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Novice Science Teachers' Thinking About The Purpose Of Teachers' Questions

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NOVICE SECONDARY SCIENCE TEACHERS' THINKING ABOUT THE PURPOSE OF TEACHERS' QUESTIONS

by

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ABSTRACT

Effective teacher questioning during whole group instruction remains an important pedagogy in science education, especially the importance of helping novice teachers to guide student thinking using effective questions. This study examined how novice secondary science teachers' understand the relationship between student thinking and teacher questioning. The sample was seven novice secondary science teachers' enrolled in the University of Central Florida's job embedded *Resident Teacher Professional Preparation Program* (RTP[3]). All participants received instruction and guided practice with the use of questions to elicit, probe, and challenge student ideas in the secondary science pedagogy class. Participants completed a questionnaire describing their teaching experience and science content knowledge. The primary data were think aloud interviews describing their thinking while observing two science instruction videos. Protocols, critical incident interviews, and field notes were transcribed and coded for analysis. Descriptive codes identified properly classified question types and the purpose or value of questions, student thinking, and student reaction to teacher questions. Pattern codes identified student engagement, feedback, wait time, and communication patterns.

The think aloud used in this study provided insight into what the participants were thinking about the purposes of questions to elicit, probe, and challenge student ideas and gave insight into the decision process. Evidence from the protocol analysis provided insight about what the participants were thinking about the decisions made when attending to teacher questions and student thinking. All seven participants identified question types using language suggesting they understood the differences, but at a naïve level. Although participants used the

correct language to show understanding of the question types, they had a fairly naïve understanding of the pedagogical purpose of the questions. This was especially true of the questions to elicit student ideas, but perhaps less true of the probing and challenging questions. The participants had more of a ritualistic understanding of the questions to elicit student ideas; they noticed them but perhaps did not have a deep understanding of this question type.

Analyses of this study also revealed novice teachers learning is framed by the priorities of the public school system. All participants attended to teacher instruction, especially wait time and student engagement, while a few participants focused on feedback, praise, and higher- and lower-order questions. This study suggested school culture and the way teachers are now assessed may scaffold and support these teachers to have a more nuanced and sophisticated understanding of questioning and student thinking than has previously been reported for novice/beginning teachers. While some aspects of school culture and assessment may be problematic- i.e. wait time, feedback, praise, higher-order questions, etc.-on the whole it seems to be leading them in the right direction.

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CHAPTER ONE: INTRODUCTION

How do novice secondary science teachers understand the purpose of teacher questions? Teachers need to notice and make sense of student ideas for understanding the world around them. This is noted in the recent release of *A Framework for K-12 Science Education* (NRC, 2012), "Ultimately, the interactions between teachers and students in individual classrooms are the determining factor in whether students learn science successfully" and "teachers also need to understand what initial ideas students bring to school and how they best may develop an understanding of scientific and engineering practices, crosscutting concepts, and disciplinary core ideas" (p. 256). Since teachers need to notice student ideas to promote successful student learning, we need to understand how teachers' understand the relationship between student thinking and teacher questioning strategies. In this study, I examined novice secondary science teacher's thinking about the relationship between student thinking and teacher questioning strategies.

Statement of the Problem

Science teaching in schools is not always consistent with the reform goals of science education in terms of students' ability to combine scientific knowledge, reasoning, and thinking to develop an understanding of science. The purpose of this study was to examine how novice secondary science teachers' understand the relationship between student thinking and teacher questioning strategies through the use of a protocol analysis. When learning science, students typically construct meaning in a social context. One social context in which students construct understanding of scientific concepts is through teacher-led classroom discussion connecting student thinking to the scientific principle. Teacher questioning with the aim of helping students assemble knowledge plays an important role in classroom discussion. The kinds of questions that teachers ask affect student engagement with the scientific knowledge and how meaning-making is constructed; yet research has shown that questioning does not always end in student construction of knowledge. Instead of posing questions to determine students' prior knowledge, to further understand student ideas, and to connect students to make new connections, most teachers request factual knowledge that does not provide for student learning (Graesser & Person, 1994). Teachers are not skilled in making decisions about the type of questions to ask when eliciting student ideas about the concept being taught (Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011).

Despite the considerable amount of research done in the area of questioning, the studies were focused on teacher *behavior* rather than teacher *thinking*. The purpose of this study is to examine how novice secondary science teachers' see the relationship between student thinking and teacher questioning strategies through the use of protocol analysis. Research has been conducted in the area of questioning patterns as teacher behaviors to evaluate what students know (Mehan, 1979) and in addition to increase teacher behaviors to elicit student thinking and allow for student construction of scientific meaning (Lemke, 1990; Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011; van Zee & Minstrell, 1997), but these studies did not look at *teacher thinking* about the questioning strategies. The problem is teachers' ineffective engagement with the questioning strategies. In Roth et al.'s (2011) Science Teachers Learning from Lesson Analysis (STeLLA) project, fourth-, fifth-, and sixth-grade teachers were instructed on the knowledge about the types and uses of questions eliciting, supporting, and challenging students' thinking about specific science content to help them improve their teaching practices. Results showed the strategies were implemented at a beginning level to make student thinking more visible, yet teachers were still not skilled at making decisions about when and how to use other questions to move students forward in their thinking without giving them the right answers. Teachers asked probing questions unrelated to the specific science ideas and also asked elicit questions designed to produce multiple responses, but as soon as a student gave the correct answer, the teacher ended the discussion. Although Roth and colleagues (2011) reported on in-service elementary science teaching, this study adds to the research on questioning by examining what novice secondary science teachers are thinking in terms of the types and uses of questions to elicit, probe, and challenge student ideas within the protocol analysis methodology to capture their real-time thinking about types of questions teachers ask and the effect on student thinking.

Theoretical insights from stage-based theories of framing in teacher development provide another contribution of framing. The research literature found novice teachers' struggle with the ability to attend to student ideas (Levin, Hammer, & Coffey, 2009). The problem of novice teacher attention to student thinking becomes more visible when science pedagogy classes are not structured with activities and assignments framed around student thinking. Novice teachers who attended more traditional pedagogy classes that focused on curricular fidelity and classroom management tended to follow the priority of educational institution encouragement to frame teaching in terms of curriculum and classroom management. This is demonstrated when teachers probe for student understanding but then reword student responses to reflect the vocabulary stressed in the curriculum (Levin, 2008; Lau, 2010). To address this concern, I framed teaching routines around student thinking with instruction and guided practice with the use of questions to elicit, probe, and challenging student ideas in the secondary science pedagogy class. Novice secondary science participants were selected from this class.

Research Questions

This study described novice secondary science teachers' understanding of the purpose of teachers' questions and the appropriateness of questioning strategies for facilitating student learning. In order to understand how novice secondary science teachers' understand the relationship between student thinking and teacher questioning strategies the following research questions are addressed:

1. What factors do novice secondary science teachers' attend to in the instructional environment when considering the effectiveness of a questioning strategy?
2. How do novice secondary science teachers' connect teachers' questions to the scientific principle?
3. What patterns emerge from novice secondary science teachers' thinking about the role of questioning during instruction?

Limitations

There are limitations to this study. A limitation of this study is the small sample of teachers involved. The original design specified 30 teachers from the University of Central Florida RTP^3 job embedded program, but after only ten volunteered, only seven participated in the study. Another limitation is that this research study found the novice secondary science participants able to attend to student thinking through their understanding of teacher questioning strategies. Although the participants were taught the procedures for questions to elicit, probe, and challenge student ideas in their science pedagogy course and attended to student learning through their understanding of questions to elicit, probe, and challenge student ideas, it was not determined that the participants learned this knowledge from the pedagogy course.

Definition of Terms

The following terms and related definitions were provided to increase the clarity of the study.

<u>Attention</u>: the focus of one's mind on something (Lau, 2010, 54).

<u>Critical incident record</u>: a specific slice of reality, one defined in advance and guided by a specific framework or theory" (Evertson & Green, 1986, p. 178).

<u>Concurrent verbalization:</u> verbalization of task-relevant thoughts generated between the start of a primary task and the completion of the associated task (Ericsson & Simon, 1984, 1993; Fox, Ericcson & Best, 2011).

Discourse: using language in social contexts and connected to social practices, "ways of being in the world…forms of life which integrate words, acts, values, beliefs, attitudes, and social identities as well as gestures, glances, body positions, and clothes" (Gee, 2001a, p. 526).

Framing: a person may take on a position or status in a situation that may govern how that person manage(s) the production or reception of an utterance (Goffman, 1981). A person's frame or framing of the situation is his or her definition of what is going on in the interaction (Tannen, 1993).

Noticing: what teachers attend to in the moment of teaching, as well as how they reason about what they observe (van Es & Sherin, 2008)

Novice teachers: a novice teacher as one with less than 3 years of teaching experience and one whose teaching tends to focus on "survival" (Huberman, 1993) and establishing basic classroom routines (Sherin & Drake, 2000).

Questions to Challenge Student Ideas: Teacher questions that challenge student thinking and pushes students to think further, to reconsider their thinking, to make a new connection, and/or to use new science vocabulary (BSCS, 2012).

Questions to Elicit Student Ideas: Teacher questions phrased in everyday language posed at the beginning of a lesson, new idea, unit of study, and discrepant event to learn about students' prior knowledge, misconceptions, experiences, predictions and ideas to determine if the ideas are scientifically accurate or not; to engage students in the topic of study so they may see the links between their ideas, peer ideas, and the science they will learn in the lesson (BSCS, 2012).

Questions to Probe Student Ideas: Teacher questions directed to one student who has already offered an answer or idea and the teacher follows up with this student posing questions to further understand the student's thinking about the science ideas (BSCS, 2012).

Think aloud: Informational processing model where participants verbalize "out loud whatever they are saying silently to themselves" (Ericsson & Simon, 1993, p. 226).

Triangulation: Patton (2002) cites Denzin (1978) to define one type of triangulation as "methodological triangulation, the use of multiple methods to study a single problem or program" (Patton, 2002, p. 247). For this study, the multiple methods used were field notes, critical incident reports, and think aloud interviews (Ericsson & Simon, 1993).

Ethical Considerations

A utilitarian viewpoint (Miles & Huberman, 1994) was used to protect participants' rights throughout this study and to guarantee ethical considerations were observed. Four main actions were taken to protect participants: the research protocol was reviewed by the Institutional Review Board (IRB) of the university, participants were recruited with an informed consent, fieldwork was conducted so as "to avoid harm to others," and participants' confidentiality was maintained through the use of pseudonyms.

Specific procedures were used to protect the participants during the study. First, participants were reminded of their rights to withdraw from the study at any time. Second, participants' confidentiality was protected through the use of audio recording. Finally, participants were only discussed by their pseudonyms and all nominal data were kept in a locked filing cabinet until the information was no longer needed. As soon as audio recordings were transcribed, the digital recorders were erased. Through careful consideration, no harm was done to participants during this study and ethical considerations were made throughout the entire process using a utilitarian viewpoint (Miles & Huberman, 1994).

This chapter introduced the research study including the problem, research questions, limitations, definition and description of terms, and ethical considerations. Chapter 2 reviews the conceptual and empirical literatures on teacher questioning, novice teachers, noticing literature, and questioning study methods. Chapter 3 explains the research methods used in this study. Chapter 4 presents the data analysis and summary of findings of the research questions and Chapter 5 connects the literature review and methodology with the summary of findings in the conclusion and discussion section.

CHAPTER TWO: LITERATURE REVIEW

Introduction

In this literature review, the research on teacher questioning, novice teachers, noticing literature, and questioning study methods in science education are discussed. Students come to school with a considerable amount of knowledge from their previous experiences. Noticing these ideas and guiding students to build on these ideas through teacher questioning strategies will allow for a coherent understanding of the scientific explanations of how the world works. To determine how novice secondary science teachers think about the relationship between student thinking and teacher questioning strategies, the literature reviewed within the study was guided by my research questions. The research questions required a focus on teacher questioning, teacher thinking, and novice teacher attention to student thinking and a focus on questioning study methods in order to better understand the factor's related to how novice teachers understand the purpose of teacher questions.

Consultation appointments with University of Central Florida's research librarian began and finalized the literature review process. The literature research process explored various educational databases (Education Full Text, Professional Development Center, Science Direct, Springer, Science & Technology, Teacher Reference Center, Web of Science, and ProQuest Dissertations & Theses). Due to the omission of dissertations in ProQuest for some universities, searches were conducted at each major university that was a member of ProQuest to locate dissertations pertaining to the literature of this study.

In this chapter, the conceptual framework is presented, explained and supported with literature. The research methods that have been used to study questioning are reviewed and critiqued, and think aloud research methods are presented as a means of overcoming the limitations of earlier research methods.

Literature Review of Conceptual Perspective

Teacher questioning is a prominent part of classroom discourse and it is important to gain insight into these discussions to understand student achievement. Researchers have categorized questions for teacher use, tallied participant frequency of use of types of questions and have more recently engaged teachers in strategies to reveal the purposes of teacher questions to support student achievement. The focus on this research was to understand novice secondary science teachers understanding of questions and their purposes.

A conceptual framework emerged from the synthesis of previous studies and will be used in analyzing the research on questioning. Science is constructed in the social context of science classroom discourse between the teacher and students. Student's initiate ideas and ask questions. Teachers ask follow-up questions, such as eliciting, probing, and challenging questions, to understand student thinking and guide the student towards the science concept being taught. Novice teachers are able to attend to student thinking early in their teaching practice, but it may depend on how the teacher frames what is taking place in the classroom. Teachers may show shifts in their thinking, showing attention to student thinking at some points, shifting their attention to other aspects such as classroom management or the curriculum.

