples

Level	Student response	Description	Example
0	No student talk	No student talk and therefore no student rigor	NA
1	Definitions / Fact	Definitions, textbook answer, short, basic	*Herbivores are on the primary consumer level*
2	Descriptions / Observation	Coming from personal experience of a certain phenomenon, observation without further explanation, idea of what is happening void of explanation	*It appears like the plants can't grow without sunlight*
3	Under theorized science explanation	Talking about how a phenomenon is part of a process, simple cause-effect relationships, talk about what is happening on an unobservable level	*I think recent industrial usage has caused chemical runoff and then the water, like when it rains and the rain touches chemicals on the ground, it runs into rivers and deposits and algae blooms. An algae bloom happens to cover the lake*

4	Fully theorized science explanation	Explaining theoretical “workings” for why a phenomenon happens, includes science theories, models, laws that reach beyond simple cause-effect relationships.	NA

Note. There were no moments of rigor coded as “4” in the data set.

Adapted from Thompson et al. (2016), we coded the level of student rigor on a scale from 0 to 4, which can be seen in Table 5. It is important to note that we did not expect there to be any student talk graded in a 4 category, given that the analysis takes place during the elicitation discussions where students likely were not contributing fully explained theories while attempting to make sense of a phenomenon. However, we left the 4 categories open in case situations of explanation arose. The 0 to 4 scales we used are defined as follows: 0 = no talk and/or no rigor, 1 = definitions/facts, 2 = descriptions/observations, 3 = under-theorized science explanation or explanation as to how a phenomenon works, and 4 = fully theorized science explanations or explanations for why a phenomenon happened (Table 5).

Of particular interest in student responses was how students and teachers navigated and created an understanding of the Week 8 Trophic Web Lab phenomenon. We identified moments in the elicitation discussion where TAs and students were building on ideas together and using scientific concepts in explanations and in other talk. In coding the student talk turns, a description of analytical markers used for assigning a code to a talk turn is warranted and follows Table 5. To assign a student talk turn a 4 (fully-theorized science explanation), the talk turn needed to include science ideas of why a phenomenon occurred as well as include science connections that go beyond simple cause-effect relationships. To assign a student talk turn a 3 (under-theorized science explanation), the talk turn needed to include talk specific to how a phenomenon is part of a process or talk includes simple cause-effect types of relationships between observable features. Further, if the talk turn used any of the other categories of code (definition, fact, description, or observation) but linked those lower cognitive responses to unfolding classroom ideas related to the focal phenomenon, the talk turn was coded as either a fully-theorized (4) or under-theorized science explanation (3). To assign a student talk turn a 2 (descriptions/observations), the talk turn needed to include a student description of something they had previous seen or experienced. These talk turns were void of any interpretation of their observation, and simply expressed some experience without dissecting it. To assign a student talk turn a 1 (definition/fact), the talk turn was short, allowing one word or phrase often resulting in the student vocalizing a vocabulary or relevant term.

TA responsiveness was determined using the previously described categories for TA talk moves associated with our second research question: ambitious and conservative. While coding for specific talk moves to address our first research question, the category of talk move will also be recorded, which will act as three different levels of TA responsiveness.

Reliability

The dimensions of TA responsiveness and student rigor were openly discussed within thesis committee meetings and continuously monitored and modified until the committee members reached consensus. To ensure inter-rater reliability while coding episodes, we cross-coded Fred's three cases, compared codes with each other, and discussed any differences in coding until a consensus was made. Our team aimed for an 80 percent match between coded sections, and after a single review, our inter-rater reliability match was 83% accurate. Even though we surpassed our 80 percent match goal, we continued to discuss discrepancies to ensure the highest and most accurate coding of transcript data.

Analysis Patterns

Addressing the qualitative component of our first research question “what are the talk moves that TAs utilize to elicit and respond to student ideas while teaching an undergraduate biology laboratory course and how do those talk moves change over multiple enactments”, we qualitatively described the common talk moves TAs used throughout the 18 enactments across three semesters. These talk moves were expressed not only in their respective three categories, but also the specific type of talk moves common during all of the enactments. From determining which talk moves to study, we then coded classroom transcripts to acquire counts and percentages of talk moves for each TAs’ classroom section. Our team looked for moments in which TAs used the talk moves while discussing the phenomenon in question during the initial elicitation discussions in the engagement phase. We were specifically interested in seeing any qualitative talk move trends that occurred across the three semesters for each TA. To address the quantitative component to this research question, we used an uncertainty analysis, the Welch-Satterthwaite method, to determine if there were patterns of TA talk moves across multiple enactments.

To quantitatively address our second research question “how does the responsiveness of the TAs affect the rigor of student discourse”, a Pearson’s Chi-squared test of independence was utilized. The contingency table analysis was performed to test for an association between the TA talk move category and the rigor level of the student responses. Qualitative methods were also utilized by exploring coded transcripts to further support the statistical patterns we observed when relating rigor and responsiveness. We were most interested in the context of the TA and student interaction, specifically the TA talk move category that immediately preceded student responses in an effort to both qualitatively and quantitively show trends.

CHAPTER 4

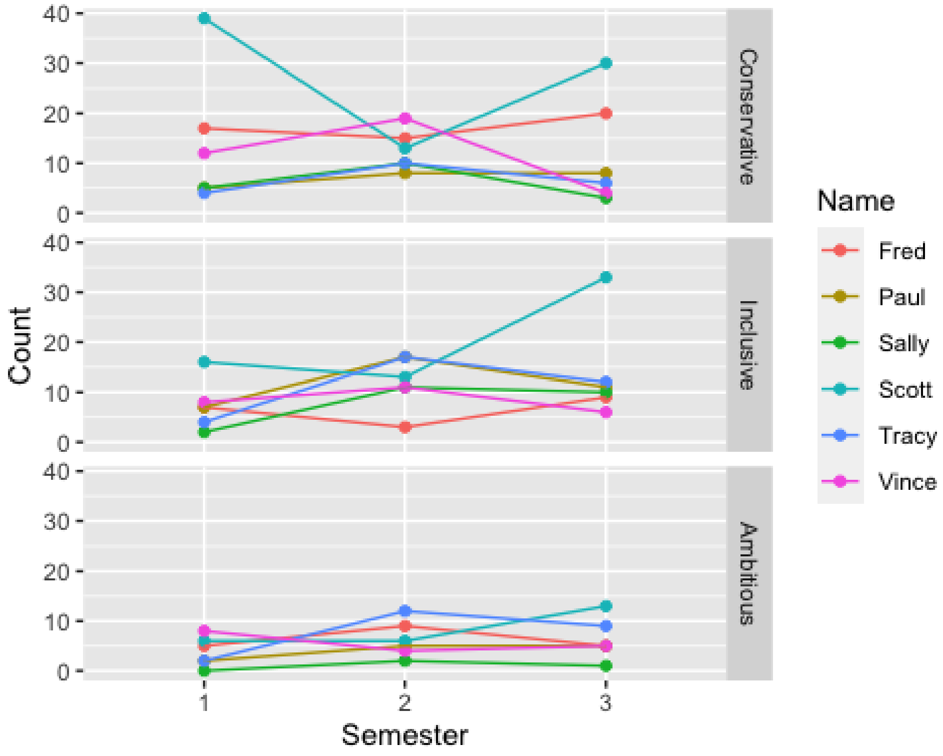
FINDINGS

Talk Moves Over Multiple Enactments

To address the first research question, what are the talk moves that TAs utilize to elicit and respond to student ideas while teaching an undergraduate biology laboratory course and how do those talk moves change over multiple enactments, each TA elicitation discussion was transcribed and analyzed over the three semesters of instruction. Observing each category of talk move (conservative, inclusive, and ambitious), an analysis for differences of talk move category counts across each semester was conducted. Figure 2 shows the graphed trends for each talk move category over time for each of the six TAs.

Figure 2

Count of Three Types of Talk Moves across Three Semesters of TA Enactment



Note. TA: teaching assistant.

An uncertainty analysis, the Welch–Satterthwaite method, was used to calculate an approximation to the effective degrees of freedom of the linear combination of the independent sample variances. The assumption of homogeneity of variance was violated, so the Welch-Satterthwaite method was used to adjust degrees of freedom. Nonsignificant results were found for conservative, inclusive, and ambitious talk moves indicating no statistically significant differences in the TA talk moves across time. For conservative talk moves, F(2, 46) = 0.16, *p* value > .05. For inclusive talk moves, F(2,46) = 2.24, *p* value > .05. For ambitious talk moves, F(2, 28) = 1.27, *p* value > .05. For conservative, inclusive, and ambitious talk moves, there were nonsignificant signals of TA patterns over the three semesters, including large variability among TAs. This analysis was repeated for the percentage of TA talk moves, instead of isolated talk move counts, to standardize each TA variability. This analysis supported previous findings that no statistically significant differences in the TA talk moves exist over time during the three semesters we investigated. However, some interesting non-longitudinal trends did appear for TAs, such as the consistency of talk moves and the use of inclusive and ambitious talk moves without much pedagogical training. Overall, the first research question can be addressed by stating there were no TA talk move longitudinal changes across time that were not equally well explained by random chance.

Responsiveness of TAs Influencing Three Different Levels of Student Rigor

In the following section, there are three components to discuss. Student rigor codes, from low, moderate, to high rigor, were examined. Within each of the student rigor level paragraphs below, the findings as to which talk moves TAs used prior to a specific level of student rigor are discussed. Transcripts and brief discussions allow for more robust insight into not only the category of talk move used by the TA (conservative or ambitious), but also which specific talk move was most commonly used and associated with the three levels of student rigor. We will begin by briefly reviewing a broad perspective of our methodology, and will then discuss low student rigor, moderate student rigor, and high student rigor respectively.