Teacher Questioning

Prior to 1970, researchers categorized question types, observed and analyzed teacher questioning behaviors. Types of questions were classified into different categories for teacher use in asking questions at different cognitive levels. Categories such as Bloom's (1956), Gallagher's (1965), and Carner's (1963) allowed for questions to be categorized by their cognitive level. The question classification systems are composed of categories based on the cognitive processes that are required to answer questions. Bloom's Taxonomy, today, categorizes question types into the following categories: remembering, understanding, applying, analyzing, evaluating and creating and is widely used by science teachers today to construct the questions they use in classroom discussions (Krathwohl, 2002). Although the categories are a useful list, the problem is if it is used as a set sequence to guide learning (Ritchhart, Church, & Morrison, 2011). Ritchhart and colleagues point out that all items in Bloom's Taxonomy do not operate at the same level. Student understanding requires thinking and remembering and the way understanding is phrased does not require thinking (p.7). Another point, even though teachers ask higher cognitive questions, they may not be assessing student knowledge the way they were intending or creating student understanding. This was a point Gall (1970) stressed in her review of the literature of research on questioning.

Building on Bloom's Taxonomy, Blosser (1973) introduced a tool for researchers to understand open and closed question types asked by teachers and study teacher questioning behavior, the Question Category System for Science (QCSS). Closed questions for limited acceptable responses, "right answers," and open questions to anticipate multiple acceptable responses that draw on student past experiences. Open questions promote discussion and allow students to share ideas, predict, interpret, infer, and justify. Open questions can be further subdivided into divergent, evaluative, questions such as ‘What do you think?’ or ‘What is the best …?’

Beliefs that using higher cognitive questions result in student achievement still prevails today despite research finding that student achievement does not occur (Winne, 1979; Gall, 1970). Winne analyzed 18 quasi-experimental studies investigating teacher questioning practices effect on student achievement to determine if assumptions and claims were supported by literature. Winne found teachers’ use of higher cognitive questions had little effect on student achievement. Gall (1970) illustrated this view, in her review of research, that the weakness of question classification can be an inferential process (Bloom, 1956). One example would be to ask a student “What are some similarities between compounds and mixtures?” The intentions for the question may have been to be a high cognitive level question to create critical thinking, but the student may have recalled this information from reading the textbook. Gall also stated that there were questions teachers should be asking, such as follow-up questions, to probe students for understanding their thinking. But, the use of the categories levels of cognitive questions still prevail because Redfield and Rousseau’s (1981) meta-analysis of Winne’s meta-analysis showed using higher cognitive questions did have an effect on student achievement.

Asking follow-up questions takes a student forward in their thinking and enables the teacher to provide scaffolding for students in building their understanding of a concept (Martens, 1999). Martens discussed a teachers’ use of Eltgeest’s (1985) guide to questioning of the proposed six types of productive questions to facilitate and guide elementary students through science lessons. The six types of productive questions defined by Eltgeest are questions that follow a pattern in the course of studying science. Attention-focusing questions begin the study by asking students what they notice. Measuring and counting questions follow for student skill practice and use of new instruments. These questions lead to comparison questions for sharper observations, how objects differ when comparing properties. Eltgeest's action questions followed and were posed as 'what happens if' to lead to experimentation, and then problem-posing questions posed after experimentation to move students to explore further, 'can you find a way to?' Teachers reasoning questions, 'how' and 'why' questions, create discussion making students think and reason independently about their experiences. The productive questions stimulate reasoning in students and carry them forward in their thinking.

Carr (1998) conducted a study where paired science teachers observed each other's lessons on questioning and compared notes. Types of questions asked included open questions, probing questions to obtain further detail of specific information, reflective questions to crystallize a particular point, closed questions and hypothetical questions. Carr's found closed questions were asked more frequently than open questions, pairing questions with diagrams and illustrations were more effective for student involvement, and posing multiple questions resulted in student confusion and unhelpful to their thinking and learning.

Koufetta-Menicou and Scaife (2000) classified science teachers' questions into categories according to the mental operation that is required to answer the question. Lower level questions were subdivided to include a) recall of facts, events and definitions and b) descriptions of situations and variable identification. Higher level questions included questions that ask for a description and justification of procedures, begin with ‘how’; seek evidence; recognize a pattern or describe a trend; ask for reasoning, ‘Why’, ‘What if’, and conclusion questions. Findings of this study found that asking lower level questions were not positively related to any desired learning outcome, asking ‘how’ questions was an important step towards metacognition when students though about procedures and the underlying reasons, and questions asking for evidence were associated with teacher guidance in resolving cognitive conflicts.

These early studies examined question categories. Although categories, such as Bloom’s taxonomy and productive questions, enable teachers to follow a pattern of questioning to help students to move through investigations with understanding, this pattern of questioning did not focus on determining student’s prior understandings of the concept and further guiding students with alternative conceptions to accept a more scientific view of the concept.

Questioning in Science Discourse

Question and answer sequences were a large part of the research on questioning in the 1980s. Earlier versions of the Initiate-Respond-Evaluate (IRE) questioning sequencing began with a question initiated by the teacher, a student response, and the teacher evaluation on the correctness of the student answer (Cazden, 1988; Mehan, 1979). The teacher dominated questioning sequence resulted many times in preformulating or reformulating the questions (French & MacLure, 1981) to enable the lesson to proceed as planned. The teacher would preformulate the question to orient student answers in the range of the answer the teacher was looking for instead of an open-ended question that would provoke many answers. When a student incorrectly answered a question, the teacher would reformulate the question that would include clues to the answer. Both situations decreased the cognitive level of the student.

Lemke's (1990) seminal work, *Talking Science: Language, Learning, and Values*, applied a social semiotic perspective to discourse in secondary science classrooms, emphasizing that science lessons are constructed in a social context. In studying the dialogue in science classrooms, Lemke's analyses identified patterns, as described above, which showed the teacher controlled the discourse, without student presentation of ideas. Lemke emphasized that the students needed to learn to talk science, to observe, describe, classify, discuss, question, challenge, generalize, and "combine the meanings of different terms according to accepted ways of talking science" (Lemke, 1990, p. 12). Lemke argued that the teachers control over the science discourse did not allow for discussion, justifications, and re-examining issues. Instead, the teacher's portrayal of science was ideological, science was difficult to learn and for the elite. Lemke concluded that students may have lost interest in science because of these actions. Instead of science talk, some teachers talked science.

How teachers talked about science was another frame of research in science discourse (Moje, 1995), a sociolinguistic view. In some studies, language use was identified to position science teachers and science as authorities. This perspective limited students to the understanding of science as knowledge about the natural world. Moje gave an example where a teacher's view of scientific practices was reflected in the classroom discourse when a student was told to repeat an imprecise answer three times. This view of scientific practices as a means to enforce exactness of scientists limited student views of science instead of being able to view science as a resource for understanding the social practices of a community. Similarly, Carlsen (1991a, 1991b, 1992) examined the role of teacher subject matter knowledge in classroom discourse and found that subject matter knowledge increased the range and type of questions posed to students. Teachers with little subject matter knowledge tended to ask more questions, but the questions were on a lower cognitive level, more fact oriented, and produced less conversation. He found students were put on the defense when the teacher asked questions. But, there were also studies that showed good use of questions.

In contrast, other studies showed language to be purposeful, using questions to guide classroom discourse and giving students access to scientific knowledge. Instead of using questions to dominate or control the classroom discourse, van Zee and Minstrell's (1997) case study showed how Minstrell used questions to engage students with the scientific knowledge. Minstrell's reflective toss opened up conversation by building on a student's initial statement. The student would make a statement, the teacher would ask a question, and the student would elaborate. This method of science discourse was not only practiced in secondary school, similar studies were conducted in elementary classrooms.

Gallas (1995) studied first and second grade students' participation in "science talks". This study made clear the importance of paying attention to student's ideas during science discourse in her descriptions of listing to children's questions as a teaching strategy. This study was an important shift in the way science discourse was viewed. Students became inquirers "whose interests, questions, and theories emerge from the inside-out, rather than the outside in"

(Gallas, p. 101). Similar studies followed with the teacher as co-investigator (Crawford, Kelly, and Brown, 2000; Kelly, Brown, & Crawford, 2000) and student as learning to pose questions in science contexts (Gallas, 1995; van Zee, 2000). These studies contribute important patterns to the flow of classroom conversation when trying to understand student thinking about science concepts and in guiding students towards making connections between prior knowledge and the scientific principle.

Science should be socially constructed between teacher and students where students learn to talk science and understand the world through science discourse. This is a fundamental theoretical point of view is the idea that learning involves a passage from social contexts to individual understanding (Vygotsky, 1978). This study focused on participant thinking about the types of questions that should be asked in the classroom and how the questions attend to student thinking. Probe questions are equivalent to Gallas' (1995) follow-up questions that should be asked during science discourse.

Questioning for Science Thinking

Research has also reviewed the idea that teachers' can assist in student conceptual development by using questioning with the intent to elicit what students think, to encourage elaboration on student ideas, and to help students connect their evidence with the scientific principles (Chin, 2006; Lemke, 1990; Mortimer & Scott, 2003; Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011; van Zee & Minstrell, 1997). The theory on conceptual change (Posner, Strike, Hewson, & Gertzog, 1982) proposed that students' must become dissatisfied with their current beliefs in order for conceptual change to occur. In addition, teachers must help students make their implicit ideas explicit, confront students with the inadequacies of their beliefs, and provide extended opportunities for integrating old and new knowledge. When teaching for conceptual development in science education, Driver's (1989) research on children's alternative conceptions and Scott's (1998) contribution that the central part of teaching is dialogue with students to clarify their existing ideas and help them construct the scientifically accepted ideas places Gall's (1970) call to provide follow-up questions into perspective. Teacher interventions to structure science discourse to foster and monitor student conceptual development include soliciting students' initial conceptions, guiding the discussion, and engaging students in monitoring their conceptual changes in van Zee and Minstrell's (1987) study.

One way to teach for conceptual change is to use a teaching approach such as the work of the Children's Learning in Science (CLIS) group at the University of Leeds (Driver, 1989; Scott, Asoko, & Driver, 1992; Scott & Driver, 1998). Instructional activities should use students' prior knowledge as a starting point, differentiate conceptions in an elicitation phase, restructure – build new conceptions, and practice or apply the new constructions. Eliciting questions are used to make student prior knowledge explicit.

Making student thinking explicit is also the teacher's goal to guide student thinking for deep understanding (Ritchhart, Church, & Morrison, 2011). Thinking is at the center of learning (Perkins, 1992). Increasing the amount of learning requires increasing opportunities for student thinking. To understand student thinking, teachers need to make student thinking visible

(Ritchhart, Church, & Morrison, 2011). Ritchhart and his colleagues created a list of thinking moves that are integral to understanding (Ritchhart, Church, & Morrison, 2011, P. 11). Among these moves are building explanations and interpretations, reasoning with evidence, making connections, and considering different viewpoints and perspectives. Additional types of thinking useful in problem solving, decision making and forming judgments were also stated as identifying patterns and making generalizations, generating possibilities and alternatives, evaluating evidence, arguments, and actions, formulating plans and monitoring actions, identifying claims, assumptions, and bias, and clarifying priorities, conditions, and what is known. Among the routines Ritchhart and his colleagues established to help teachers uncover student thinking involved asking students a follow-up question that takes the form "what makes you say that?" This question is one way to clarify the student's thinking (Ritchhart, Church, & Morrison, 2011, p. 165) and determine if the student is thinking about the concept in terms of the scientifically accepted conception. Asking questions to understand student thinking leads to student learning.

There are other recent studies that have shown that teachers are able to use or identify questions to understand student thinking (Yip, 2004; Ritchhart, Church, & Morrison, 2011; Roth, Garnier, Chen, Lemmens, Schwille, and Wickler, 2011). To guide students towards conceptual change about scientific concepts, strategies for the use of teacher questions were developed. Yip (2004) categorized questions as probe, challenge, extend and apply questions and compared them to recall questions. Probe questions helped the teacher identify any alternative conceptions of the science concept at the beginning of a lesson. Challenge questions were used to help students resolve the conflicts of the alternative conception and guide them to a more scientific view. Questions that extended students' knowledge base linked existing knowledge and experience to the new concepts. Yip's study of 14 secondary biology teachers were taught how to use the questions in a biology methods course focused on promoting student conceptual change. Afterwards, the participants were observed and audio recorded during classroom teaching. The researcher transcribed the audio tapes and field notes and classified the questions as lower-order, higher-order, motivation, or conceptual change type questions and the frequencies were tallied. The study reported that due to the high number of higher-order questions you would think participants were skilled in using questions to challenge students to think at higher cognitive levels, but the classroom observations showed the opposite. All but two participants used questions to determine student alternative conceptions. The observations also showed participants stopped asking questions when students did not respond. Analyses showed students did not understand the questions, and did not have the prior knowledge to answer the questions, but the participants did not ask probe questions when students did not respond, they just gave the correct answer.

This finding suggests that the participant may not understand fully the use of the probe questions or may not be attending to student thinking. Also, classifying the questions into higher- or lower-order categories is difficult due to the inferential nature of the classification system (Gall, 1970).