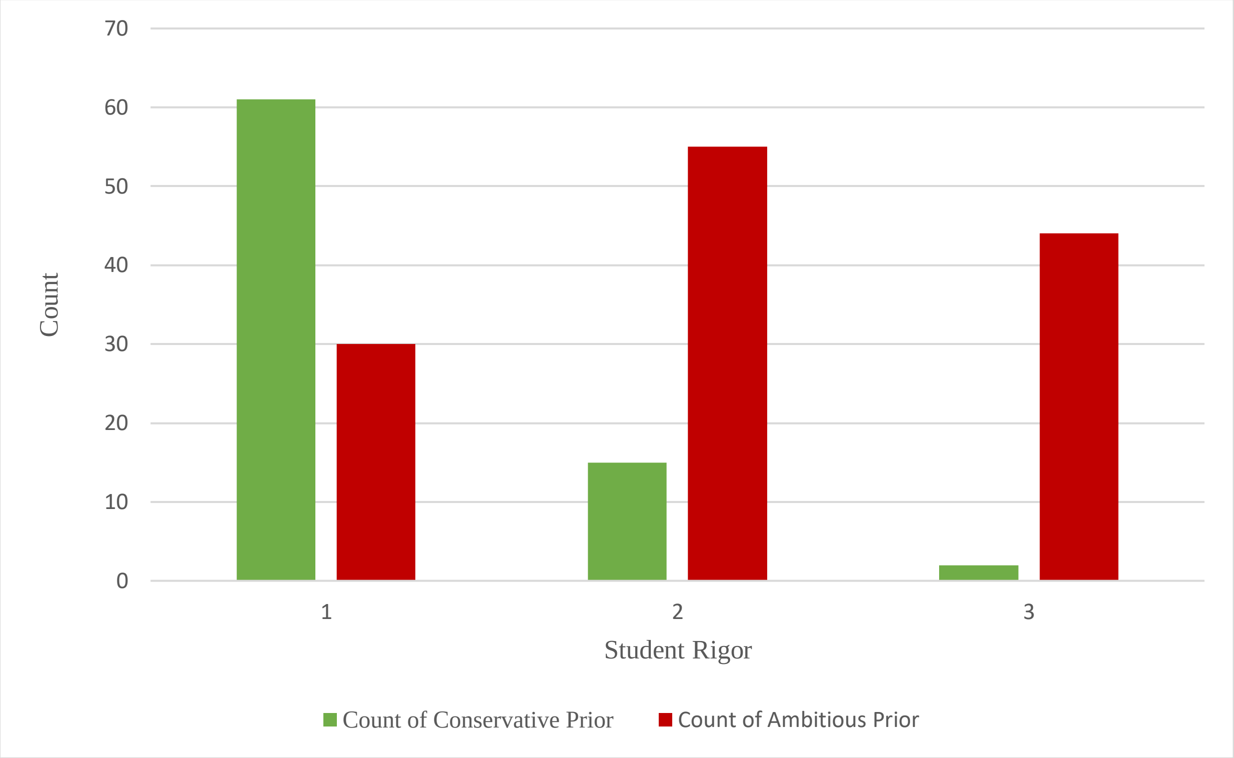
In order to address the second research question, how does the responsiveness of the TAs affect the rigor of student discourse, the elicitation discussions were transcribed and analyzed specifically by pairing student contributions to TA responsiveness. Student rigor was coded as outlined previously, although codes 1-3 were only gathered from the classroom transcripts and videos. The coding analysis did not uncover any student rigor “4” codes, which was not surprising due to the nature of the conversations. Because the analysis focused on student sense-making talk during the specific elicitation discussion lead by the TA, students were not likely to contribute a level “4” rigor code which was defined as contributing “fully theorized explanations”.

To relate TA responsiveness with student rigor, during the coding analysis, we investigated each coded moment of student rigor, regardless of the level of rigor. We then observed the moments preceding the student rigor moment to observe which TA talk move was used and in which category it was defined. Counts of conservative moves prior to a rigorous student moment were recorded for each of the three levels of student rigor. Also, counts of ambitious moves prior to moments of student rigor were recorded for each of the three levels of student rigor. These counts were acquired for each of the TAs collectively during their three semesters of instruction.

Data from all six TAs was compiled into a single graph, which can be seen in Figure 3. Table 6 demonstrates the table data relating student rigor code to the number and percentage of conservative and ambitious moves observed prior to the specific student contribution. The following findings section is divided into three major sections, each discussing the talk move moments that surround the three student rigor codes.

Figure 3

Combined Counts of Conservative and Ambitious Talk Moves Used Prior to the Three Levels of Student Rigor



Note. TA: teaching assistant. “Combined counts” includes all 18 enactments from all 6 TAs.

Table 6

Count and Percent of Conservative and Ambitious Talk Moves Used Prior to Three Levels of Student Rigor for all Six TAs

Student Rigor	Conservative Talk Move Used Prior to Rigor		Ambitious Talk Move Used Prior to Rigor	
	Count	Percent (%)	Count	Percent (%)
1	61	67	30	33
2	15	21	55	79
3	2	4	44	96

Note. TA: teaching assistant.

Rigor 1

For moments in which students contributed a rigor code of 1, which included student statements of mostly definitions without epistemic features and talk about facts, procedures, equipment, conservative talk moves dominated the conversation prior to student contributions. This suggests that TAs who primarily used conservative talk moves most often resulted in low rigor student contributions to the classroom dialogue. For all six TAs combined, conservative talk moves preceded low rigor student contributions 67% of the time, while ambitious talk moves preceded low rigor student contributions only 33% of the time, as seen in Table 6.

The most common talk move contributing to low student rigor was the display question. Display questions were questions through which the TA requested simple facts or procedures. The TA is typically searching for a single correct answer. Almost always, after a student provided an answer to the TA's display question, the TA evaluated this answer by assigning correctness to the response. This style of questioning often resulted in initiate-response-evaluate (IRE) classroom discussion. This is a traditional form of lecture pseudo-conversation that extinguishes student ideas and contributions. Classrooms can become monopolized by a single student answering all the questions, and student ideas and resources are directly given less importance than the correct answer. Student responses to IRE pseudo-conversations were almost always factual and contained low rigor ideas and answers. Below is an excerpt from an elicitation discussion where the low student rigor was preceded by conservative talk moves. Display questions are underlined while evaluating correctness is *italicized*.

TA (Fred): Yeah. Well, if they eat plants, would you expect that murkiness to happen? Possibly. You never know. So yeah. Invasive species are really important when it comes to phylogenetic trees, but we still haven't tapped on one of the most specific reasons that we're going to talk about it in this lab.

Student: Fertilizers?

TA (Fred): *Fertilizers, good!* So, what are fertilizers known as, for the plants that is?

Student: Stimulants.

TA (Fred): *Stimulants, good.* What else could we call those? Food? What else? What does food give us?

Student: Energy.

TA (Fred): What else is it called?

Student: Nutrients.

TA (Fred): *Nutrients! Good!* So, nutrients.

This instructor-student interaction was dominated by the IRE pattern. Fred initiated the questioning by searching for an answer yet to be provided by his students by claiming “we still haven’t tapped on one of the most specific reasons…”. After the student provided an answer, Fred evaluated the provided answer by assigning a correctness statement to the answer and then followed the correctness statement by asking another display question, where he searches for a single correct answer from his students. The students continued to offer answers, and Fred continued to search until he found the correct answer. The length of these IRE conversations varied from moment to moment depending on how quickly the students provided the correct answer. This excerpt exemplifies an elicitation discussion dominated by brief, factual student responses that mimic textbook answers and definitions. Therefore, each student response was coded as a 1, representing low explanatory rigor, because the students did not engage in sense-making about why fertilizer runoff increased the turbidity of the spring.

While conservative talk moves dominated the TA moves preceding low student rigor contributions, nearly 67% of the time, there were instances where ambitious talk moves appeared prior to low student rigor responses. Below is an excerpt from an elicitation discussion where the TA used ambitious talk moves with students, but students answered using low explanatory rigor. Ambitious talk moves used by the TA are <u>underlined</u>.

TA (Scott): So interesting thing about the spring is that it used to be really beautiful, we used to be able to go on these glass bottom tours, where you'd get on this boat that's got a glass bottom. You could see all the fish and wildlife. Really beautiful stuff. But now, it's really cloudy. You can't really see much. All these apple snails that you saw in that video, they're gone. It's actually an invasive species, but they did contribute to cleaning a lot of that grass off, all the algae off the grass. So there's been a little bit of a change here. What do you think are reasons that have contributed to this cloudiness?

Student: Pollution.

TA (Scott): Pollution. Okay. That's feasible. So keep going, what kind of pollution would you expect?

Student: Runoff.

This excerpt demonstrates an elicitation discussion where the TA, Scott, used ambitious talk moves in an attempt to move students toward sense-making; however, the students' responses were considered low rigor because the answers did not reveal any information about how the cloudiness of the water was influenced by factors such as pollution. Scott used probing questions such as "what do you think are reasons that have contributed to this cloudiness" and follows up with the student answer with a pressing question as he stated "so keep going". Despite Scott's efforts to engage students in a more rigorous explanatory conversation, the students continued to respond with low explanatory rigor. While not the typical finding, ambitious talk moves preceded low student rigor 33% of the all of the elicitation discussions combined.