A recent study by Roth, Garnier, Chen, Lemmens, Schwille, and Wickler (2011) also studied questions to elicit, probe, and challenge student ideas. The study used videobased instruction and a science pedagogy course to develop third and fourth grade elementary teacher's knowledge about science teaching practices and attending to student thinking. One group of participants received science content only in the science pedagogy course, while the other group of participants received science content and also engaged in video analysis-of-practice task learning to analyze and teach using strategies to support student thinking. The video analysis task group received instruction on strategies to reveal, support, and challenge student thinking from the Science Teachers Learning from Lesson Analysis (STeLLA) project level (Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011). Participants were taught eliciting, probing, and challenging questioning strategies and question uses (see Appendix B). For each question type, participants were given background reading material and provided practice identifying these question types within classroom video transcripts of teachers and students outside their study groups and later from videotaped lessons of their own classrooms and those within their study groups. Participants then taught a predetermined lesson that contained the strategies to provide further modeling and scaffolding. Further training required participants to plan their own lesson incorporating the newly learned strategies. One assessment of the participants was analyzing a videobased lesson. Participants watched four five-minute video clips and were asked to make comments. The prompt was to make analytical comments about the science content, the teaching, and/or the students. Participants also taught a lesson before learning the tasks and afterwards. The lessons were videotaped and coded for the strategies taught. Participants used all but one of the student thinking strategies. Participants asked five times more questions that probed or challenged students but did not improve on eliciting student ideas or predictions. Elicitation questions were defined as those that asked or expected students to provide a range of differing ideas and are usually posed at the beginning of the lesson or new idea. Upon implementing the strategies into the classroom, observations of post-program lessons revealed no gains in student achievement and that participants were not skilled in making decisions about when and how to use questions. Participants were “not yet skilled in making decisions about when and how to probe nor in responding to students’ ideas in ways that would move them forward in their thinking without simply telling them the ‘‘right’’ answer” (Roth et. al., 2011, p. 138).

This study utilized a think aloud to determine how novice secondary science teachers understood the types of questions the teachers asked in the video excerpts.

A more recent study on questioning, Lee and Kinzie (2012) was conducted on teacher questioning and student response with regard to cognition and language use. Participants were three pre-kindergarten teachers that participated in mathematics and science curricula, My Teaching Partner Math-Science curricula. Data was collected from classroom observations and teacher interviews. Interview questions elicited each teacher’s perception of her instructional strategies involving open- and closed-ended questions, situational factors affecting her decisions on what type of questions to use, and her experiences with the students’ responses to open and closed-ended questions. Pre-structured analytic procedures outlined by Miles and Huberman (1994) began with a coding scheme for open- and closed-ended questions as well as teacher questions coded according to apparent purpose: recognition, recall, prediction, or reasoning based on information processing theory and inquiry-based learning theory. Interview statements revealed one teacher said she was not aware of the type of question she asked in class. A second participant statement revealed she does not consciously think about what kind of questions she needs to ask during classroom discourse. She also revealed that student level of prior knowledge and language skills determined the type of question asked. Student language skills were analyzed by reviewing student responses looking for recurring patterns in their language use and assessing the cognitive level evident in their response. Cognitive levels was adopted from Bloom's Taxonomy (1956) into lower and higher cognitive operations. A teacher question for students to recognize or recall facts was classified as eliciting lower-level cognitive skills. A teacher question for students to predict or reason was coded as eliciting higher-level cognitive skills. An inductive analysis sought commonalities within student responses to the same type of questions and distinctions between student responses to the two types of questions with regard to their language use and cognitive levels (Patton, 2002). In order to judge the cognitive levels of student responses, a coding scheme to infer the purpose and cognitive level of teacher questions was applied. Two of the participants stated they could go deeper into a concept with smaller groups, one based her statement on classroom behavior. The researcher found teacher questions related to the contextual features of the classroom.

This study categorized teacher questions into higher- and lower-order questions that do not really assess students the way they may be intended to assess. Although Roth and her colleagues showed improvement in participant use of probe and challenge questions, they did not analyze teachers *thinking* about the effectiveness of the question strategies. Looking into what teachers *think* about the questioning strategies and how student thinking may affect the use of these strategies and may provide insight into how decisions are made. As such, this study provided additional insight into questioning strategies by examining how novice secondary science teachers' understand the types of questions asked and the relationship between student thinking and teacher questioning strategies.

Feedback

Another powerful moderator to enhance student achievement in science education is giving feedback (Hattie, 1999). Feedback will improve learning if it is about the substance of the and not superficial aspects (Crooks, 1988; Harlen, 1999); linked with goal setting (Black & Wiliam, 1998; Gipps & Tunstall, 1996; Hattie, 1999; Hattie & Jaeger, 1998); and linked to the students' strengths and weaknesses of the task, rather than to just the self, as in praise (Black & Wiliam, 1998; Hattie, Biggs, & Purdie, 1996). An interesting alternative to "feedback" is Sadler's (1989) response to students about the correctness of their learning, "feedforward" used to close the gap between what students knew and did not know as indicated in the standards.

Black and Wiliam (1998) suggested feedback from teachers should be about the students' particular quality of work, advice to improve, avoid comparisons with other students, and given the opportunity to work on the improvement.

Wait Time

Studies on pauses between questions and wait time also gained attention through earlier research. During an investigation into the elementary science program falling short in engaging students in inquiry in the 1960s, Rowe (1972) found no evidence that the lack of subject knowledge was a factor in student achievement but determined another factor was at play. Her comparison across studies revealed teacher questions and students responses had a common theme, very short wait time for students to answer the questions posed by the teacher. Rowe measured the relationship between question wait-time and the development of language and logic in children. Rowe's findings indicated with a longer wait time, at least 3 to 5 seconds, and student responses became longer and teacher questions were reduced.

There were few studies in secondary school. Anderson (1978) extended the wait time between the teacher's questions and the student's responses to more than the 3 seconds and observed that the increased wait time increased the length of student responses and lessons were perceived as less difficult. This study showed student responses and attitudes were affected but there was no evidence that wait time was associated with student achievement. A call for research to determine what students and teachers think during the pauses could reflect how to train them how to use the wait times more effectively.

Novice Teachers Learning to Teach

Research on teacher concerns emerged in Fuller's (1969) work with undergraduate teacher candidates "Concerns of teachers: A developmental conceptualization." His work consisted of surveys, group counseling sessions, and individual interviews and found participants to be most concerned with ability to control class, content mastery, supervisor evaluations, working conditions, and students liking them. Fuller proposed teacher concerns could be categorized and the categories may relate to amount of teaching experience. His model consisted of three stages; a pre-teaching stage identifying realistically with students, a survival stage concerned with class control, mastery of content, and teacher role; and a teaching performance stage concerned with teaching performance and classroom situations. Fuller and Brown (1975) added a fourth stage in which the teacher would turn their concerns towards the students where the teacher could relate to individual students instead of as a whole group and would be able to attend to student emotional, social, and academic needs.

Berliner (1988) elaborated on a model proposed by Dreyfus and Dreyfus' (1986) general theory of developing expertise, and developed a five stage teacher developmental model. Berliner proposed teachers progressed from novice to expert teachers through the stages of novice, advanced beginner, competent, proficient, and expert. Novice teachers attend to tasks such as "give praise for right answers", "wait time", "higher order questions", and "feedback". As they progress to the second stage (second or third year of teaching), advanced beginner, the teacher will begin to conform to whatever rules they are taught to follow, their prior classroom experiences help guide them. The third stage, competent, the teacher can make choices about their actions and knows what is and is not important. The fourth stage, proficient, intuition and knowledge will help teachers predict events. The fifth stage, Expert, have fluid, flexible, automated routines. In contrast to the stage theory, studies have shown novice teachers can focus their attention on student learning before focusing attention to themselves (Levin, 2008; Levin, Hammer, & Coffey, 2009). This research of teacher growth stages remains to be influential in researcher's implications for teacher education (Dori & Herscovitz, 2005; Kagan, 1992; Levin, Hammer, & Coffey, 2009; Loughran, 2006).

Novice teachers need to develop pedagogical knowledge. Pedagogical knowledge includes knowledge of instructional principles, classroom management, learners and learning, and educational aims that are not subject-matter-specific (Grossman, 1990). The knowledge base to be learned in a teacher education program is valued to produce strong professional teachers. Teachers learn not only the teaching strategies that have been researched to be effective, but they also learn to be mindful of how different strategies work in different situations (McCaslin & Good, 1996). Teachers must also have access to the negative aspects of the strategies or why critics say otherwise.

A type of formal knowledge that combines subject matter knowledge with understandings of how students learn the subject matter is pedagogical content knowledge (Shulman, 1987). Pedagogical content knowledge (PCK) is a critical need for new teachers. Adams and Krockover (1997) studied science teachers moving from preservice into the early years and found they come into the educational program with preconceived views of how to teach their subject matter knowledge. These existing pedagogical content knowledge views are usually inadequate for meaningful science learning and need to have experiences to properly develop. To provide the experiences for conceptual change, prior knowledge of the teachers' ideas of pedagogical content knowledge must be made explicit. Adams and Krockover reported preservice teachers were encouraged through reflections to practice towards conceptual, constructivist teaching.

Subject matter knowledge was also studied to determine the effect on science teaching, but recognized a "contradiction of control" (McNeil, 1986) describing the "social and institutional concerns act at cross-purposes with goals like promoting inquiry through discourse" (Carlsen, 1991, p. 646). Even though some studies highlight how the nature of the school set up barriers to the development of professional knowledge, this study suggested that some the content learned by the participants actually helped them to develop professional knowledge.

Induction programs may be supporting the process of teaching rather than focusing on the essential needs such as helping new teachers with the content of the lessons, explanations to be given, and questions to be asked in the lessons (Depaepe, Verschaffel, Kelchtermans, 2013; Evertson & Green, 1986; Schneider & Plasman, 2011; VanDriel, Beijaard, & Verloop, 2001). There are four central areas for instructional support for new teachers: understanding how the structure of knowledge is transformed into content knowledge, going beyond the basic facts and concepts, subject matter knowledge; training in PCK – use of demonstrations, analogies, illustrations, examples, etc.; teach a topic at a particular level with a variety of instructional strategies; and reflective and critical thinking about their own teaching (Evertson & Green, 1986, p. 562). Review of research on science teachers' pedagogical knowledge concluded that novice teachers may not have adequate knowledge of new content or pedagogy or may have different beliefs from intended implementation of the new content or pedagogy and require professional development (Van Driel, Beijaard, & Verloop, 2001). Professional development must be long-term in order to restructure teachers' knowledge and beliefs. Also, knowledge and experiences must be carefully selected for the novice teacher that will have lasting effects (Barnes, 1987).

In summary, the literature recommends science teacher education programs need to determine preservice teachers prior conceptions on pedagogical content knowledge, provide essential needs with content, explanations and questioning skills. Long-term professional development programs can continue with the progression from novice to expert teaching. This study framed the attention on instructional strategies for novice secondary science teachers to learn how to attend to student thinking by learning about questions to elicit student prior knowledge, probe for understanding, and challenge students to connect their ideas to the scientific principles.

Attention to Student Thinking

Recent focus to studies exploring teacher attention to student thinking has emerged in the research. Studies have shown that teacher attention is largely organized by aspects of educational institutions (Rop, 2002; & Settlage & Meadows, 2002) and that new teachers are able to begin to pay attention to student thinking (Davis, 2006) when teacher routines are framed around student thinking in the university science pedagogy class (Lau, 2010; Levin, Hammer, & Coffey, 2009).

Davis, Bain and Harrington (2001) previously discussed the four aspects of teaching: learners and learning, subject matter knowledge, assessment, and instruction. In determining the teaching aspects undergraduate elementary science teachers attend to, Davis' (2006) found the preservice teachers did include ideas about the learners and learning more than expected. Novice teachers were also found to be able to attend to student thinking in their early years of teaching (Lau, 2010; Levin, Hammer and Coffey, 2009) if pedagogy courses focused attention on student thinking. Findings from Lau and Levin and colleagues showed some novice teachers attended to student thinking and some novice teachers struggled to attend to student thinking. Novice teachers who were able to begin to attend to student thinking were found to have focused on student thinking in a pedagogy course. Data showed participants who struggled to attend to student thinking were getting through the curriculum or shifting attention from student thinking to the curriculum emphasis on vocabulary. This attention to the curriculum supported the notion of framing; participants framed their thinking around the curriculum and/or classroom management.

Researchers have argued that teacher attention is largely organized by aspects of educational institutions (Rop, 2002; & Settlage & Meadows, 2002). Rop (2002) reported an in-service chemistry/physics teacher attended to student thinking, but discussed his frustrations with student questions that were annoying, difficult to deal with, and too far off topic to cover the content that will prepare students for future classes. Settlage and Meadows (2002) reported on the frustration of one in-service secondary science teacher between the school curriculum and Alabama's Scholastic Aptitude Test (SAT). Their findings showed one teacher was discouraged teaching science skills beyond the requirement of the SAT due to classroom preparation and time in which she exhibited teaching to the test. These findings support the notion that teachers' frame their thinking on the curriculum taking place in the school public system.

To focus attention to student thinking, this study focused novice teacher attention to student thinking in the science methods pedagogy course in the spring 2013 term. Participants applied their learning of the types of questions and purposes to attend to teacher questions and student thinking in the excerpts of video lessons.

Noticing Literature

The ability to notice and understand what is happening in the classroom is a key component of expert teaching argued by many researchers (Berliner, 1994; Frederiksen, 1992; Mason, 2002). Because teachers do not typically focus on students' ideas and reasoning in their planning, teaching, and analysis of teaching (Sherin & vas Es, 2002) they need to develop routines to pay attention to student thinking. In a response to the mathematics reform to pay attention to student ideas (NCTM, 2000), van Es & Sherin (2002) proposed and implemented (Sherin & Han, 2004; Sherin & van Es, 2005, 2006, 2008, 2009; 2012) *The Learning to Notice Framework* to help teachers develop the ability to notice student interactions in the classroom by identifying important aspects of video classroom situations and make connections with specific classroom interactions and the teaching principles. The video cases used Video Analysis Support Tool (VAST) to prompt participants to analyze student thinking, teacher roles, and classroom discourse. VAST also prompted participants to respond to questions that included what they noticed, supported with evidence, and their interpretation of that information. The goal was to help teachers identify and interpret student ideas in mathematics (Sherin & van Es, 2005; 2008; 2009; 2012) and the findings showed improvement in their tendencies to notice student and teacher issues of mathematical thinking.

Levin (2008) and his colleagues, Hammer and Coffey (2009), studied novice teachers and their ability to focus on student thinking before focusing on themselves as noted in stage based theory. Their findings reported novice teachers could notice student thinking if learning material was framed around student thinking in the pedagogy course. Of the four participants described in Levin, Hammer, and Coffey's (2009) study, two participants had no trouble noticing student thinking. One participant showed shifts between attending to student thinking and towards the pressure of keeping up with the curriculum from administration and the science department. One participant did not attend to student thinking, but also did not attend the summer pedagogy course that was framed around attention to student thinking.

This study focused participant attention on questions to elicit, probe, and challenge student ideas in the participant's pedagogy course and utilized two public use TIMSS video excerpts for participants to notice teacher questions and student thinking.

Review of Research Study Methods Used to Study Questioning

Methodologies for early studies on question classification consisted of frequency counts. An example is Santiesteban's (1976) study. Forty-eight preservice elementary teachers were assigned to treatment groups in which participants were trained in asking observational and classification questions by means of either an audio or video model. Afterwards, the teachers taught a 15 minute microteaching lesson in which they posed questions using Science-A Process Approach materials. A frequency count of the types of questions revealed no difference between audio or visual models and students reported teachers asked too many questions. Frequency of questions does not give any insight on student thinking about the questions, just the number of the type of question.

Following classification of question types were studies that classified questions by cognitive level such as Carlsen (1997). Question types were still tallied into categories. Analyses consisted of instructional materials, journals, conferring daily with a team-teaching collaborator, videotape transcriptions, and summary descriptions of the lessons and analyzing teacher and student questions by cognitive level (high, low, procedural/noninstructional). The study reported quantitative data that consisted of tallied teacher question types into the appropriate category, and qualitative data from classroom videotape transcriptions and journal entries. Although this study found the teacher asked more probing questions when teaching familiar subject area knowledge as opposed to teaching unfamiliar subject are knowledge, student thinking about the questions was not investigated. Again, counting the number of questions asked tells us nothing about student understanding of the concepts that should be the result of questioning.

Minstrell, a high school physics teacher studied ways to promote conceptual development with his questioning. He invited van Zee to analyze his approach to teaching. It was documented (van Zee & Minstrell, 1995) that Minstrell asked questions for many reasons, opening and closing discussion, and engaging students in thinking about science concepts. In the case study in which van Zee studied Minstrell's (van Zee & Minstrell, 1997) use of questions to guide student thinking during physics class discussions, field notes and videotaped teacher interviews and class discussions were transcribed and coded. Analyses of teacher and student utterances were studied to determine the use of questions to elicit student misconceptions and guide students in their thinking. The methodology to examine student statements and teacher questions allowed the researcher to trace how the teacher questions influenced student thinking. This methodology is good for analyzing teacher questions and student statements for substance of student understanding but does not analyze how the teacher is thinking about the questions.

Levin, Hammer, and Coffey (2009) used video recordings of participant teaching in their internship, field notes from in-class observations, papers from pedagogy seminar, interview remarks from field notes and videotaped sessions. The strengths of the study were framing the pedagogy course around student thinking with cases studies, interns implementing their learning in the classroom, and coding requirements for attending to student thinking. Participants learned to attend to student thinking through case studies and by creating their own case study from the classroom of their internship. Analyses on data collected from the classroom observation videos, field notes, and written class submissions were coded for attention to student thinking when the intern noticed or responded to a student idea. Responses could be asking a student to explain or elaborate on reasoning, rephrase a student idea, or shift the flow of the classroom activity that addressed a student idea. It was also evidence if the intern reported noticing student thinking at a later time even if the intern did not respond to the idea in the classroom. If the intern noticed or responded to correctness, it was not considered evidence. A weakness in the methodology was the absence of teacher thinking. Revealing teacher thinking may have given insight into the participant who showed shifts in attention to student thinking, and insight into the participant who showed no attention to student thinking.

Roth, Garnier, Chen, Lemmens, Schwille, and Wickler (2011) provided professional development from the Science Teachers Learning from Lesson Analysis (STeLLA) project to thirty two fourth-, fifth-, and sixth-grade elementary science teachers during a three week summer institute. The study was guided by situated cognition model of teaching learning, together with a cognitive apprenticeship model of instruction. Learning was naturally tied to the authentic activity, context, and culture (Brown, Collings, and Duguid, 1989; Lave, 1988). Participants received instruction on science content knowledge, strategies to create coherent science content storylines, strategies to reveal, support, and challenge student thinking, video based instruction practicing and attending to student thinking and then were observed during classroom teaching. For the strategies to reveal, support, and challenge student thinking, participants were taught eliciting, probing, and challenging question types and their uses (see Appendix B). For each question type, participants were given background reading material and provided practice identifying these question types within classroom video transcripts. Participants were provided with a lesson plan with all strategies already implemented to further practice and then were asked to create their own lesson plan incorporating the strategies. Videotaping of teacher lessons were collected at the beginning of the program and at the end of the program and coded for the strategies taught to assess learning. For the video analysis task, participants were instructed to watch four five-minute video clips of fourth- and fifth-grade science lessons about the science content targeted in the program. A prompt to make analytical comments about the science content, the teaching, and/or the students was given. Comments were coded for the strategies and rated for teacher understanding and correct use. The strengths of this professional development study were teaching science pedagogical knowledge and content and having the participants implement learning in the classroom. Participants were taught different types of questions to attend to student thinking and when data was taken on the ability to use questions to elicit, probe and challenge student ideas in classroom, it was found participants did not use eliciting questions as frequently as probing and challenging questions. A weakness of the methodology is in obtaining teacher thinking about the types of questions and their uses. Although participants were prompted to comment about science content, teaching and students, participants were not prompted to comment specifically on teacher thinking about the types of questions teachers ask students and the effect on student thinking. A think aloud would capture participant thinking to reveal possible insights about the questions and their uses.

Sato, Akita, & Iwakawa, (1993) used think aloud by sending a videotape of a poetry lesson, taught by an expert teacher, and an instruction manual to five expert and five novice teachers to watch the lesson and comment about their perceptions about what they saw, felt, and thought while recording on a cassette. Participants also wrote a summary of their thoughts after observation of the lesson. Comparative analyses between novice and expert participants formed idea units from what teachers say (verbal activity, non-verbal communication such as body language, classroom climate, pedagogical skill, content and cognition, and teaching context) and how teachers talk (perspective, point of view, relevance, involvement, and framing). Idea units (sentences) were sorted into categories of fact, impression, reasoning and interpretation. Sato and colleagues found the think aloud revealed important differences between novice and expert teachers. Expert teachers covered a wide range of content with elaboration while novice teachers covered a narrow range of content with no elaboration. Expert teacher can be involved actively and thoughtfully in student learning where novice teachers are passively involved in student behaviors. Although this study used think aloud to determine teacher thinking about a poetry lesson, the study did not focus on teacher questioning.

A summary of methodologies of the above studies reveal counting the number of questions asked or the number of different types of questions asked did not attend to student or teacher thinking about the questions. Although, van Zee and Minstrell's methodology was sufficient for determining the relationship between teacher questions and student thinking, the methods were not able to report on teacher thinking about the questions. Also, sorting teacher idea units from their thinking about a poetry lesson did not focus on teacher thinking about questions to elicit, probe, or challenge student ideas.

Summary

In this chapter, the conceptual perspective was developed. Science is constructed in the social context of science classroom discourse between the teacher and students. Student's initiate ideas and ask questions. Teachers ask follow-up questions, such as questions to elicit, probe, and challenge student ideas, to understand student thinking and guide the student towards the science concept being taught. Novice teachers are able to attend to student thinking early in their teaching practice, but it may depend on how the teacher frames what is taking place in the classroom. Teachers may show shifts in their thinking, showing attention to student thinking at some points, shifting their attention to other aspects of the literature on stage based theories of development.

CHAPTER THREE: METHODOLOGY

The study's intent was to describe novice secondary science teachers' thinking behind teaching behaviors, therefore, a protocol analysis (Ericsson & Simon, 1993) was chosen as the most effective means for capturing real-time thinking during a task. Due to a weakness in teacher thinking in the research literature on attention to questioning and student thinking, the study utilized protocol analysis to describe novice secondary science teachers' understanding of the purpose of teachers' questions and the appropriateness of questioning strategies for facilitating student learning.

During the 20th century, psychologists became interested in the insight of complex thought. Behaviorist John B. Watson (1920) proposed the use of verbal reports, "think aloud", and the gestalt psychologist Karl Duncker (1924) established it as a major method for describing insight into complex thought. Although there have been theoretical and methodological controversies about verbal reports, the controversies have centered beyond the view of thinking as the sequence of thoughts where participants are asked to do more than merely verbalize their thoughts. Previously, introspective reports were used in the discovery of the psychological processes which involved looking into the minds of humans and reporting what was discovered (James, 1980). Introspective reports looked at eye fixations, electroencephalograms, functional magnetic resonance imaging, or heart rate variability along with reactive explanations and detailed descriptions of thought. Asking participants to explain their thinking or give detailed descriptions of their thoughts can change the flow of their thinking processes (Ericsson & Simon, 1993). In the Ericsson and Simon (1993) model of the think aloud, no one is looking or reporting on the internal structure of the processes. Furthermore, prior to the publication of Ericsson and Simon's book, *Protocol Analysis: Verbal Reports as Data* (1984), few studies utilized explicit directions for participants not to plan what they will say and not to explain what they are saying. In order to verbalize task related thoughts that will not disrupt the processes mediating execution of the task, the verbalization is linked to the entry of thoughts in attention. Participants primarily focus on completing the task and the verbalization is considered secondary leading to incompleteness rather than reactivity. When participants were given explicit instructions to think aloud on a task analysis, Ericsson and Simon (1993) found no evidence that the sequence of thoughts was changed when participants thought aloud compared to participants who remained silent. Therefore, instructions were given and read to participants (see Appendix A) to explicitly tell them to verbalize constantly everything they were thinking aloud without the need to explain their thinking.

Additionally, the validity of verbal reports depends on the time interval between the occurrence of the thought and its verbal report. By having participants verbalize their thoughts at the time they emerged, the difficulties and sources of error associated with retrieving thoughts from short term memory is eliminated (Ericsson & Simon, 1993, p. 60). Participants are able to recall sequence of thoughts accurately for concurrent think aloud verbalizations when silent pauses are less than 5 to 10 seconds (Ericsson & Simon, 1993, p. 83). Pause durations will cause problems with accurate recall and reduce the validity of verbal reports; therefore, the researcher prompted the participant to keep talking during silences exceeding 5 seconds.

Pilot Study

A pilot study was conducted to determine if I could obtain intended results with the protocol analysis. Five preservice secondary science teachers from a secondary science pedagogy course participated in a pilot study on August 2, 2012, and one secondary science in-service teacher from a neighboring county participated in the same pilot study on August 4, 2012. Participants were asked to think aloud about the kinds of questions teachers ask while viewing two public-use U.S. TIMSS 1999 Video Study science lessons. Participants were read the following instructions "*I don't want you to plan out what you say or try to explain to me what you are saying. Just act as if you are alone in the room speaking to yourself (see Appendix A).*"

Data collection.

Two public-use U.S. TIMSS 1999 Video Study science lessons were viewed. One video was an eighth-grade science lesson about pulleys, and the other video was an eighth-grade science lesson about rocks. Participants were given think aloud protocol instructions to watch and listen to the classroom videos with attention to teacher questions. They were instructed to talk out loud continuously from the beginning of the video to the end of the video. The five participants viewed the two science video lessons in a classroom where each participant was stationed with a computer to view the video lessons, audio headphones, an audio recorder, and transcripts of each of the video lessons. As the five participants viewed the two video lessons, they were audio-recorded as they talked out loud to report their thinking of the kinds of questions the teacher asked and how students responded. The one in-service participant viewed the two science video lessons at her home and recorded think aloud thoughts on paper as an alternative to being audio-recorded.

I conducted debriefing interviews immediately following the think aloud to clarify any ambiguous participant remarks and to allow an opportunity for participants to elaborate further. Participants were asked the following questions in a retrospective debriefing:

What did the teacher do well?

What could the teacher have done better?

Is there anything you would like to elaborate on further?

Data analysis.

Audio tapes of the think aloud protocols and debriefing interviews were transcribed by the researcher. Protocol segments were coded from literal copies in the context of properly identifying three types of questions: eliciting, probing, and challenging questions (see Appendix B). Descriptive codes were used to properly identify questions and the purpose/value in questions. Inferential codes were developed from patterns where participants identified teacher questioning with instruction only, or teacher questioning with a combination of instruction, subject-matter knowledge, assessment, learners and learning (Davis, 2006). Another science education doctoral student also coded the transcriptions for inter-rater reliability of 93%.

Results.

Results indicated the preservice secondary science teachers could attend to student thinking through some teacher questions in a combination of categories. One participant identified two elicitation questions and three participants attended to questions that probe student ideas by noticing students elaborated on an idea but did not identify the type of questions as probing. None of the participants identified challenging questions, which connect the evidence of science activities to the scientific principles.