Rigor 2

For moments in which students contributed a rigor code of 2, which included students offering descriptions or observations of a specific phenomenon, usually by offering "what" they could see happening, a more balanced number of conservative and ambitious talk moves were used in the conversation prior to student contributions. However, ambitious talk moves outnumbered conservative talk moves to a noticeable extent. Level 2 rigor emphasize “what” happens to X when Y is changed when describing a correlation between two events, variables, or factors, which begins the steps often used toward explaining a phenomenon or offering an idea of “how” a phenomenon works. Therefore, it is not surprising that ambitious talk moves made up the majority of overall talk moves used by TAs prior to moderately rigorous student contributions. This suggests that the TAs that primarily used ambitious talk moves often resulted in students beginning to offer more rigorous contributions to the classroom dialogue. According to Table 6, for all six TAs combined, conservative talk moves preceded moderately rigorous student contributions only 21% of the time, while ambitious talk moves preceded moderately rigorous student contributions 79% of the time. Moderately rigorous student contributions were preceded by ambitious talk moves compared to conservative talk moves in a higher ratio than low rigor student contributions, suggesting that ambitious talk moves were necessary, but not sufficient, alone, to encourage rigorous student contributions. Unlike low student rigor contributions, the TAs’ moderately rigorous student talk moments were primarily preceded by ambitious talk moves.

Some of the most common talk moves that contributed to moderate student rigor were distributing participation, acknowledging contributions, and pressing for explanation. Distributing participation allowed the TAs to isolate different student ideas and focus on them within the classroom discussion. For an elicitation discussion, it was critical that the instructor allowed student ideas and resources to be “put on the table” for all students to work with. By using student ideas, the classroom reaches a more organic process of sense-making. In addition to distributing participation, pressing for explanation was common in contributing to moderately rigorous student contributions, and the moments of TAs pressing their students typically happened after multiple student ideas had been contributed, likely in response to the TA distributing participation. Below is an excerpt from an elicitation discussion where the moderate student rigor was preceded by ambitious talk moves, specifically distributing participation, to allow multiple student ideas to emerge. Talk moves that distribute participation are <u>underlined</u>**.**

Scott (TA): All right. <u>What else? So what do we have on the bottom?</u> We got algae, sea grass…

Student 1: Okay, well, hi. On the bottom we have algae and sea grass.

Scott (TA): Mm-hmm (affirmative).

Student 1: And then the manatees, the small fish, and the apple snails eat that. And then the birds, the snapping turtles and the larger fish eat that.

Scott (TA): Okay. Sounds about right. You got manatees there, birds. Yeah, looks good.

Student 1: Thank you.

Scott (TA): <u>Cool. Table number two, what do you guys have? On the bottom right?</u>

Student 2: We went to tertiary consumer based on the size of the fish that the alligator snapping turtles are eating. So, yeah, we figured that might put the alligator snapping turtle in the tertiary category.

Scott (TA): So if the alligator snapping turtle are eating large fish and the large fish are eating small fish, then yeah, I would make it a tertiary. Have we seen the other fish eating other fish? I don't think we saw directly, but there are probably fish out there that are eating other fish.

In this excerpt, Scott used the lines "What else? So what do we have on the bottom?" and "Table number two, what do you guys have?" to spread the participation between different students and groups within the classroom. Both student responses offer observations as to what they saw in a provided video and the short reasoning behind why they included certain components of their food webs in certain locations. The second student used vocabulary language useful in understanding the trophic food web topic, such as “tertiary”. These contributions were considered moderately rigorous, because while students did not begin to offer explanations as to why or how a phenomenon occurred, students were sharing observations and “what” they could see happening. This goes beyond simply giving single word answers, definitions, or yes/no responses, which was seen in low student rigor. Interestingly, not all moments of the ambitious talk move of distributing participation looked the same between TAs. The following is another excerpt from an elicitation discussion where distributing participation occurs and contributes to moderately rigorous student contributions. Talk moves that distribute participation are underlined**.**

Sally (TA): So maybe a decrease in algae or a decrease in the vegetation - because the algae has to be on the vegetation - caused a decrease in the apple snails? Okay, cool, what else?

Student 1: Maybe an increase in the amount of birds.

Sally (TA): Okay. So we get an increase in birds, might decrease the snails. Yeah. Group six, you guys want to add on to that one? They had an interesting one with the birds.

Student 2: Well, I was thinking more so along the lines of an invasive species that comes in and doesn't have a set predator in that ecosystem. So then there is not really anything going to kill that bird, so there's an increase in the population of that which takes more snails in its diet.

Sally (TA): Okay, good. So they can have an even more increase. That's just another way to increase the bird population. Okay. What other predictions did you guys come up with?

Student 3: Less fish

Sally (TA): Okay. So if you have less fish for some reason you have an increase, in the predation of the snails because the turtles would need food, but also birds would need more food. So you'd have almost like an increase in birds and turtles, even though the actual number's not increasing, their predation on the snails would increase. So I'm just going to put the increase. <u>Does everyone follow that? An increase in turtles, birds, which would decrease the snails. Anything else?</u>

In this elicitation transcript, Sally uses several student's ideas to unpack the idea of why the apple snails are no longer seen in the spring, one of the driving phenomena of the lesson. Notice the way in which Sally used the ambitious move of distributing participation differently than seen previously with Scott. Sally asked "what other predictions did you guys come up with", "anything else", "what else", and "you guys want to add on to that one". This differed from Scott who, while still distributing participation, did so by asking another group specifically to share their ideas: "table number two, what do you guys have". While both are considered talk moves that distribute participation, Sally's examples demonstrated a more effective way at allowing students to feel as if they are contributing their ideas as resources freely with encouragement. From this more advanced type of distributing participation, we can see more student ideas were considered and examined by the class, which is ultimately the goal of any elicitation discussion. While distributing participation helped lead to moderately rigorous student contributions, occasionally it also led to rigorous student contributions, coded by a 3 in this project. While this will be discussed in greater detail later in this chapter, it can be seen in the previous discussion by student 2, who offered a brief explanation of why the phenomenon is occurring. Notice that the TAs are also evaluating student responses occasionally, as Sally stated "okay, good" and Scott states "okay, sounds about right". However, the IRE pattern of pseudodiscussion that was seen with low student rigor contributions begins to fade away as more ambitious talk moves are used, which begin to advance student rigor. Now that moderately rigorous student ideas are being resented by students, Sally can be seen working with ideas to make the class better understand the topic of the elicitation discussion.

As previously mentioned, one of the other primary ambitious talk moves preceding moderately rigorous student talk was the acknowledging contribution talk move. Acknowledging contributions occurred when a TA indicated the contribution was valuable without indicating correctness. This talk move encourages listening and responding to ideas presented by either other students or the instructor. By not assigning a correctness condition with the contribution, students feel like their ideas are incorporated into classroom conversations simply from the TA repeating or acknowledging them to begin with. While acknowledging contributions traditionally doesn’t necessarily work with, or expand on, student ideas, this talk move is often paired with an additional talk move that follows acknowledging student contributions. That can be seen in the following excerpt from an elicitation discussion. Talk moves that acknowledge student contributions are <u>underlined</u>. Revoicing talk moves are *italicized.* Probing questions and pressing for explanations are shown in ***bolded italics.***

Student 1: Yeah, so when it's too much algae, the water turns dark and stuff like that.

Paul (TA): <u>The water turns dark.</u> *So we can say, we know we have a decreased number of snails and since the snails eat the algae, that would give us an increased amount of algae which makes the water really murky.* ***What do you think could be contributing to there being the decrease of snails?***

Student 2: Like a disease or more population of birds.

Paul (TA): Yeah. *So maybe we've got an increased amount of birds because birds eat the snails so you have more predators. So if you got more predators, whatever they eat is going to decrease. And then since there's less snails, there will be more algae. So we'd have the decrease of snails and the water would be murky***.** That's one explanation. What's another one?

Student 3: Climate change.

Paul (TA): <u>Climate change</u>. ***Okay, how so***?

Student 3: So, maybe their habitat isn't equipped to their needs anymore, so they're dying out.

Paul (TA): Okay.

Paul acknowledged his students' contributions several times in this excerpt as he repeated "the water turns dark" and "climate change". Notice that these talk moves, alone, do very little to help drive the classroom toward understanding, and are followed by other talk moves that do work toward sense-making. When Paul first acknowledged student 1's contribution by repeating "the water turns dark", he then revoiced the student's ideas to emphasize part of the response in order to connect the student idea to the relevant science concept. Paul followed up his revoicing with another ambitious talk move: pressing for explanations and asking probing questions. Paul asked "What do you think could be contributing to there being the decrease of snails", which probes the classroom for initial ideas that move toward an explanation. Student 2 response is categorized as a moderately rigorous answer given that the student offered an observation as to "what" is happening, and doesn't go as far as to offer "why" or "how" the phenomenon is occurring. Later in the transcript, when Paul acknowledged student 3's contribution by repeating "climate change", he then proceeded to ask "okay, how so" to press the student for more of an explanation in order to move student thinking forward. Notice, for the sake of clarity in this study, isolated instances of “okay” or “alright” were not coded as the TA actively using a talk move to acknowledge a student contribution. It was difficult to determine if these isolated words were used to encourage participation or if they were simply vocal habits that the TAs used when hearing a student response. Several of these moments can be seen in Paul’s transcript, which were not coded.

Rigor 3

For moments in which students contributed a rigor code of 3, which included students offering explanations as to “how” or “why” a phenomenon works potentially through cause-effect relationships, ambitious talk moves were used almost exclusively prior to student contributions. Level 3 rigor goes further than level 2 rigor in that instead of simply offering observations as to “what” happens to X when Y is changed, the student now is connects an explanation to “why” or “how” X changes Y. Therefore, it is not surprising that ambitious talk moves make up nearly all of the talk moves that preceded highly rigorous student participation. This suggests that TAs that primarily use ambitious talk moves often result in students offering more rigorous contributions to the classroom dialogue.

For all six TAs combined, conservative talk moves preceded highly rigorous student contributions only 4% of the time, while ambitious talk moves preceded highly rigorous student contributions 96% of the time. This 96% to 4% difference is the most robust finding of all of the rigor and responsiveness patterns, suggesting that ambitious talk moves were, and are, absolutely necessary for highly rigorous student participation. Paul and Sally each used only one conservative talk move prior to highly rigorous student contributions, totaling only two instances in which this occurred across all TAs for all semesters, which are also the only two instances that contributed to the 4% statistic. For both Paul and Sally’s single moment of a conservative talk move preceding highly rigorous student contributions, the conservative talk move used was evaluating correctness that was then followed by an ambitious move to trigger the level 3 student response. Below are excerpts from both Paul and Sally's elicitation discussions where the student contributed a rigorous explanatory answer, but a conservative talk move preceded the contribution. Conservative talk moves, specifically evaluating correctness, are <u>underlined</u>. Ambitious talk moves are **bolded**.

Paul (TA): Okay. So let's say we have an increase in fertilizer. **So like, we'll say an increase in nutrients. What would that do? How do you think that would be applied to this.**

Student 1: Less algae, which makes the water less green and darker.

Paul (TA): Okay. **So I'm going to say that increased nutrients are going to increase...let's say increased fertilizer is going to cause a decrease in algae.**

Student 2: The snails eat the algae so they decrease the apple snails in the area.

Paul (TA): Okay. **So the decreased algae will have decreased snails. We also said that decreased algae can also cause the water to be less green to be more brown you said?**

Student 2: Yeah.

Paul (TA): Okay. **So, we are going to say that makes the water dark. Okay. So increasing fertilizer causes a decrease in the algae. And we're going to say that the fertilizer is enough to kill the algae, the snails eat the algae. So there is no algae which causes the water to be darker. Yeah?**

Student 3: Do you think that too much human traffic with the water would cause kickup of like dirt on the bottom of the water?

Paul (TA): So an increasing amount of people visiting the spring, which would cause an increase in the kick up and more dirt would be in the water. Which would make our water more dark. So with this explanation, how would that affect the snails?

Student 4: Makes it hard for them to see or to reproduce?

Paul (TA): <u>Okay yeah, that's right.</u> So hard for them to see what they are doing. So it's hard to find and reproduce. Okay. **So we can have a decrease in snails that way. What else? What are some other ways?**

Student 5: Couldn't you say the opposite with the fertilizers as well? Because it make the algae bloom out of control which takes oxygen out of the water which kills everything in it?

Paul (TA): Okay. So let's try that. **So a little bit different thinking, increased fertilizer which causes an increase in algae. Okay. What does that do?**

Student 5: And then the algae sucks all the oxygen out of the water because there so much of it.

Paul (TA): So less oxygen.

In this excerpt from Paul's second semester, we can see several moments in which Paul used ambitious talk moves to gradually build on student ideas and move them toward sense-making. Paul used a variety of ambitious talk moves, such as revoicing, pressing for explanations, and distributing participation. This specific excerpt also demonstrates the single moment where Paul used a conservative talk move prior to a highly rigorous student response. Paul evaluated the correctness of student 4's contribution by stating "Okay yeah, that's right". The following student contribution, seen from student 5, is highly rigorous because the student described how algae blooms can take oxygen out of water and kill everything living in the water, which was offering an explanation to the phenomenon presented. Notice, however, that when

Paul used the conservative talk move of evaluating student 4's correctness, he followed his evaluative statement with the ambitious move of distributing participation. Without Paul using this ambitious talk move, it is unlikely that a student would have volunteered a highly rigorous explanation without encouragement to do so in the first place. This is similar to the isolated moment for Sally in which a conservative talk move, specifically evaluating correctness, preceded a highly rigorous student response. Below is an excerpt from Sally's second elicitation discussion. Conservative talk moves, specifically evaluating correctness, are <u>underlined</u>. Ambitious talk moves are **bolded**.

Student 1: The sparrows are over populated, so they are eating all the snails before the snails are able to repopulate. Like there's two, small fish are also overpopulated. So that there is too much competition for the algae.

Sally (TA): Okay. So you want to say increase in sparrows which are decreasing apple snails.

Student 1: Yeah. It's increasing the competition for algae.

Sally (TA): <u>That's right</u>. So it would decrease algae, which would then decrease apple snails, but that's through competition. Okay, good. **And then if you do, can you tie in like the murky water to either of these?**

Student 2: I feel like the murky water comes from polluted stuff like algae.

Sally (TA): From algae?

Student 2: Yes, from the increase in algae.

In this excerpt from Sally's second semester classroom, we can see the single moment where Sally used the conservative talk move of evaluating student 1's contribution by stating “that’s right”. The following student contribution from student 2 was highly rigorous because this student explained that the murky water comes from increases in algae and other polluted matter. Notice that after Sally evaluated student 1’s contribution, she presses for an explanation from the student by asking “and then if you do, can you tie in like the murky water to either of these” which encouraged the students to think about an explanation for the murky water using the previously presented student ideas. It is unlikely that student 2, or other students in the classroom, would have contributed a highly rigorous contribution without this ambitious talk move that proceeded the conservative talk move of evaluating student 1’s ideas. One could argue that these two instances of conservative talk moves that precede highly rigorous student ideas and explanations should not have been grouped in the same moment given that after the conservative talk move, both Paul and Sally use ambitious moves to trigger rigorous student talk. However, we believe it is important to demonstrate that both moments in which this happened, across all 18 TA enactments, the conservative move was never used in isolation, and it is likely that the ambitious move that followed the conservative move specifically contributed to rigorous student talk.

As previously stated, for student contributions rated as “highly rigorous”, 96% of the preceding talk move was categorized as ambitious. This is not surprising, as we would expect higher cognitive demand be placed upon students challenged with more ambitious teaching practices. These ambitious talk moves encouraged students to explain the phenomenon in question. Examples of how ambitious talk moves were used in order to elicit highly rigorous student responses can be seen in an excerpt from Paul’s second semester classroom, which was previously shown. In this conversation, Paul repeatedly used a variety of ambitious talk moves to move students toward explanatory understanding. Paul pressed students for explanations by using phrases such as “What would that do? How do you think that would be applied to this?”, “So with this explanation, how would that affect the snails?”, and “What does that do?”. Paul also used more inclusive ambitious talk moves, such as revoicing, by stating:

> So, we are going to say that makes the water dark. Okay. So increasing fertilizer causes a decrease in the algae. And we're going to say that the fertilizer is enough to kill the algae, the snails eat the algae. So there is no algae which causes the water to be darker.

By using this revoicing talk move, Paul was able to repeat student contributions in order to emphasize science concepts and connect students’ ideas together. There were also moments in which Paul used the inclusive talk move practice of distributing participation, stating “What else? What are some other ways?”. This excerpt from Paul’s classroom acts to represent the general trend seen in all TA-student interactions that included highly rigorous student responses. All highly rigorous student responses were preceded by at least one ambitious talk move, and rarely, also, a conservative talk move.

Advancing Student Rigor With Ambitious Talk Moves

An excerpt from an elicitation discussion is shown below which demonstrates how different categories of talk moves helped influence student rigor and direct student sense-making. Conservative talk moves are **bolded**, while ambitious talk moves are <u>underlined</u>.

Tracy (TA): Okay. So we have those primary producers and then a primary consumer eats a primary producer, a secondary consumer eats a primary consumer and so on. Do those levels make sense to you guys how we got to that? Okay. <u>And then group three, you three girls over here, you guys added something at the very bottom. So what was that?</u>

Student 1: Sunlight is important.

Tracy (TA): Okay, so why is sunlight important?

Student 1: It's needed for plants and algae

Tracy (TA): Okay. **And so that video didn't explicitly say that the primary producers needed sunlight or nutrients, but that's a really important part of it. So just keep that in mind throughout this whole lab, because we're focusing on algae this week. And so they're going to need some sunlight and they're going to need nutrients. Okay. And so that video is about 20 years old. That's when the spring was super clear and super pretty, but now the water is dark and murky and those apple snails have disappeared. And so we don't really understand why. And I want you guys to work in your groups and kind of go back to your energy flow models and just try and come up with some explanations as to why the water is dark and murky and why the apple snails have disappeared. So I want each group to come up with at least two explanations, and then we'll talk about it as a group and make a cohesive list, just take a couple of minutes to discuss that**

Okay. So let's go ahead and think of some explanations as a class and kind of go through them. So what are just some explanations that you guys talked about in your groups?

Student 2: Climate Change.

Tracy (TA): Okay and how's that going to affect everything?

Student 2: It affects the migration of certain animals. So like, it'll change where the manatees go also they're endangered so that like, compounded, it makes it very hard to find manatees.

Tracy (TA): Okay. So how would a decrease in manatees affect everything?

Student 3: Overgrown plants

Tracy (TA): Okay. And what effect is an increase in plants going to have you guys think? Riley?

Riley: Increase in things that eat plants?

Tracy (TA): Okay. So how could an increase in either the plants or the plant predators, maybe make the water dark and murky or affect the apple snails? What were you thinking?