Problems were found with all five participants talking aloud in the same room. Even though they were wearing head phones, it was possible the students could hear one another and became distracted or influenced by another participants' talk. Changes were be made to schedule individual times for each participant to schedule a time to participate in the protocol analysis in my University of Central Florida office where the participants are enrolled. Another problem surfaced when transcriptions of the audiotapes revealed periods of silence from the participants. Since longer pause durations will cause problems with accurate recall and reduce the validity of verbal reports, think aloud protocol instructions will be edited to add a prompt for participants to "keep talking" during a period of silence. Further, participants stated reading the written transcriptions did not allow for continual viewing of the videos and they preferred to read the embedded video transcription captions, therefore, written transcription will not be included.

Context

Novice secondary science teachers concurrently enrolled in the University of Central Florida's job embedded *Resident Teacher Professional Preparation Program* (RTP^3), and in my spring 2013 secondary science pedagogy course, examined the types of questions teachers ask to further student understanding about specific science principles. The University of Central Florida and five school district partners offered a job-embedded teacher preparation program for Science, Technology, Engineering, or Mathematics (STEM) graduates wishing to teach mathematics or science in Florida's middle and high schools. Novice secondary science teachers in the RTP^3 program were selected because this group included teachers in the first or second year of teaching and held a bachelor degree in science. The novice secondary science teachers were also enrolled concurrently in an internship I course, and were enrolled in obtaining their master's degree. The types of questions examined were questions to elicit, probe, and challenge student ideas. Teachers received instruction and practice on the types of questions and their uses for student understanding in the pedagogy course taught by the researcher during one semester (spring 2013) and beyond what they did in class (see Appendix B).

Population and Sample

Thirty students concurrently enrolled in the University of Central Florida's job embedded *Resident Teacher Professional Preparation Program* (RTP^3), and in my spring 2013 secondary science pedagogy course were asked to volunteer for the proposed study. An informed consent was distributed and read to thirty graduate students who were concurrently enrolled in the University of Central Florida RTP[3] job embedded program and my spring 2013 secondary science pedagogy course. Ten volunteers for the study were instructed to answer questions regarding teaching experience, familiarity of the rocks and weather science content knowledge, and number of college or university courses taken relating to weather or rocks questionnaire to maximize variation within this small sample (Patton, 2002). The questions consisted of teaching experience, familiarity of the rocks and weather science content knowledge, and number of college or university courses taken relating to weather or rocks (see Appendix E). Follow-up emails were sent to the ten participants to schedule appointments for the protocol analysis. Of the ten volunteers, three did not schedule appointments to participate in the study. To ensure maximum variation sampling (Patton, 2002) of teaching experience and science content knowledge about rocks and weather, a sampling matrix was constructed in Table 1.

Table 1 *Sampling matrix*

Teaching experience	Content knowledge			
	Slightly familiar for both videos	Somewhat familiar for both videos	Moderately familiar for both videos	Slight (rocks) somewhat (weather)
6-12 months	Stellah	Ally	John	Keith
12-18 months	Andy			
18-36 months	Payton	Brock		

The maximum variation matrix displayed that each participant in the sample is different from other participants using the dimensions for familiarity of rock and weather content knowledge and teaching experience. Categories for familiarity of content knowledge were pre-determined and participants self-reported on the questionnaire. This showed that data collection and analysis would turn out case descriptions showing uniqueness as well as shared patterns across all participants (Patton, 2002, p. 235).

To maintain participant confidentiality, once audio tapes were transcribed, each participant was assigned a pseudonym (Table 1). Profiles were written as a narrative for each participant and included evidence from multiple data sources (e.g., dissertation study questionnaire and interview transcripts. Data from the questionnaire and think aloud interview described each of the participants.

Brock

Brock was a novice secondary science biology teacher with 18-36 months teaching experience and a bachelor's degree in molecular microbiology. He had somewhat familiarity with both rocks and weather science concepts. Brock stated he knew the three types of rocks and they are formed from lava when cooled.

Payton

Payton was a novice secondary science chemistry teacher with 18-36 months teaching experience and a bachelor's degree in exercise science (physiology). Payton shared her knowledge of the science concepts of rocks was limited. She knew about how rocks formed, that the rocks are formed through the process of weather. Payton also knew the older layers of rocks are on the bottom, volcanoes, and changes in sea level. Payton stated she knew very little on the concepts of weather, she would have to refresh her memories from grade school. Her knowledge included different types of storms, different cloud types have different names, and some weather symbols on weather maps from the news.

Andy

Andy was a novice secondary science teacher with 12-18 months teaching experience and a bachelor's degree in Biology. He had slight familiarity of both the rock and weather science concepts. Andy indicated that he knew of one cloud type, cumulous clouds, and he knows the basis of hurricanes. He knows that the color red identifies warm air and the color blue identifies cold air. Andy stated he only knew the three classifications of rocks: igneous, metamorphic, and sedimentary.

Stellah

Stellah was a novice secondary science biology teacher who had 6-12 months teaching experience and a bachelor's degree in biological sciences. She had slight content knowledge of both weather and rock science concepts. Her knowledge on rocks was that some rocks are formed from lava, but didn't know what they are called, and that she learned about the rock cycled in middle school. Stellah's recall on the science concept of weather was that there are different clouds, but didn't know the names, and knew some vocabulary, but didn't recall what they mean.

Ally

Ally was a novice secondary science biology teacher with 6-12 months teaching experience and a bachelor's degree in both psychology and preclinical health science. She was somewhat familiar with both the rock and weather science concepts. Ally stated that she did not know much about weather except other than living in Florida and what happens here. Her knowledge on rocks was that they get compressed; this is how the layers are made.

John

John was a novice secondary science teacher who also had 6-12 months teaching experience and a bachelor's degree in biology. He had a moderate familiarity with both rocks and weather science concepts. John taught earth science in a local middle school and said he knew a lot about the concept of rocks. As for the concept on weather, John stated that there are various types of winds and precipitations, including topics such as the Coriolis effect, warm/cold fronts, changes in temperature as well as various storms, hurricanes, tornadoes, and monsoons.

Keith

Keith was a novice secondary science biology teacher who had 6-12 months teaching experience and a bachelor's degree in biology. He had slight content knowledge of the science concept on rocks and somewhat content knowledge of the science concepts on weather. Keith stated he never took a class on weather, just what he researched himself. He stated he knows how hurricanes, storms form, hail forms. He also knew how weather patterns form, weather symbols and content about weather mapping. Keith knew a little less about the concept of rocks. He stated he was not very familiar with rock formations, although he knew the types of rocks: "sedimentary, igneous, compound rock, and there is a fourth kind". Keith said it depends on their type, most are from volcanoes and magma coming up and some are just dirt getting compounded under pressure. The rock cycle is little rocks getting broken down, crust and eventually comes down as magma. Keith ended with "I don't know a whole lot about rocks."

Instrumentation

Concurrent verbal reports examined participants' verbalizations while they performed the task of viewing two public-use U.S. TIMSS 1999 Video Study science lessons.

A questionnaire was developed to maximize variability across participants with five questions that consisted of teaching experience, familiarity of the rocks and weather science content knowledge, and number of college or university courses taken relating to weather or rocks.

Materials

Two US TIMSS 1999 Video Study classroom lesson video excerpts were used in the study: US1 Weather and US4 Rocks. Both videos were of eighth grade classrooms and were chosen to use with middle and high school teachers in the study because they were public use and the study can be replicated easily. Additionally, the US1 Weather, was a science lesson focusing on weather maps (56 minutes duration) and was selected by the researcher because it exhibited ineffective teacher questioning for eliciting student knowledge, probing students for deeper understanding, and connecting data to scientific principles through challenging questions (BSCS, 2012). The second video, US4 Rocks, was a science lesson about rocks (41 minutes duration) and was selected by the researcher because it exhibits effective teacher questioning to elicit student knowledge, probe student responses, and connects understanding to the scientific principles (BSCS, 2012).

After participants were read think aloud protocol instructions (see Appendix A) explicitly telling them to pay attention to the kinds of questions the teacher asks and the verbal and nonverbal responses of the students, participants viewed the US1 Weather video excerpt between the elapsed times 03:11 – 8:21 to capture the discussion of the concept before students began working on the assignment. The science video lesson on rocks Participants viewed the US4 Rocks video excerpt between the elapsed times 00:08 – 15:21 to capture the end of the concept of how igneous rocks form discussion.

Data Collection Procedures

Ericsson & Simon (1993) present two types of verbal reporting, concurrent verbal reports and retrospective reports. Both of these reports claim to be a close reflection of the cognitive processes. Concurrent verbal reports provide accurate evidence in which people directly express what they are thinking in real time tasks from information stored in the short-term memory, part of their own cognition. Retrospective reporting takes place after the task is completed which utilizes information stored in long-term memory to reconstruct or infer thinking.

Protocol analysis (Ericsson & Simon, 1993) was considered to be the primary data to answer the research question of how secondary science novice teachers' attend to student verbal and nonverbal behavior to infer student thinking.

Participants scheduled individual appointments to view the two U.S. TIMSS video excerpts (US1 Weather and US4 Rocks) on a computer with headphones in my University of Central Florida office. First, each participant was asked about their content knowledge on the topics of weather and rocks and if they previously viewed the US1 Weather or US4 Rocks TIMSS Video Study videos; this information was audio recorded. For practice, participants were given think aloud protocol instructions (see Appendix A) to watch and listen to two 5-minute excerpts of one public-use U.S. TIMSS 1999 Video Study seventh grade classroom on US5 Blood. Participants watched the video excerpts on a computer with captioned lesson transcriptions and listened to the video lessons with audio headphones, the practice was not audio recorded. Participants were asked to say whatever they were looking at, thinking and feeling about the kinds of questions the teacher asks and the verbal and nonverbal responses of the students. Participants were encouraged to talk constantly during the task. A gentle reminder by the researcher, such as "keep talking", directed the participant to continue thinking aloud after 5 to 10 second pauses (Ericsson & Simon, 1993, p. 83). At the end of the first 5-minute video excerpt, participants were asked to tell me everything they remembered about the lesson and anything they were thinking while watching the video, but were told explicitly not to explain. After the participant finished talking, I told them we would practice one more time.

Participants were told to do the same thing for the second practice video excerpt as they just did. I told them not to plan out what they would say or try to explain anything to me. Participants were reminded to pay attention to the kinds of questions the teacher asks and the verbal and nonverbal responses of the students. Again, participants watched the second practice video excerpt on a computer with captioned lesson transcriptions and listened to the video lessons with audio headphones, the practice was not audio recorded. Participants were asked to say whatever they were looking at, thinking and feeling about the kinds of questions the teacher asks and the verbal and nonverbal responses of the students. Participants were encouraged to talk constantly during the task. A gentle reminder by the researcher, such as “keep talking”, directed the participant to continue thinking aloud after 5 to 10 second pauses (Ericsson & Simon, 1993, p. 83). At the end of the second practice 5-minute video excerpt, participants were asked to tell me everything they remembered about the lesson and anything they were thinking while watching the video, but were told explicitly not to explain. After the participant finished talking, I told them we were ready to move on to the videos.

Instructions on the process of the think aloud was provided (Appendix A). Participants were told the same protocol would be used as they used with the two practice video excerpts. Participants were again reminded to pay attention to the kinds of questions the teacher asks and the verbal and nonverbal responses of the students. They were told to tell me everything that that they were thinking from the moment they began viewing the video excerpt. Participants were told when they were finished with the first video excerpt, I may ask them to remember what you were thinking while viewing the video. They were told if I was not going to ask them this, I will simply tell them to view the second video excerpt.

Participants watched the video excerpts on a computer with captioned lesson transcriptions, listened to the video lessons with audio headphones, and a digital audio recorder captured participant verbal thoughts and I wrote field notes about participant remarks and behavior.

Participants immediately participated in a critical incident interview after each video excerpt to provide clarification of any ambiguous remarks made during the think aloud and provided the opportunity for participants to elaborate. The data needed to answer questions that were not addressed in the think aloud or areas identified to need clarifying were addressed in this critical incident debriefing. Participants were asked if they wanted to further expand on the videos and were thanked for their participation. The critical incident interview was used to triangulate the think aloud data and field notes.

Data Analysis

Prior to data analysis, a committee of experts was formed to attend to missing data that I might believe all participants miss or fail to appreciate. The committee of experts viewed the video excerpts and identified questions to elicit, probe, and challenge student ideas the teachers asked, identified student remarks and behaviors that resulted, and whether the students did or did not respond to the questions. The committee of experts identified a review linking prior knowledge to the new content conducted by the teacher at the beginning of the US4 Rocks video and the lack of a review at the beginning of the US1 Weather video excerpt. The committee also noted participants needed to notice the US1 Weather video teacher's inappropriate reformulating questions (French & MacLure, 1981).

Protocols, critical incident interviews, and field notes were transcribed and coded to answer the research questions. Three classes of codes were assigned: descriptive, interpretive, and pattern (Miles & Huberman, 1994). To begin data analysis, descriptive codes were assigned to properly identify questions and the purpose/value in questions. To determine what novice secondary science teachers' attend to in the instructional environment, teacher questions were coded as eliciting, probing, or challenging teacher questions; teacher behavior was coded as teacher instruction; student response to teacher questions were coded as student engagement and student thinking; and the physical environment comments were coded as classroom management and class culture.

Teacher questions were classified into three categories; eliciting, probing and challenging questions. Participant remarks for each of the questions were compared to the experts' analysis. A table of codes that some or all participants attended to across both videos became visible in the development of pattern codes. Codes were deleted due to no data: subject matter knowledge and assessment. Codes were renamed to reflect the data: learners & learning became student engagement and student thinking. Classroom management became class culture. Then within class culture new codes were developed: student confidence and teacher demeanor. Patterns emerged once participant remarks were analyzed after video excerpts were classified into science concepts.

If a participant noticed students were thinking about a teacher question, the remarks were coded as teacher question leads to student thinking (TQ→ST).

Teacher questions were coded as questions to probe student thinking if the question was directed to a specific student to further understand their thinking, build on their ideas, or clarify their thinking.

Teacher questions were coded as questions to challenge student ideas if the question challenged student thinking to develop deeper understandings of science ideas. If the question pushed students to make new connections to the scientific principle (scientific thinking), the comment was coded TQ-c-conn. If the question pushed students to use new vocabulary, the comment was coded TQ-c-voc.

Other patterns that emerged was attention to communication patterns during science class discussions, the use of feedback (TI-pf), praise (TI-pr), wait time (TI-WT) use of higher order questions (HQ), and a shift (SHIFT) from instruction to student thinking in the attention to instruction (see table 2).

Table 2 *Table of codes*

Beginning codes		Ending codes	
Teacher Question-elicit	TQ-e	Teacher Question-eliciting	TQ-e
Teacher Question-probe	TQ-p	Teacher Question-probing	TQ-p
Teacher Question-challenge	TQ-c	Teacher Question-challenging	TQ-c
		Higher Order Question	TQ-e-HQ, TQ-p-HQ, TQ-c-HQ
		Teacher Question Leads to Student Thinking	TQ→ST
		Teacher Challenge Question pushes student use of new vocabulary	TQ-c-voc
		Teacher Challenge Question pushes student to make a connection to the scientific principle	TQ-c-conn
Review	Rev	Review	Rev
Teacher Instruction	TI	Teacher Instruction with wait time	TI-WT
		Teacher Instruction with positive feedback	TI-pf
		Teacher Instruction with praise	TI-Pr
		Shift-teacher instruction to student thinking	SHIFT
Subject Matter Knowledge	SMK		
Assessment	Assm		
Learners & Learning	LL	Student Engagement	SE
		Student Thinking	ST
		Communication Pattern	CommPatt
Classroom Management	CM	Class Culture	CC
		Student Confidence	SC
		Teacher Demeanor	TD

Summary

The methodology used to conduct the study has been described in this chapter. The pilot study and a description of the population were described. The instrumentation used in the study was also described. Finally, data collection and analysis procedures were explained. The analysis of the data is presented in chapter 4.

CHAPTER FOUR: DATA ANALYSIS

Purpose and Summary of Methods

The purpose of this study was to describe novice secondary science teachers' understanding of the purpose of teachers' questions and the appropriateness of questioning strategies for facilitating student learning. Protocol analysis was chosen as the research method to overcome the limitations of prior research, especially the failure of that research to attend to student and teacher thinking during questioning. The qualitative data were collected using audio-recorded think aloud protocols, critical incident interviews, and field notes to answer the research questions. A committee of experts was formed to view the video excerpts and video transcriptions to identify student remarks and behaviors that result whether the student did or did not respond to the questions, and also assign preliminary codes to the video transcripts. This information helped to identify questions to elicit, probe, and challenge student ideas in the video transcripts and attend to missing data that I might believe all participants may miss or fail to appreciate. The factors identified for students to attend to were attention to teacher elicit, probe, and challenge questions and student thinking. A comparative analysis across participant cases for the factors that some or all attended to, and for what they understood from those factors was conducted.

Description of Sample

Seven novice secondary science teachers concurrently enrolled in the University of Central Florida's job embedded *Resident Teacher Professional Preparation Program* (RTP^3), and in my spring 2013 secondary science pedagogy course enrolled in the University of Central Florida were participants in this study. A total of thirty students were concurrently enrolled in the University of Central Florida's job embedded *Resident Teacher Professional Preparation Program* (RTP^3), and in my spring 2013 secondary science pedagogy course but only ten of these graduate students volunteered to be in the study. These ten volunteers were asked to complete a questionnaire to maximize variation within this small sample (Patton, 2002). The dissertation study questionnaire expressed questions regarding number of years teaching experience, content knowledge familiarity on rocks and weather, and also the number of college or university courses taken inclusive to weather or rock content knowledge. Follow-up emails were sent to the ten participants to schedule appointments for the protocol analysis. Of the ten volunteers, only seven scheduled appointments to participate in the study. To ensure maximum variation sampling (Patton, 2002) of teaching experience and science content knowledge about rocks and weather, a sampling matrix was constructed which shows each participant in the sample is different from other participants (Table 1).

Analysis of Data

This section of chapter four has been structured around the two research questions which guided the study. In each case, the research questions are stated and followed by a presentation of the data using descriptive narratives. This study used think alouds to provide insight into novice secondary science teachers' understanding of the purpose of teachers' questions and the appropriateness of questioning strategies for facilitating student learning. I will begin by presenting the evidence for the factors participants attended to in the video excerpts: attention to student thinking through teacher questions, communication patterns, and teacher instruction. I will then turn to attention to teacher questions that challenge student ideas towards the scientific principle, attention to communication patterns, and then to attention to teacher instruction.

Research Question 1

To determine how novice secondary science teachers' understand the relationship between student thinking and teacher questioning strategies, the first research question will be discussed. What factors do novice secondary science teachers' attend to in the instructional environment when considering the effectiveness of a questioning strategy?

The factors participants attended to were student thinking through teacher questions to elicit and probe student thinking, communication patterns, and teacher instruction.

Evidence in research shows novices can attend to student thinking (Darling-Hammond & Snyder, 2000; Davis, 2006; Levin, 2008), but it may depend on how the novice teacher frames their teaching (Levin, Hammer & Coffey, 2010). Levin and colleagues discussed framings around student thinking can take place in pedagogy courses and also in terms of the focus of the institution the novice teacher is employed.

Concise Findings

1. Attention to student thinking. One participant, Stellah, elaborated on student thinking in both video excerpts.
2. Three participants noticed the questions to elicit student ideas reviewed the previous lesson in the rock video excerpt. Five participants attended to student thinking with their understanding of questions to elicit student ideas. Teachers with more experience showed understanding and attended to student thinking in questions to elicit student ideas more than first-year teachers.
3. All participants showed understanding of questions to probe student ideas. Six participants attended to student thinking with their understanding of questions to probe student ideas. One participant consistently identified each question type by the language taught in the science methods course. There were no noticeable differences between first-year teachers and more experienced teachers.
4. Attention to communication patterns. Three participants noticed the communication patterns between the teacher and students.

5. Attention to teacher instruction. All participants paid attention to teacher instruction, especially wait time and student engagement. Teachers with more experience showed attention to feedback and praise. One first- and one second-year teacher referred to the questions as “lower-order” and “higher-order” questions. Teachers with little teaching experience are more likely to refer to questions as “lower-“and “higher-order” questions.

Attention to student thinking.

I will begin with one participant who elaborated on student thinking in both video excerpts, Stellah. I then turn the attentions to student thinking through teacher questions to elicit and probe student ideas. Questions to challenge student ideas will be discussed in research question 2.

Elaboration on Student Thinking

Stellah

Stellah is the only participant that elaborated on the content of student thinking significantly. Stellah attended to student thinking in both the think aloud and in the critical incident debrief. Stellah attended to student thinking in the US4 Rock video excerpt think aloud by noticing the questions to elicit student ideas called for multiple student responses to a review question, in the US4 Rock video think aloud and critical incident debrief about multiple student answers and misconceptions, and in the US 1 Weather video think aloud and critical incident debrief about student agreement to teacher leading questions.

In the beginning section of the US4 Rock video excerpt (00:22 – 03:22), the teacher posed a question to elicit student ideas to review prior knowledge from the previous day's lesson. Stellah noticed the review and attended to student thinking with her understanding of the elicitation question,

> He is starting with a review. So he asked a question to the whole class and called on one student really quickly, which is review. If we are all gearing up for a review question, he said it was from the day before. Now he is giving them a little more time to answer. So, her answer is wrong and he told her it was wrong in a very nice way but he said good because it was something they all needed to know. So she will still have confidence to answer a question again. Other kids have their hands up though.

After the teacher elicited prior knowledge about sedimentary rocks, the teacher continued to guide students through a discussion, probing for student understanding in how to identify sedimentary rocks. Stellah noticed the teacher asked a question and called on several students to give their answer to the question. After hearing the same answer from the students, Stellah made the remark in her think aloud, "A couple of students give their answer. Now he is calling on a specific person. So even if that person didn't know the answer, three people already said that answer out loud." Further discussion in the critical incident debrief, Stellah showed attention to student thinking when she revealed her concerns about students hearing correct answers. She wondered if the last student the teacher called on to answer the question maybe changed her answer because someone previously answered correctly because that person always had correct answers. Stellah wondered if the student didn't change her answer and shared the incorrect answer, could that be a chance to discuss the misconception that other students may have also.

> He calls on a student after three people said the right answer. And then he calls on this one student, so is that student going to have a different answer or is she going to give that answer now? And maybe because she changed her answer, because this girl is always right, and these two are always right and they said it. So, could her wrong answer, if she had a wrong answer, could that have been a chance to go back and talk about something to kind of clear that up? Or, maybe other students that had that same misconception.

Stellah also attended to student thinking in the weather video think aloud and critical incident debrief when she discussed student answers and behaviors to teacher leading questions. Stellah noticed the teacher asked leading questions that elicited agreement and nodding heads from students. The weather video excerpt began with teacher instructions to look at weather maps on four different textbook pages in reference to the elicit question, "What do you notice about the fronts and the high pressure; and the fronts and the low pressure?" and then immediately changed the question to a challenge question asking about what patterns students noticed. Throughout the video excerpt, the students were unable to answer the question. After a short direct teach illustration of cold, warm, and cooler air masses utilizing different colored balloons as models on a map displayed on the board from the overhead projector, the teacher tells the information to the students accompanied with leading questions. The leading questions, such as “see?”, “ok?”, and “get it?” along with eye and head movement resulted in nods of agreement from the students.

In the think aloud, Stellah showed attention to student thinking when she noticed the teacher asked questions, answered her own questions, and then used eye and head movement to lead students to agree with her. Stellah said, “So “get it?” and then “do you see?” it’s not really a question but that corresponds to nodding their heads and ok we are going to move on and explain” and “She says ok a lot and moves her head in a way that the kids know they’ve got to answer her with just a yes or ok”.

In the critical incident debrief, Stellah showed attention to student thinking when she talked about student agreement to teacher leading questions. Stellah said, “And they are not going to disagree with the teacher, instead of a ‘why do you think?’ she tells them and then says right? You are not going to disagree with the teacher on that.” Stellah discussed that students will agree with the teacher because they do not want to be the only person with a question, “And students respond ‘yes’ and nobody wants to be the only person with a question, they feel like they are slowing everybody down from getting started when they don’t understand.” Stellah suggested the teacher could have had students discuss the question on fronts and pressure centers within their small groups.

The evidence of Stellah's attention to student thinking included noticing the rock video elicit question called for multiple student responses to a review question, her discussion around students not revealing their true answers and possible misconceptions when multiple students previously give correct answers to questions in the rock video excerpt, and her discussion on student agreement with teacher leading questions in the weather video excerpt.

Attention to the Connection between Teacher's Questions and Student Thinking

First, I will present the data according to questions to elicit student ideas. Next, I will present the data according to questions to probe student ideas. The data will be presented for each participant (See Table 3). Data regarding questions to challenge student ideas will answer research question 2.

Table 3 *Participant attention to questions to elicit student ideas*

Participant	Teaching experience	Rock content knowledge	Weather content knowledge	Understanding of questions to elicit student ideas	Attended to student thinking in questions to elicit student ideas	Noticed question review
Stellah	6-12 months	Slight	Slight	√	√	√
Keith	6-12 months	Slight	Somewhat			
Ally	6-12 months	Somewhat	Somewhat	√	√	
John	6-12 months	Moderate	Moderate			
Andy	12-18 months	Slight	Slight	√	√	√
Payton	18-36 months	Slight	Slight	√	√	
Brock	18-36 months	Somewhat	Somewhat	√	√	√

Questions to Elicit Student Ideas

Questions to elicit student ideas are addressed at the beginning of a lesson or new concept and are posed to multiple students for a variety of student ideas. They are designed to reveal how students are thinking about a particular concept. Questions to elicit student ideas determine students' prior knowledge, alternative conceptions, predictions, and explanations. Of the four first-year teachers, only two showed understanding of the questions to elicit student ideas. Of the second- and third-year teachers, they all showed understanding. However, even when they noticed the elicitation questions, their understanding of the purpose of questions to elicit student ideas was naïve and lacked detail of the purpose of the questions and student thinking about the questions. Also, while three participants noticed the teacher review, their understanding of it was somewhat formulaic. Two participants were second- and third-year teachers and the first-year teacher was the participant that expanded on student thinking throughout both video excerpts.

There were two questions to elicit student ideas asked in the US4 Rock video excerpt. One question to elicit student ideas was presented at the beginning of the lesson reviewing sedimentary rocks and the second question to elicit student ideas was presented at the beginning of a new concept about igneous rocks. There was one question to elicit student ideas in the US1 Weather video excerpt.

(US4 Rocks section 00:22)	from yesterday, what's gonna happen to the sediments?" (e - elicit question; elicit prior knowledge, engage in topic)
(US4 Rocks section 07:25)	Any idea where I am? Well, I don't mean the exact-I can tell you the exact location, but the type of landscape I'm on.
(US1 Weather section 03:11)	What do you notice about fronts and pressure centers? What do you notice about the fronts and the high pressure and the fronts and the low pressure? (e – elicit question)

Brock

Brock showed attention to student thinking in both rock video excerpts with the questions to elicit student ideas. Brock showed an understanding of questions to elicit student ideas, for finding out multiple students' prior knowledge. Brock also noticed the question to elicit student ideas was not appropriate in the weather video and did not elicit student answers. Brock suggested the teacher ask some guiding questions.