Student 4: Well, some of the fish that eat plants also ate apple snails. So if there's more predators overall, there's a worse environment for the apple snails.

This excerpt from Tracy's second semester classroom demonstrates how she was using ambitious talk moves to try and move her students from low rigor to high rigor, eventually leading to a student provided explanation. Tracy began by distributing the participation of the discussion to hear different groups' ideas regarding a group-drawn trophic web representing a video they had just watched. Student 1 answers with a low rigor response, claiming "sunlight is important". Tracy then used an ambitious talk move that pressed the student asking "so why is sunlight important" to which the student responded "it's needed for plants and algae". In this single ambitious move, Tracy helped move a student from a low to moderate student rigor response. This pattern can be seen across several TA-student interactions during this specific semester. Tracy even used specific language at times, directly asking for explanations: "so let's go ahead and think of some explanations as a class and kind of go through them. So what are just some explanations that you guys talked about in your groups?" At times, Tracy pressed the classroom for a more robust and rigorous explanation by asking "so how would a decrease in manatees affect everything", and when a student idea lacked an explanation, she continued to press for a robust explanation of the phenomenon in question. The culmination of Tracy continuing to press her students for an explanation for the phenomenon led her to gather a variety of ideas from several different students across the classroom. This is an example of how ambitious talk moves, primarily seen in this excerpt as pressing for explanations and distributing participation, can help encourage and lead students to higher, more rigorous, explanatory explanations.

Talk Move Categories Change with the Different Levels of Student Rigor

During each elicitation discussion, across all TA enactments over multiple semesters, as student rigor increased in conversation so did the percentage of ambitious moves that were used prior to the student contributions. Further, as student rigor increased throughout conversations, the percentage of talk moves that were used prior to student contributions declined. This suggests an association between ambitious talk moves and highly rigorous student explanations. Figure 4 and Figure 5 depict the percentages of conservative and ambitious talk moves used prior to each of the student rigor codes for the three semesters of each TA. Notice the trend of conservative talk move percentages declining at each “step” of student rigor, while the ambitious talk move percentages increased at each “step”.

Figure 4

Percent of Conservative Talk Moves used Prior to Three Levels of Student Rigor for Each TA

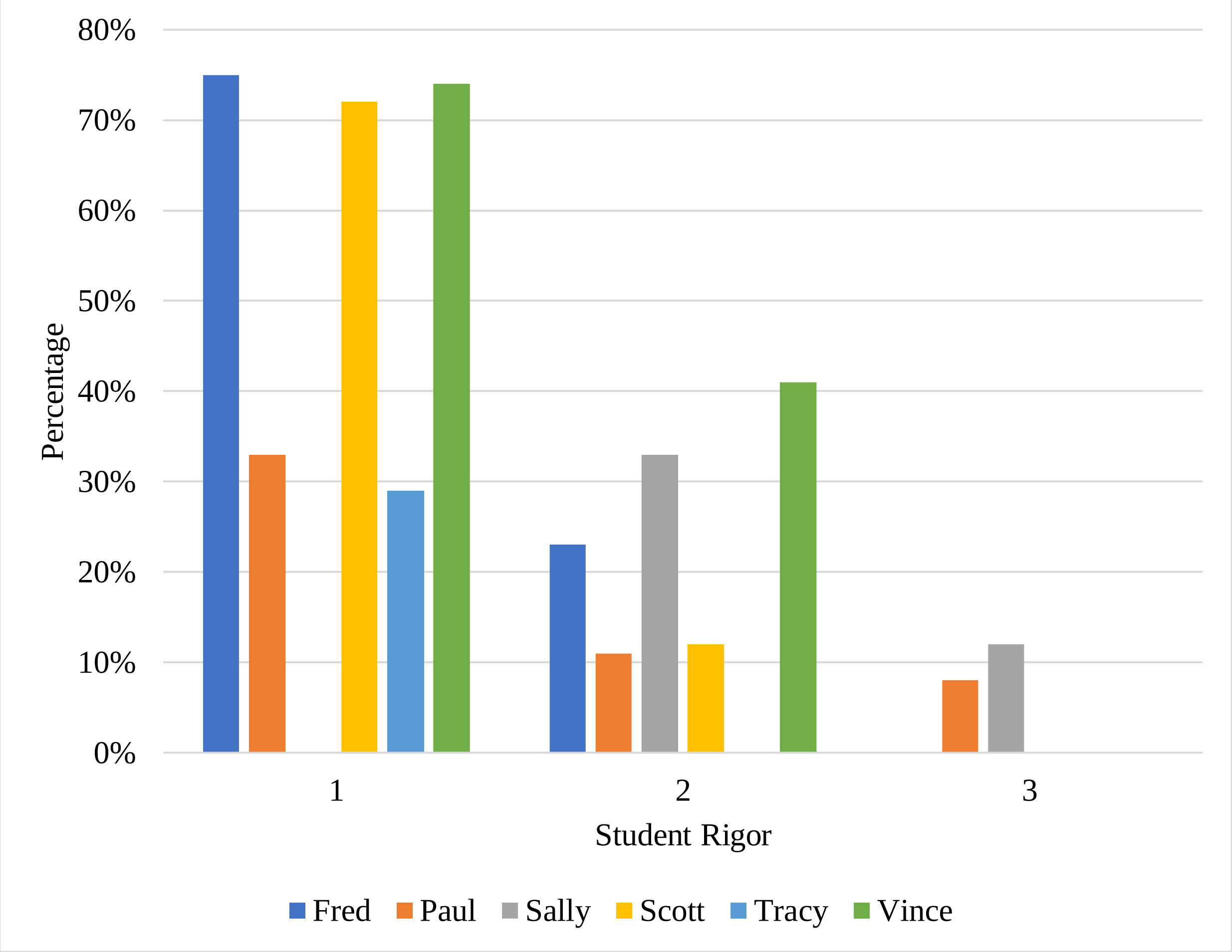
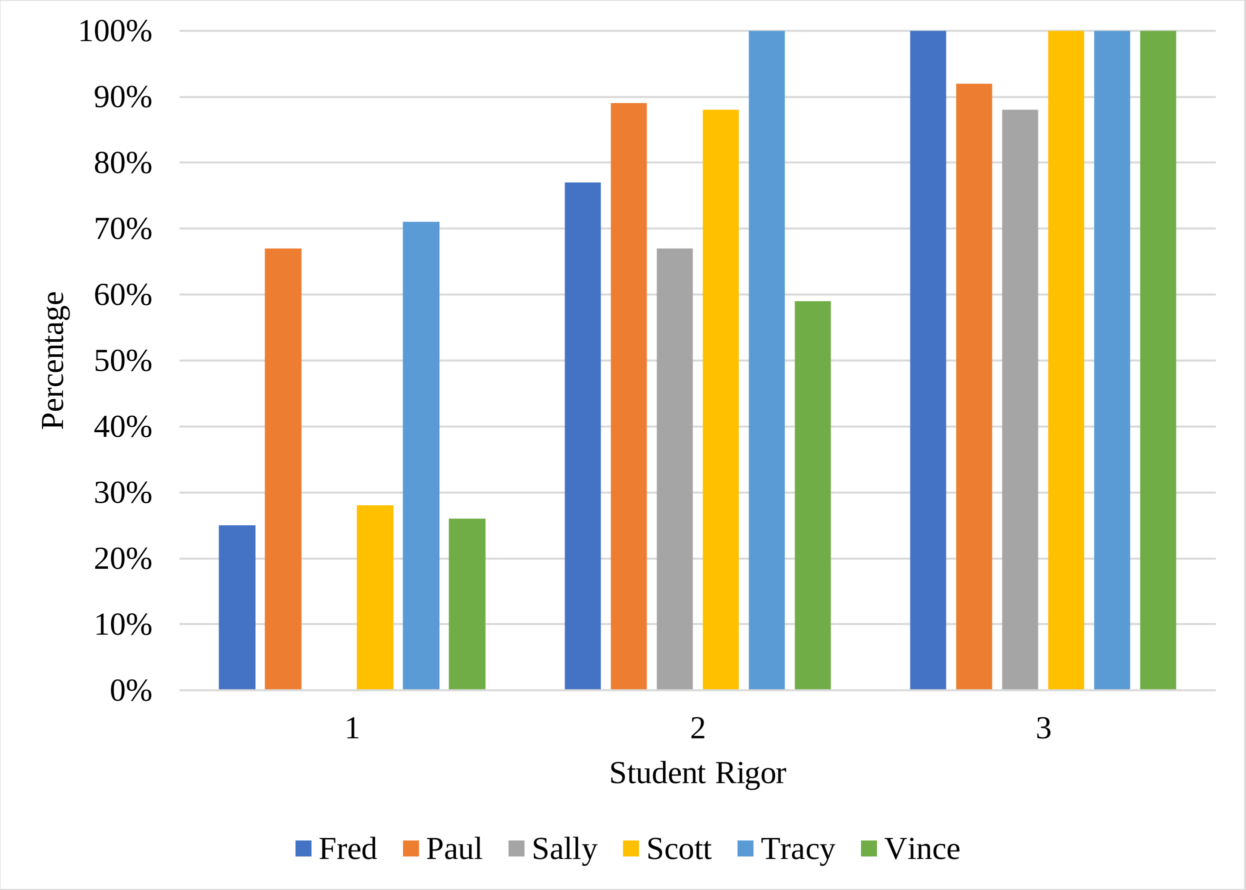


Figure 5

Percent of Ambitious Talk Moves used Prior to Three Levels of Student Rigor for each TA



Specific Talk Moves and Their Frequency During Three Levels of Student Rigor

While Table 6 demonstrated the count and percent of the two categories of talk moves (conservative and ambitious) used prior to three levels of student rigor for all six TAs, a more fine grained analysis on which specific talk moves embedded in each of the two categories was conducted. Table 7 expands on the data provided in Table 6 by providing counts for each of the 8 individual talk moves. As previously described, three talk moves made up the category of conservative talk moves: display questions, evaluating correctness, and minilectures. Five talk moves made up the category ambitious talk moves: distribute participation, acknowledge contribution, revoice, press for explanation, and probing questions.

Table 7

Counts and Percent of Specific Talk Moves Used Prior to Three Levels of Student Rigor for All Six TAs

		Rigor Level 1	Rigor Level 2	Rigor Level 3
Conservative Talk Moves	Display question	49 (54%)	6 (9%)	0 (0%)
	Evaluating correctness	9 (10%)	8 (11%)	2 (4%)
	Minilecture	3 (3%)	1 (1%)	0 (0%)
Ambitious Talk Moves	Distribute participation	3 (3%)	20 (29%)	11 (24%)
	Acknowledge contribution	10 (11%)	10 (15%)	6 (13%)
	Revoice	0 (0%)	1 (1%)	5 (11%)
	Press for explanation	7 (8%)	16 (23%)	18 (39%)
	Probing question	10 (11%)	8 (11%)	4 (9%)
	Total Instances of Each Rigor Level	**91**	**70**	**46**

Note. TA: teaching assistant. Percent values are from total counts within each rigor level. Example: display questions make up 54% of the talk moves used prior to level 1 student rigor.

From Table 6 and Table 7, conservative talk moves made up 67% of the talk moves used prior to level 1 student rigor. There were 61 moments in which conservative talk moves were used prior to level 1 student rigor, and within those 61 moments, 49 moments were display questions. Therefore, display questions were the primary talk move used by TAs in this category, and they made up 80% of the conservative talk moves used prior to level 1 student rigor. Ambitious talk moves made up 33% of the talk moves used prior to level 1 student rigor. Within the 30 moments, acknowledge contributions and probing questions each made up 10 moments.

Therefore, those were the two commonly used ambitious talk moves preceding low student rigor. For moderate student rigor, conservative talk moves made up 15 of the 70 moments (21%) preceding level 2 student rigor, while ambitious talk moves made up 55 of the 70 moments (79%). Within the 15 moments in which conservative talk moves were used, evaluating correctness and display questions made up 8 (53%) and 6 (40%) of the moments, respectively. Within the 55 moments in which ambitious talk moves were used, distributing participation and pressing for explanation were the specific talk moves, making up 20 (36%) and 16 (29%) of ambitious talk moves, respectively. For high student rigor, conservative talk moves only made up 2 of the 46 moments (4%) preceding level 3 student rigor, while ambitious talk moves made up 44 of the 46 moments (96%). Within the two moments in which conservative talk moves preceded level 3 student rigor, both moments were due to the TA evaluating correctness. For the 44 moments of ambitious talk moves, 18 came from pressing for explanation (41%) and 11 came from distributing participation (25%).

The Statistical Relationship Between Rigor and Responsiveness

To test if there was an association between the TA talk move category (ambitious vs conservative) and the rigor level of the student response, a Pearson's Chi-squared test of independence using a contingency table analysis was performed. α was set to .001. The null hypothesis stated: there is no association between the TA talk move category and the rigor level of the student response. The relationship between talk move and rigor level variables was significant, χ^2 (2, N = 18) = 63.03, $p < .001$. Given the statistically significant p-value, we rejected the null hypothesis suggesting that the data was consistent with the alternative hypothesis that there was an association between the TA talk move category and the rigor level of the student response. The following contingency table (Table 8) demonstrates the expected values for the student rigor levels and talk move category assuming the null hypothesis. Table 6, previously listed, demonstrated the observed values for each of the variables.

Table 8

Expected Instances of Talk Move During Each Student Rigor Level

Student Rigor	Conservative Talk Move Used Prior to Rigor		Ambitious Talk Move Used Prior to Rigor	
	Count	Percent (%)	Count	Percent (%)
1	34.3	44	56.7	44
2	26.4	34	43.6	34
3	17.3	22	28.7	22

CHAPTER 5

DISCUSSION

TA Talk Moves Over Multiple Enactments

As previously described, there were no discernable longitudinal patterns to the TAs' talk moves over the three semesters in which the TAs instructed students. It should be noted that by longitudinal patterns we meant measurable increases and decreases in talk move usage during and across each case. Outside of these patterns, other trends are worth discussing. The fact that nearly every TA had instances of using inclusive and ambitious talk moves is worth discussing, considering any high-level pedagogy from novice instructors is surprising. The finding that these inclusive and ambitious talk moves didn't increase or decrease statistically over time was not surprising, but the fact that these entry level educators used any high-level talk move was unanticipated. This trend extended to nearly every TA and happened consistently during each semester. Considering the TAs took part in a pedagogically-focused ambitious science teaching seminar course simultaneously with their teaching load, the lack of longitudinal patterns for each TA across their three semesters is problematic and exposes issues many TAs, educators, and practitioners face (Grinath & Southerland, 2018). However, while the TAs did not show discernable "growth" in moving from a more conservative to ambitious/inclusive talk move ratio, the finding that TAs at least used some ambitious and inclusive moves throughout the three semesters was unexpected and could be a future research direction. This was one of the only studies investigating the talk moves that TAs utilize in an undergraduate classroom, and one of the only studies focused on how the patterns of these talk moves develop over time.

The closest comparison study we have was from Thompson et al. (2013) who described how 26 novice high school and middle school teachers attempted to apply the ambitious science teaching practices during their first year of teaching, and they found thee discrete patterns of application: full integration, partial integration with specific attributes, and lack of integration outside of language. According to the authors, novice K-12 teachers should not be expected to fully appropriate ambitious science teaching practices within the first year of teaching primarily because implementing such practices is vastly challenging. In our study, however, no distinct longitudinal patterns were isolated amongst TAs, given that the variability of students using talk moves was essentially random across time. At the same time, our study found that nearly every TA did at least use some inclusive and ambitious talk moves each semester, which, while not fully supporting a ”total integration” discussed in Thompson et al. (2013), does showcase an interesting finding in our sample of TAs.

TAs are critical characters in post-secondary education that often get overlooked in science education research. TAs are responsible for much of the curriculum in many college and university settings, yet little to no pedagogical training is focused at preparing TAs for educating students. The little research that does exist focused on TA pedagogy suggests TAs need practice and preparation to notice and engage with students' ideas (Hill et al., 2018). Therefore, these novice educators clearly struggled using inclusive and ambitious talk moves during their first semesters teaching, and according to our findings, they also struggled to move toward a pattern of more ambitious talk moves over time. They did, however, tend to use at least one ambitious move each semester, suggesting that the TAs are not incapable of encouraging high-level pedagogical discussions in their classrooms.

Research continues to support the notion that novice teachers, even if they have experience and education practicing the ambitious science teaching practices, struggle effectively using them to move students toward sense-making. Corcoran and Gerry (2011) observed over

120 K-12 classrooms and found that less than one third of classrooms contained any higher order thinking conversations among students. Beyond simply knowing that the talk moves exist, and understanding which are considered more rigorous than others, knowing what *to do* with students' ideas by using the ambitious science teaching practices remains challenging. The findings from our study continue to affirm O'Connor and Michaels' (2019) principle that novice, and even many experienced, teachers tend to recite talk moves rather than use them for any reasoning purposes while eliciting student ideas. Perhaps the most important discussion to be made with the findings from our first research question is that even while TAs were being supported through ambitious science teaching-focused preparation, this support was not sufficient to encourage all TAs to elicit rigorous student contributions, which suggests implications for TA professional learning.

Interestingly, even though all of the elicitation discussions lasted for nearly identical amounts of time, the number of student ideas and talk moves used by TAs differed dramatically within the three semesters each TA taught as well as between TAs during different semesters. For example, during Scott's first semester teaching, he used 85 total talk moves, but by the time he had the same elicitation discussion the following semester, he used only 46 talk moves. This inconsistent pattern is seen across all TAs, and the variance in the number of talk moves per semester of teaching was large. This suggests that the student contributions, among other factors, played a critical role in determining the classroom conversations.

While an advanced educator may be able to move students toward high explanatory rigor regardless of a "starting point" of conversation, as seen in Thompson et al. (2013), our study showed that novice educators, especially TAs, had difficulty doing so. In order to elicit student thinking and move student responses past simple factual responses, carefully planned initial questions and general discourse patterns need to be used, and the TAs in this study did not develop that skill over the duration of time we investigated their classroom conversations. Therefore, instead of the TA directing student understanding, it was often the responsiveness of the classroom that dictated how the TA moved students toward learning.

Numerous times, with various TAs, when the classroom lacked responsiveness and offered low rigor answers, instead of the TA continuing to press the classroom for explanations or build on the ideas students presented, the TA provided much of the explanation themselves. Once a TA provided explanations themselves, this would effectively “shut down” student talk, and the sheer number of both student ideas and TA talk moves were dramatically decreased. The inconsistencies of student ideas and TA talk moves from semester-to-semester suggests that the TAs were heavily influenced by the responsiveness of the classroom. While it is helpful to look at the total numerical counts of talk moves each TA used during each elicitation discussion, the counts can be misleading for the same reason previously described. Some TAs’ elicitation discussions resulted in many talk moves being used simply because the students were more responsive, but not necessarily more rigorous, to classroom conversation. Because of this, the percentages of talk moves for each TA per semester is a helpful visualization tool to understand the story of each semester’s elicitation discussion.