Brock noticed the question to elicit student ideas in the rock video reviewed the content from the previous lesson. “So, I like that the teacher has a model on his desk and is trying to relate that to what the kids were working on yesterday.” Brock also noticed both questions to elicit student ideas in the rock video excerpt elicited a variety of students to give their individual answers, “Getting individual responses from students about what they learned yesterday. So, I like the way he is tying it back together in asking students how to identify rocks he is giving some good wait time to get different responses from a variety of students.” And, “Again, he is doing a good job of wait time to get a variety of answers from students.” In the weather video excerpt, Brock noticed the question did not elicit answers from the students and suggested asking guiding questions,

> She is not really giving much feedback to her students at all. She is asking them to look for specific items but no response from students if they found them or not. She is asking them to tell her something different between high and low pressure systems; students don’t seem to be looking at their maps. I think some guiding questions might help a little and get some feedback from students. She is asking the same questions over and over without changing her wording. She needs to try to get more students involved. She needs to ask some different questions, she is not getting responses from students. She is practicing wait time to try and get more students involved.

Brock showed evidence of attending to student thinking in the both video excerpts. He noticed the question to elicit student ideas in the rock video reviewed the content from the previous lesson. Brock noticed a variety of students gave individual answers to the question to elicit student ideas in the rock video. Brock noticed the question did not elicit answers from students in the weather video and suggested asking guiding questions.

Andy

Andy showed attention to student thinking with questions to elicit student ideas. Although Andy showed understanding that questions to elicit student ideas elicited prior knowledge from multiple students to get a variety of student ideas in his comments on the rock video excerpt, he did not show that same understanding in the weather video. Andy did not notice that this question was not appropriate for an eliciting student ideas at the beginning of a lesson. Andy showed more attention to teacher instruction. Andy did notice the students did not seem to understand and that the teacher answered the question.

Andy showed attention to student thinking in both questions to elicit student ideas in the rock video. Andy noticed the first elicitation question was a review from the previous lesson and that question was posed to all students to elicit their prior knowledge. Andy said, "Teacher is activating class introducing what they went over yesterday. After a very broad question, he asked the same question to a specific student. Giving a little praise, that's good." Andy was consistent with his knowledge on the purpose of questions to elicit student ideas in the second elicitation question of the rock video excerpt, "Oh, somewhere he has been, checking the students' knowledge seeing if they recognize the location. He is definitely probing for the different types of answers."

Andy did not show attention to student thinking with the question to elicit student ideas in the weather video excerpt. He paid more attention to teacher instruction. Andy's understanding of the purpose of questions to elicit student ideas he displayed in the rock video was not applied in the weather video elicitation question. Andy paid more attention to teacher instruction, "I like her pause. She is giving a lot of pause in her questioning. I don't like that she didn't give a lot of wait time in that question. She had two questions too close together. Her students don't have a clue what they're doing, or they don't look like they know what they are doing. She is giving good advice for figuring this out. She re-asked the question. One student had his hand raised but she didn't call on him. Here is another student with his hand raised. She just asked a question, she just answered it for them."

Andy showed some evidence of attending to student thinking in the rock video questions to elicit student ideas. He noticed the questions to elicit student ideas in the rock video reviewed the content from the previous lesson. He noticed the questions to elicit student ideas evoked prior knowledge from multiple students, and he noticed students were not answering the question in the weather video excerpt.

Ally

Ally showed attention to student thinking through the questions to elicit student ideas. Ally showed understanding that questions to elicit student ideas elicit prior knowledge from multiple students to get a variety of student ideas in her comments on both elicitation questions in the rock video excerpt. Ally's comment for the first rock video elicitation question was,

> Oh, so he is talking about sediments, pressure. He asked a question directly "what's going to happen, what you think?" Oh, so he is asking them to think and point out characteristics about sedimentary. How do you know if it is sedimentary or not? So he is asking questions, so students are telling him. So, he [teacher] is talking about deposition, talking about how the rock is made, but I am not sure the student answered the question about how are you going to know. So, he [teacher] is refreshing their memory, what happens with sediments, it gets deposited and he is pointing out what is happening. Oh, so he is going back to the question, how are you going to spot it? He [student] didn't answer the question. So what are the characteristics of sediments? So how can you spot it? So he says [student says] they have layers, so he [student] is actually answering the question.

Ally's comment for the second rock video question to elicit student ideas was,

> Assuming that is a picture of him when he was younger, he is putting it on the board, he is asking the students to um guess or think where he is, so they kind of have to guess. Oh so now he clarifies, you don't have to tell me exactly where I am like the city, he wants them to tell what type of landscape, what type of surface, mountain, to identify. So based on their previous knowledge they are going to have to answer. So the students answered a rock or a cliff

Although, Ally showed understanding of the purpose of questions to elicit student ideas in the rock video excerpt, she did not show that same understanding of questions to elicit student ideas in the weather video. Ally noticed the teacher asked the questions and that students needed time to think about the questions, but she did not notice that this question was not appropriate for a question to elicit student ideas at the beginning of a lesson. Ally showed attention to student thinking when she noticed the students did not make the connection to the concept,

> I am noticing that she keeps talking as she is asking questions and she is not giving enough think time. She asked a question and then she keeps talking. Oh, now she is giving them enough time to think, so she is not taking the first answer, which is good. I don't know, she is waiting, that's good. So someone asked a clarifying question. So they are asking a clarifying question if this what we are looking at is correct, the cold fronts or warm fronts? Ok, so she is stating that she is waiting for them to get the OH! Look, like that epiphany, so she is waiting for it, for students to make the connection. So she is probably prompting a student who is not making the connection and is off task, or she is helping guide their thoughts, maybe probing him, the student Scotty. He probably had a puzzled look, so she is obviously observing the classroom. So he is explaining it and she is asking him to dig deeper, what do you mean? So everything he says she asks another question to clarify what he means. She is helping him get to where he can make a connection between the low and high pressure centers. She is trying to

scaffold his thinking and he is still thinking, so he still hasn't made the connection.

The evidence showed Ally did not have an understanding of the purpose of questions to elicit student ideas in the weather video excerpt, although evidence in the rock video excerpt showed Ally did have an understanding of the purpose of questions to elicit student ideas.

Ally showed some evidence of attending to student thinking. She noticed the questions to elicit student ideas called for students to think about different characteristics of sedimentary rocks in the first question to elicit student ideas. Ally also noticed the second question to elicit student ideas was posed for multiple students to give a variety of answers from their prior knowledge in their guessing. Ally showed evidence students needed to think about their answers to questions in the weather video question to elicit student ideas and that students did not make the connection to the concept.

Payton

Payton showed a shift between some evidence of student thinking and teacher instruction. Although Payton did not discuss the purpose of the questions to elicit student ideas, Payton showed she focused on teacher instruction with some attention to student thinking when she noticed the students were answering the questions using academic vocabulary to both rock video questions to elicit student ideas. For the first question to elicit student ideas Payton said, "He's giving, he asked a question and gives feedback. I like how he is using academic vocabulary and I like how the student just answered the question with academic vocabulary. Gave them positive feedback." For the second question to elicit student ideas Payton said, "He is showing a picture of himself and I am sure the students are very engaged and interested, it looks like in his younger days, of where he must be. I am really impressed the students are using their academic vocabulary answering questions." Payton seemed to be surprised at student use of vocabulary.

Payton identified the question to elicit student ideas in the weather video as an elicit question. Although Payton did not show a thorough understanding of the purpose of questions to elicit student ideas in the rock video excerpt, she showed an understanding that questions to elicit student ideas elicit student ideas about a concept in the weather video excerpt. Payton noticed the questions to elicit student ideas was to elicit what students noticed about fronts and pressure systems, but Payton showed conflict in understanding that question. Payton said,

> Now she is asking what I think is an elicit question because she is asking about what they notice about having them compare. She is continuously asking about what patterns they notice. Now she is giving them wait time. I notice how she is giving the students time to look over and think about, she is not letting them answer because there are some students that are getting it quicker than others, she wants everybody to have a chance to compare.

The teacher asked students what they noticed about fronts and pressure systems and then immediately changed to a question to challenge student ideas asking about patterns they noticed. Students could not answer that question. Payton showed a conflict in trying to understand this change. Payton did not notice that this was an inappropriate question to elicit student ideas.

Payton showed a shift between some evidence of student thinking. Payton attended to student thinking by noticing students used academic vocabulary in their answers and that the weather video asked for students to respond with their thinking about what they notice about a fronts and pressure systems.

John

John did not attend to student thinking. John did not show he had an understanding for the purpose of questions to elicit student ideas in the rock video excerpt. His comment for the first question to elicit student ideas was, "Oh good question to start, nice deep question." John's comment on the second question to elicit student ideas focused more on student engagement, "Alright, more questioning with each visual it is also accompanied not by an explanation but by a question. Lots of engagement, lots of responses from the kids. They are thinking about it, they are completely engaged." Although John did not show understanding of the purpose of questions to elicit student ideas, John did notice the question to elicit student ideas in the weather video excerpt was not an appropriate question. John noticed it was a difficult question for students to answer and the students were not responding. "Ok first question of the class…So, this is like that discovery formative assessment at the beginning, there is no involvement. Also, asking what do you not see is difficult for people not just 12 year olds. I would like this more if they were in twos or threes and trying to figure things out for themselves, to bounce ideas off." Although John suggested students work together to figure out the answer, John did not show an understanding of questions to elicit student ideas; for eliciting multiple student's ideas about a concept.

John did not show evidence of attending to student thinking. He only noticed students were not engaged in the weather video excerpt.

Keith

Keith did not show attention to student thinking. Keith did not show an understanding of questions to elicit student ideas, for finding out multiple students' prior knowledge. He focused on asking questions that are higher-order for students to explain and analyze. This is not consistent with the purpose of questions to elicit student ideas. For the first question to elicit student ideas in the rock video, Keith said, "There's a little bit, he is already asking higher-order questions, his first question was to explain and now he is asking higher-order questions from the students, and he is given good wait times." For the second question to elicit student ideas in the rock video, Keith said, "And he seems to have good rapport with the students, he is not putting anything down, he kind of jokes with everybody and they have kind of a good environment. He's asking questions like having to analyze certain evidence like pictorial evidence; they are having to analyze that, which again, is a higher order question."

Keith did not notice the question to elicit student ideas in the weather video excerpt was not an appropriate question to elicit student ideas. He again focused on the question being higher-order question for explanation and the teacher should have explained the concepts first due to lack of responses from students,

> She didn't explain what a low pressure center is, what low pressure looks like. She hasn't explained any of this yet and you can see a student in the blue- he

> doesn't seem to know what is going on. She's not really, she's never really explained what a low pressure or high pressure is unless she did it in an earlier chapter but the way the kids are responding they don't know what a front is because a lot of kids are reading the book instead of looking at the pictures, I think she notices that now, one student responded and another lowered his hand, she says she is waiting, there you go and there's the question. He didn't even know what a cold front or warm front looks like so that could be a little bit more effective if she would have explained it when she said she was waiting to get that look on her face like ohh. And then she called out one student specifically, most of the kids are unengaged right now they are kind of. I think this question is a higher-order question but she didn't get the lead up to this point she basically started them out without the necessary information.

Keith did not show evidence of attending to student thinking. He only noticed students were not engaged in the weather video excerpt.

Five participants attended to student thinking with their understanding that question to elicit student ideas elicited prior knowledge from multiple students to get a variety of student ideas about a concept, Stellah, Brock, Andy, Ally, and Payton. Teachers with more experience showed understanding and attended to student thinking in questions to elicit student ideas more than first-year teachers. Two participants did not attend to student thinking when the question to elicit student ideas were posed in the video excerpts. Three participants noticed the question to elicit student ideas reviewed the previous lesson in the rock video excerpt, Stellah, Brock, and

Andy. The committee of experts identified the lesson review to be an important part of the lesson for participants to attend to.

Questions to Probe Student Ideas

All participants showed understanding of questions to probe student ideas. Six of the seven participants attended to student thinking in their understanding questions to probe student ideas. There were no noticeable differences between the first-year and more experienced teachers with regard to questions to probe student ideas. Questions to probe student ideas are provided throughout lesson directed to a specific student to further understand their thinking, build on their ideas, and clarify their thinking.

Table 4 *Participant attention to questions to probe student ideas*

Participant	Teaching experience	Rock content knowledge	Weather content knowledge	Understanding of questions to probe student ideas	Attended to student thinking in questions to probe student ideas
Stellah	6-12 months	Slight	Slight	√	√
Keith	6-12 months	Slight	Somewhat	√	√
Ally	6-12 months	Somewhat	Somewhat	√	√
John	6-12 months	Moderate	Moderate	√	
Andy	12-18 months	Slight	Slight	√	√
Payton	18-36 months	Slight	Slight	√	√
Brock	18-36 months	Somewhat	Somewhat	√	√

Below is the US1 Weather video section (04:22 – 05:00) when the teacher probed a particular student about what he meant about the weather symbols on the map. This data was used for data analysis.

04:22 Stuart, are you noticing anything?
04:41 Besides the-besides the points?
04:44 Besides the what?
04:45 The points, the triangles
04:49 That there's like more (inaudible)
04:49 There's more triangles where?
04:53 No. There's more triangles
04:54 Oh.
04:55 Than there's (inaudible)
04:59 Oh. Ok, so there's more cold fronts than warm fronts?
05:00 Yeah.

There were several instances the US4 Rock video teacher probed the students. The data is displayed in Tables 5, 6, and 7.