These numbers, however, also can create a problematic understanding of the effectiveness of TA talk moves. For those TAs that had very few talk moves due to the classroom either being unresponsive or due to the TA offering explanations themselves, the percentages in our study were slightly skewed based on the low total number of talk moves during that elicitation discussion. The findings presented in this study fail to demonstrate any pattern of TA talk move usage over the three semesters in which they taught the undergraduate biology laboratory section. Further, the inconsistencies in the TAs' talk move counts each semester suggests students might dominate classroom conversation to a greater extent than previously thought for novice educators, and it takes highly trained teachers to be able to move any and all classrooms toward rigorous explanations and conversations.

The Relationship Between Rigor and Responsiveness

From the statistical analysis using chi-square contingency tables and tests of independence, there was an association between the talk move category, a proxy for responsiveness, and the rigor of student responses. This finding supports a long line of research suggesting that highly rigorous student talk cannot be reached without the use of highly ambitious or rigorous teacher talk moves (e.g., Thompson et al., 2016). This finding offers further support that it was indeed the TAs that used more ambitious talk moves that noticed their students speaking with higher explanatory rigor. There was also clear step-wise relationship between the three levels of student rigor and the talk moves that preceded student rigor. As demonstrated in Figures 3 and 4, as student rigor increased from level 1 to level 3, the count and percentages of conservative talk moves preceding student contributions declined. At the same time, as student rigor moved from level 1 to level 3, the amount and percentages of ambitious talk moves increased.

While this result is altogether not surprising, and positively shows the relationship between ambitious science teaching practices and higher student explanatory rigor, it is interesting that although there were no longitudinal patterns in TA talk moves, the rigor and responsiveness pattern persists amongst individual instances across the data set. Figure 2 demonstrates the combined counts of conservative and ambitious talk moves used prior to the three levels of student rigor, and the results from this figure support the idea that highly rigorous student talk cannot be supported without the educator implementing ambitious talk moves. This holds true for both level 2 rigor and level 3 rigor instances, as ambitious talk moves accounted for 79% and 96% of the talk moves preceding student contributions, respectively. Interestingly, moments of low student rigor, rated at a level 1, were preceded by ambitious talk moves 33% of the time.

While ambitious talk moves were absolutely necessary to support highly rigorous student contributions, they were not sufficient themselves at promoting high rigor. As an educator, simply implementing ambitious talk moves in classroom conversations will not automatically move students toward rigorous sense-making and classroom dialogue, and one must be careful of what some authors consider reciting talk moves rather than using them for reasoning (O’Connor & Michaels, 2019). This begs the question, why did the ambitious talk moves used prior to low student rigor contributions not result in rigorous student talk? What are the different purposes ambitious talk moves serve? It must also be considered that low student rigor was accompanied by many conservative talk moves, and overall, for all the TAs combined, low student rigor was still predominately preceded by conservative talk moves. Michaels and O’Connor (2015) suggested that requiring teachers to use evidence-based discussion and argument talk moves, such as ambitious talk moves, does not spontaneously create a rigorous classroom environment. The findings from the current study support this notion, as not all TAs who used ambitious talk moves moved their students toward more rigorous talk.

Specific Talk Moves Used for Each Rigor Level

In the following three sections we will discuss the specific talk moves that were used prior to each of the three levels of student rigor and the implications behind these findings.

Relationships and comparisons between the talk moves used for each rigor level will be discussed, along with postulations for such patterns.

Level 1 Rigor

Table 7 demonstrates each of the specific conservative and ambitious talk moves and their frequency during each of the three levels of student talk. Not surprisingly, display questions made up 80% of the conservative talk moves that preceded low student rigor. This result adds to a plethora of education research, especially in the sciences, that notices IRE patterns continue to dominate classroom conversations at all levels of education (Billings & Fitzgerald, 2002; Michaels & O'Connor, 2015). This pseudo-dialogue does little to encourage conceptual thinking or to engage students in building science knowledge, so we expected low rigorous student contributions to be most linked to IRE patterned questions. By providing simple one word answers, it was difficult to understand if the students truly understood the topic being discussed. It is possible that students randomly offered an answer that happened to be the correct answer. Therefore, the TA, students, and researchers cannot determine if the student truly comprehended the classroom content while providing simple, low rigor answers.

In addition to display questions making up 80% of the conservative talk moves that preceded low student rigor, evaluating correctness made up another 15%. Together, display questions and evaluating correctness made up 95% of all the conservative talk moves that preceded low student rigor contributions, certainly exposing the dangers of IRE teaching and student learning. The transcripts from moments in which student rigor was low support this finding, which further maintains the principle that low cognitive talk moves seen in the conservative talk move category do little to nothing to build on students' ideas and drive students toward more rigorous science explanatory understandings. While the TAs were being taught ambitious science teaching practices, and more specifically the talk moves discussed in this thesis, the findings from this study support Michaels and O'Connor (2015) who claimed that even through growing research knowledge and professional development implementation, the majority of science teachers continue to use teacher-led talk IRE patterns in the classroom.

In addition to conservative moves being used prior to low student rigor, there were some ambitious talk moves used as well, specifically acknowledging contributions and asking probing questions. While the finding that ambitious talk moves preceded low student rigor nearly a third of all level 1 rigor moments may be initially surprising, the specific ambitious talk moves used offers meaning to the numbers. Acknowledging student contributions was one of the main ambitious talk moves used prior to low student rigor, suggesting that this talk move may not be the most powerful move to engage students in rigorous conversation.

This intuitive finding may be due to the fact that TAs do little with students' ideas when simply acknowledging their contributions. In fact, the category (ambitious or conservative) in which to place this specific talk move was of initial debate for the research team, as this specific move does little to no work with student ideas and was therefore difficult to categorically place. However, acknowledging student contributions does incite an inclusive community of learners by making ideas public, and the move demonstrates to students that their ideas and contributions are worthwhile (Grinath & Southerland, 2018). Because of this reason, our research team decided to include the talk move of acknowledging student contributions in the "ambitious" category.

Because this ambitious talk move does little with students' ideas, it seems appropriate for there to not necessarily be a push toward rigorous conversations following the move. Acknowledging contributions were nearly always paired with another talk move, and the other specific ambitious talk move that appeared prior to low student rigor was asking probing questions. As probing questions were often used to initial elicit student ideas before pressing into a student idea, the student responses frequently ranged from providing nearly no rigor at all to offering fairly rigorous initial thoughts. Because the TA was not searching for a single correct answer, but rather opening up the conversation to invite students' initial ideas about a concept, probing questions were considered ambitious. Therefore, while it may be initially alarming to see several ambitious talk moves used prior to low student rigor contributions, the nature of both acknowledging contributions and asking probing questions allows non rigorous dialogue to potentially form.

Level 2 Rigor

Ambitious talk moves made up the majority of the overall talk moves used prior to moderate student rigor, and the specific moves of distributing participation and pressing for explanation made up the majority of these ambitious moves. Pressing for explanation was used when TAs wanted to focus the classroom conversation on a specific student idea by pressing either an individual student or the classroom on a student-generated idea. Pressing for explanation was the most closely related ambitious talk move to accompany any higher rigor conversation, and whenever it was used by TAs in the classroom, it almost always was followed by moderate or high student rigor.

We know that when teachers initial elicit student ideas using open-ended questions and then focus on the ideas that students offer, student reasoning and explanations become more common. These students are then more likely to participate and to explain and reflect on their answers (McNeill & Pimentel, 2010; Oliveira, 2010). The finding that TAs who used the pressing for explanation ambitious talk move resulted in more rigorous student conversations supports the findings from Grinath and Southerland (2018) who found that extending student thinking was significantly related to TAs pressing student for explanations. The idea that students will not reach higher levels of explanatory rigor without the TA pressing students for explanations that accompany their observations was upheld in our study, and was one of our primary findings.

In addition to pressing for explanation, the ambitious talk move of distributing participation was another talk move preceding moderate student talk. The inclusive move of allowing multiple ideas to emerge during elicitation discussions is perhaps one of the most valuable components of initial talk in the classroom. Following the social constructivist theory of education, because each student comes to the classroom with diverse experiences and understandings, it is critical for teachers to explore students' existing conceptions in order to build new science comprehension (Treagust & Duit, 2008). Because there are clear connections between allowing multiple students to contribute to classroom conversations and student growth in complex forms of understanding, it is insightful that distributing participation, in this study, seemingly led to higher rigor in student conversations.

While there were some conservative talk moves used prior to moderate student talk, the number of conservative talk moves were reduced dramatically from low to moderate student rigor. The dominating conservative talk move for moderate student rigor was evaluating correctness, which was rarely used in isolation and was nearly always used in tandem with another talk move. For moderate student rigor, evaluating correctness did not lead to traditional IRE patterns, as seen in low student rigor, because the move of evaluating correctness was often followed by an ambitious talk move (pressing for explanation, distributing participation, etc.) instead of a display question. Therefore, the principle that conservative talk moves contribute to moderate student rigor is not entirely true, given that evaluating correctness was often coupled to an ambitious talk move, which were the primary moves that led to moderate student rigor.

Level 3 Rigor

The dominance of ambitious talk moves preceding level 3 rigor student contributions in our study supports the principle that a responsive classroom cannot be accomplished without a specialized repertoire of talk moves that teachers and students use together. These ambitious talk moves support sense making and scaffolded discussions in the classroom which are often considered the primary mechanisms for promoting deep understandings of complex concepts and robust reasoning (Engle, 2006; Leinhardt & Steele, 2005; Minstrell & Kraus, 2005; Scott & Mortimer, 2005). The two dominant specific ambitious talk moves that were used prior to high student rigor in our study were distributing participation and pressing for explanation. Much like level 2 rigor, these two specific ambitious talk moves do work with students' ideas to move them toward rigorous science understanding by explaining their ideas and hearing their classmate's ideas. While moderate rigor student contributions were preceded by mostly ambitious talk moves, with some conservative talk moves, high student rigor was rarely preceded by any conservative talk moves. As previously explained, the only two moments a conservative talk move was used prior to high student rigor was due to the TA evaluating the correctness of a student's answer. However, this conservative talk move was always coupled with a higher cognitive and more ambitious talk move that ultimately was the contributing factor to high student rigor.

One of the patterns observed in several of the elicitation discussions with higher proportions of highly rigorous student talk was the language TAs used while utilizing ambitious talk moves. Specifically, while pressing students for explanations, TAs used phrases such as “what is another explanation”, “let’s talk about our explanations together”, and “anyone want to share their explanation”. The direct use of the word “explanation” encouraged students to rigorously develop an explanation that could be shared with the class and allowed for more rigorous talk to develop between students in the classroom. When TAs would simply state “what else” or “what are other thoughts” and not directly use the word “explanations”, we often saw a variety of levels to student contributions as opposed to directly asking the student for an explanation. While examining exact words or phrases that motivate high student rigor was not the direct purpose of this study, it is worth mentioning that there seemed to be a relationship between the phrases and direct words TAs used and the ensuing student rigor.

Moving Students from Low Rigor to High Rigor with Ambitious Talk Moves

During each elicitation discussion, students rarely began the classroom conversation by offering highly rigorous contributions; therefore, we found it worth investigating how TAs used talk moves and classroom dialogue to influence highly rigorous student talk and direct student sense-making. Tracy’s classroom discussion excerpt from her second semester included in the findings chapter offers an example for how TAs used ambitious talk moves and practices to increase student rigor. The common trend seen in Tracy’s excerpt, as well as other TAs who successfully moved their students toward highly rigorous talk, began with distributing participation to uncover classroom ideas from different students. Using student ideas, the TA then pressed each idea for explanations. The TAs that successfully moved students toward high explanatory rigor did not allow low rigorous contributions to go unchallenged. Upon hearing student contributions, regardless of the level of rigor, successful TAs would withhold from assigning any correctness statement to such student contributions. Instead, the ambitious talk move of acknowledging contributions took the place of the conservative talk move of evaluating correctness. Tracy's elicitation discussion also highlighted a previously described yet critically important component of encouraging highly rigorous student responses, as she used direct language when asking students to offer *explanations*. Interestingly, the TAs that were most successful at driving student conversation toward more rigorous explanations were also the TAs that tended to call on their students by their names. The culmination of Tracy, and other successful elicitation discussions, continuing to press students for an explanation for the phenomenon resulted in more student ideas being generated, made public, and ultimately given an explanation.

The finding that using ambitious talk moves in a patterned arrangement led students to higher cognitive demand and more rigorous explanations supports much research suggesting that teachers who succeed in supporting productive discussion seemingly always rely on core sets of ambitious talk moves to elicit, respond to, and comment on student response (Osborne et al., 2004; Wells, 2007). These ambitious talk moves are distinguished as moves that do productive work with student ideas, that go beyond common classroom talk, and that continually press student ideas to form collective science knowledge.

Limitations

As with all studies, the present study has several limitations that should be considered when interpreting our findings. The first limitation was the size of the study, specifically when it came to the amount of variability found in the number of talk moves each TA used. While this variability was natural, by tracking only six TAs over three semesters for 18 total enactments, the statistical power in answering our first research question may have been compromised. While we used a variety of statistical tools in an attempt to help offset this challenge to our first research question, we suggest a larger sample size. By using additional TAs or following TAs over a longer period of time, more robust findings could be found.

Another limitation to our study comes from our decision to use a chi-square statistical test to find relationships between TA responsiveness and student rigor. Our chi-square test failed to take into account the different TAs and different semesters of nested data, as all of the TAs' data were combined for one statistical variable and subsequent p-value. While this statistical test was appropriate in this study for finding initial relationships between rigor and responsiveness, to account for the nested data, a generalized linear mixed effects model would be more appropriate to discover highly fine grain moment-to-moment associations between rigor and responsiveness across the varying TAs and semesters.

The data collected and used in this study come from previously acquired data from a different university in which our entire research team was not present to witness. This was primarily due to the research restrictions put in place due to the COVID-19 pandemic. Because of this, the data collected for this study was not collected from a project strategically designed by the committee, but rather retroactively used from previous acquisitions. Therefore, the research questions for this study were limited by the scope of what the already acquired data allowed us to examine and could have been more robust in data collection. For example, science teacher self-reflection is known to be a critical component in increasing effective pedagogical techniques over time, as demonstrated by Hollingsworth and Clark (2017), and could have aided in the TAs developing a more patterned improvement in talk move usage across the three semesters. Further, questionnaires and TA interviews could have given the research team a more robust understanding of metrics such as TA development.

As previously demonstrated and discussed in Figure 1, the laboratory course used for this study was designed as 12 modified learning cycles which each laboratory day consisting of three components: the engagement phase, exploratory phase, and explanation phase (Bybee et al., 2006). This study solely focused on the engagement phase of the laboratory day, and therefore our transcript, video and other classroom data did not account for the talk moves or student talk that occurred during the entire class period each week. While this was not necessarily an issue for this study, considering that our research questions and results were tailored for this isolated phase of the classroom day, it is worth considering the possibility that TAs may have moved students toward learning in ways we did not capture with our single phase data. For example, according to Table 5, adapted from Thompson et al. (2016), we left open the possibility to coding a 4 for students who would offer fully theorized science explanations or explanations for why a phenomenon happens. While we did not expect to see this type of rigorous explanatory student talk during our study specifically because we were only investigating the engagement phase of the laboratory, there may have been interesting moments in which this happened either during the exploratory or even the explanatory phase. Therefore, future studies may benefit from examining our research questions in context of the entire laboratory classroom time and may find patterns worth discussing that were embedded within each of the three phases.

Implications

The implications of this project are far reaching and extend to science educators of all levels. Even while TAs in our study were actively involved in a weekly course aimed at improving their pedagogical skills and refining their ambitious talk move strategies, we found no differences in TA talk move count across three consecutive semesters of teaching the same content and enacting the same elicitation discussions. This suggests professional development implementors need a more effective way of teaching and applying ambitious science teaching practices in educators’ work, especially for novice educators such as TAs. This also suggests more longitudinal research should be done focused on how and why educators adapt their teaching styles across their educational careers. It is clear that simply training teachers in the ambitious practices of science teaching does not ensure that they will effectively use them in their classroom, and it is now clear that these approaches are still not customary even across time and even while continuously being exposed to ambitious teaching demonstrations.

This study offers further implications for research founded on the sociocultural theoretical framework supporting how ambitious science teaching practices are crucial for ensuring a high quality and highly rigorous science classroom environment. The findings that rigorous student exploratory talk resulted only when ambitious talk moves preceded student contributions builds on this framework and should be authentically considered by researchers, educators, and practitioners alike.

CHAPTER 6

CONCLUSION

In answering our first question, we did not find any statistically relevant pattern in TA talk move use over three consecutive semesters of teaching. While this result seems insignificant, this result exposes issues in the implementation of TA pedagogical training. Even while TAs were participating in a course to increase their pedagogical skills, we were not able to find discernable longitudinal patterns that would reflect such training. While longitudinal patterns were not seen, other patterns of interest did emerge, such as the finding that nearly every TA was using ambitious and inclusive talk moves during each semester case. This result was unexpected given the minimal TA pedagogical training and novice-nature of their instructional skills. This finding may allow for future research investigating how novice educators are able to use high-level pedagogical moves with nominal training. Through this result, we also were able to determine that it was the students that primarily influenced the rigor of classroom talk instead of the TAs directing the conversations. These results have implications for future professional development work and can be used to better target how to improve TA teaching performance across time.

In answering our second question, we were able to demonstrate that TA talk moves have direct influences on the rigor of student talk. Improving rigorous student participation during elicitation discussions has long been a goal in science education (National Research Council, 2015). However, very little is known about how talk moves influence the rigor of student explanations when it comes to discussing a phenomenon. This study demonstrated clear patterns linking TA responsiveness, by proxy of ambitious talk moves, to high levels of student explanatory rigor. Not only was a link between the two statistically important, but there also cannot be sustained, highly rigorous student talk without ambitious responsiveness from the TA. This result supports previous work suggesting instructor responsiveness is crucial to ensure high quality student rigor (Grinath & Southerland, 2018, Thompson et al., 2016). However, this work had never been done in teaching assistants at the post-secondary level prior to this study, and therefore this study adds valuable research results for post-secondary and higher education. In addition to ambitious responsiveness being critical for high student rigor, this study also determined that specific TA language, such as asking students directly for explanations, can help move students toward higher levels of explanatory rigor.

This study was among the first to explore the talk move patterns exhibited by TAs at the post-secondary education level, and several themes were observed to assist educators in future research. Further replications of this study, with adjustments to previously mentioned limitations, are needed to draw generalizable conclusions for longitudinal TA teaching performance as well as for the relationship between rigor and responsiveness in college classrooms.

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