Table 5 *First rock video question to probe student ideas*

02:05 -02:16 Now, how do you know that's sedimentary rock? How do you know? How do you know it's stuck together?	
Andy	Kind of building on the same question he just asked with a little bit more detail
Brock	So he is relating back to an answer a student gave but reiterating the actual question for what he is looking for, for identifying the rocks, he is doing a good job of leading back to it with what they said
John	Alright, probing, going deeper, asking open-ended questions getting responses for going deeper on sediments, how sediments are made Doing a good job restating what the other students have said, throwing a question back out there for the remaining students to provide deeper information
Stellah	So he is switching that now and it is "How do you know that?" Now How do you know, why would you say that?
Keith	He is asking how do you know, and he got a correct answer, and he is checking, so, he is checking and making sure the students hear it multiple times
Payton	He is asking probing questions
Ally	So one of the students says it is stuck together, and he asks what does that mean stuck together.

Table 6 *Second rock video question to probe student ideas*

03:46 – 06:23 Suppose- suppose an animal, the remains of an animal, got deposited in the river along with the sediments. Which would you say is older? Why is the bottom older?	
Andy	Answer correct but not quite what he was looking for so he is probing a little bit more
Brock	Showing them pictures and then having them expand on what they know and why they know that. I like the way that he is asking why something is happening, how they can tell that. Getting them to think about what they actually know
John	Oh, that's amazing, another concept, relative aging, superposition. Bringing a lot of concepts into one base visual, base example. Oh good, I am jealous
Keith	And there he goes, he asks a question and then he asks Why?, he needs justification which falls in the claim and justification
Payton	I think he is asking, he is asking a lot of questions probing and challenging questions
Ally	So the student answers the question what they think is going to happen and – its going to blend into the rocks it is going to go into the rocks, and he says that's a good answer but because they didn't say a specific vocab, he is always trying to relate to specific vocab, so another student makes the connection that the animal will become fossilized

Table 7 *Third rock video question to probe student ideas*

10:52 -11:55 Yeah, but how is it different than sedimentary rock? Think the way this rock forms, How did it form? What comes out of a volcano? What has to happen to magma, or in other words, molten rock – that's where the heat comes in- in order for it to become solid?	
Andy	he is probing for more details
Brock	Again, having different students trying to expand on their answers to try to figure out the different kind of rock that he is on
John	Digging deeper. Alright, keeps going back to their explanations, rephrasing questions, incorporating prior student responses
Keith	And he is asking a lot of Why? Questions, a lot of explain
Stellah	Wow that was the first time he said "no" when a student answered He keeps leading them toward the right answer, so the next person that answers the question can build on that to get towards what he is asking them for

Payton

Payton attended to student thinking with her understanding of the purpose of questions to probe student thinking. Payton consistently used the correct term, probing, to refer to probing questions. Payton used the term probing, “He is asking probing questions,” I think he is asking, he is asking a lot of questions, probing and challenging questions,” and showed her understanding of questions to probe student thinking with her statements, and “She is probing one of the students …She is probing him for what he understands about the points”. Payton showed evidence of student thinking with questions to probe student thinking.

Ally

Ally attended to student thinking with her understanding of the purpose of questions to probe student thinking in the US1 Weather video excerpt. Ally said, “So someone asked a clarifying question. So they are asking a clarifying question if this is what we are looking at is correct, the cold fronts or warm fronts? She is helping guide their thoughts, maybe probing him.” In another instance Ally noticed the teacher probing another student and said,

> He probably had a puzzled look, so she is obviously observing the classroom. So he is explaining it and she is asking him to dig deeper, what do you mean? So everything he says she asks another question to clarify what he means. She is helping him get to where he can make a connection between the low and high

> pressure centers. She is trying to scaffold his thinking and he is still thinking, so he still hasn't made the connection.

Ally showed evidence of student thinking with her understanding that the goal of questions to probe student thinking is to clarify student thinking and to obtain more information for what an individual student is thinking.

Stellah

Stellah attended to student thinking with her understanding of questions to probe student thinking. In the weather video excerpt Stellah said, "But everything she says back to the kid is a question. So they are giving an answer and she is rephrasing it to get to more information out of that person." Stellah showed further insight into the situation adding, "But she didn't call on anybody else to answer or clarify or to add to when the kid was struggling with the answer." In the rock video excerpt, Stellah noticed the teacher switched his questioning style to "how do you know," and "why would you say that." Stellah also noticed the teacher would let the students know if they were wrong and he would continue to ask questions. Stellah said, "He keeps leading them toward the right answer, so the next person that answers the question can build on that to get towards what he is asking them for." Stellah shows an understanding that questions to probe student thinking build on ideas already presented by a student. Stellah attended to student thinking with her understanding that questions to probe student thinking can be used to clarify student thinking and obtain more information.

Brock

Brock attended to student thinking in his understanding of questions to probe student thinking. Brock showed understanding of the questions to probe student thinking by noticing the teacher was having the student expand on his ideas in the weather video excerpt, “So a student is volunteering an answer he thinks and she is having him expand on his answer. She still is trying to get the same student to expand on his answer, sticking with him.” And also in the rock video excerpt, “Showing them pictures and then having them expand on what they know and why they know that. I like the way that he is asking why something is happening, how they can tell that. Getting them to think about what they actually know.” Brock also stated, “Again, having different students trying to expand on their answers to try to figure out the different kind of rock that he is on.” These statements are consistent with the purpose of questions to probe student thinking, to obtain more information from a student and to build on ideas already presented by a student. Brock attended to student thinking with his understanding of questions to probe student thinking.

Andy

Andy showed his knowledge that questions to probe student thinking clarify student thinking in his response to the questions to probe student thinking in the weather video excerpt, “The student just gave a response and now she is clarifying his response of what he just said.” Andy also noticed when the rock video teacher was probing for more information from a student, “He is probing for more details,” and “Answer correct, but not quite what he was looking for so he is probing a little bit more,” and again with, “Kind of building on the same question he just asked with a little bit more detail.” Andy’s statements agree with the purpose of questions to probe student thinking, to determine more information and build on ideas already presented by a student. Andy attended to student thinking with his understanding that questions to probe student thinking can be used to clarify student thinking and build on ideas already presented by a student.

Keith

Keith attended to student thinking in his understanding of questions to probe student thinking. In the rock video excerpt Keith commented about teacher and student interactions, “but he is still, you can tell he is really stretching the students, they are all looking at their notes, they are all very eager to answer the questions as well.” Keith further said, “he asks a question and then he asks why, he needs justification which falls in the claim and justification,” and “he is asking a lot of why questions, a lot of explain.” In the weather video excerpt Keith simply said, “There she goes she did a little guiding questioning.” To guide student thinking, you have to understand what the student is thinking. Keith attended to student thinking in his understanding that questions to probe student thinking are used to find out more information about what the student is thinking.

John

Although John showed understanding of questions to probe student ideas, John did not attend to student thinking. Although John did not attend to student thinking, he gave one example of his understanding of questions to probe student thinking. In the rock video excerpt, John commented, “Alright, probing, going deeper, asking open-ended questions getting responses for going deeper on sediments, how sediments are made. He continued his comment, “Doing a good job restating what the other students have said, throwing a question back there for the remaining students to provide deeper information.” This example is evidence that John noticed the rock video teacher probed students for understanding.

All participants showed understanding of questions to probe student ideas. Six of the seven participants attended to student thinking in their understanding of questions to probe student thinking. There were no noticeable differences between the first-year and more experienced teachers with regard to questions to probe student ideas. Participants showed evidence of their attention to student thinking in their understanding that questions to probe student thinking obtain more information from a student, build on student ideas and clarify student thinking.

Communication pattern between teacher and student

Three of the four first-year teachers, and none of the more experienced teachers noticed the communication patterns between teacher and student. The participants noticed the teacher attended to student answers by restating the answer and built on those answers with another question for further student understanding.

Stellah

Stellah attended to the teacher-student questioning strategy in the third section of the US4 Rocks video excerpt (section 06:59-15:03). Stellah noticed the teacher took the student statement and turned it into a question for the students to add to the knowledge, “he keeps leading them toward the right answer, so the next person that answers the question can build on that to get towards what he is asking them for.” At the end of this rock video section, Stellah summarized the teacher strategy, “He was setting them up before the question with just reviewing; now asking the question just to hammer in that point.”

Keith

Keith similarly attended to the teacher-student questioning strategy in the third section of the US4 Rocks video excerpt (section 06:59-15:03). Keith noticed the teacher asked a lot of questions that asked for explanation, “He is asking a lot of ‘why’ questions, a lot of explain”, and “asking them to explain, a lot of explain questions, to check for their understanding because he wants them to not answer yes or not, he wants them to explain.” Keith further discussed how the teacher asked lower order questions to help explain and then lead up to the higher order questions. In this section of the video, the teacher asked students how the rock formed. When two students replied “by heat”, the teacher answered heat was necessary, and added a question asking if it was metamorphic rock. When another student answered magma, the teacher asked what comes out of a volcano and then what has to happen to the magma when it comes out of the volcano. Keith noticed that the teacher listened to student responses and asked more questions to further their thinking, “He added another question to help build on it, to build on that information. I like how he is still keeping the students going.”

Andy

Andy also attended to the teacher-student interaction in the first section of the US4 Rocks video excerpt (section 00:22-03:22). His comment, “I like how he draws on what the students says, ties in answers in with what other students said” showed evidence that he attended to a communication pattern between the teacher and student.

All six participants above attended to the teacher-student questioning strat egy. Three participants noticed the reflective toss (van Zee & Minstrell, 1999) pattern with the student statement, teacher question, and student statements of understanding, Three participants only noticed the interaction between the teacher and a single student. One participant did not comment on the teacher student conversation patterns.

Attention to instruction

All participants paid attention to teacher instruction consisting of wait time and six out of seven participants attended to student engagement. There were no significant differences between first-year and more experienced teachers with regard to wait time and engagement. The more experienced teachers were more likely to notice feedback and praise. One first-year teacher referred to all questions as “higher-“and “lower-order questions” and one second-year teacher commented twice on “higher-order” questions. These aspects of instruction were emphasized by the participants teacher evaluation system used in their school districts. The frequency of occurrence of these factors are displayed in Table 8 below.

Table 8 *Novice term frequency*

Participant	Teaching Experience	Rock Content Knowledge	Weather Content Knowledge	Wait Time		Engage(d)		Praise		Feedback		High-Order Low-Order Questions	
				R[a]	W[b]	R[a]	W[b]	R[a]	W[b]	R[a]	W[b]	R[a]	W[b]
Stellah	6-12 months	Slight	Slight	2	2	1							
Keith	6-12 months	Slight	Somewhat	1	4	2						12	3
Ally	6-12 months	Somewhat	Somewhat		2								
John	6-12 months	Moderate	Moderate	1	2	7	1						
Andy	12-18 months	Slight	Slight	2	3	1		4				2	2
Payton	18-36 months	Slight	Slight		2	2	1			3	1		
Brock	18-36 months	Somewhat	Somewhat	4	1	6		1			2		

Note. [a]Refers to Rock Video Excerpt. [b]Refers to Weather Video Excerpt.

Wait time

All participants noticed whether or not the teachers used wait time in the video excerpts. Wait time was referred to twenty times in the video excerpts (See Appendix B). Examples of comments were "He gave good wait time, several students had their hand raised" and "She is practicing wait time to get more students involved".

Engagement

Six out of seven participants used the term "engaged" to comment on student reactions to both teacher questions and visuals. Keith, Brock, John, Payton, and Stellah all used the term "engaged" to refer to student response to teacher questions; Ally did not any form of the term engage. Brock stated, "Again, I like the way he is doing a good job of keeping students engaged by asking them to ask questions and telling them they did well previously." Payton gives another example of evidence with her statement, "Calling the students by name, trying to engage all the students, walking around the entire class."

Four participants, Brock, John, Payton and Andy, all give evidence that they noticed visuals with teacher instruction evoked student engagement. An example of this evidence is given by Brock's statement, "Showing them a real life example to keep them engaged." Another example that supported this notion is with John's statement, "He has lots and lots of props and visuals which is part of what is keeping the students so highly engaged."

Six out of seven participants used the term “engaged” to describe student reaction to teacher questions and/or teacher instruction with visuals.

Novice secondary science teachers’ documented evidence that they noticed several factors when attending to teacher questions in the science classroom. The factors included attention to student thinking through teacher questions, attention to teacher questions that elicited student thinking, the attention to communication patterns between teacher-student and student-teacher-student, and teaching instruction.

Praise

Two participants used the term “praise” when the teacher in the US4 Rocks video excerpt responded to students. Brock said, “He is asking good questions and giving student praise and getting good responses.” Along the same kind of thinking, another participant, Andy, commented four times about the teacher in the rock video excerpt. Andy said, “Giving a little praise, that’s good”; “He just asked a question, gets students answers, and gives praise”; “Gave them specific praise”; and finally, “Now they finally hit it, give them praise.”

Feedback

Two participants discussed the teacher “feedback” to the students. Payton commented three times that the teacher in the rock video excerpt gave feedback. Payton commented, “He asked a question and gives feedback”, and “Gave them positive feedback”, and “He is giving the students positive feedback." Brock also used the term "feedback". Brock used this term twice while he viewed the US1 Weather video excerpt. He said, "She is really not giving much feedback to her students at all." Brock also remarked, "I think some guiding questions might help a little and get some feedback from the students."

Higher-Order Lower-Order Questions

Two participants used the term "higher-order" or "lower-order" when talking about teacher questions. Keith used the terms 12 times in the rock video excerpt and three times in the weather video excerpt. One example of Keith's comments in the rock video excerpt was, "So there you go, he uses wait time and his lower-order questions help to explain, they are normally not dead end questions. He asks other questions based on those higher-order questions." In the weather video excerpt Keith made three comments about higher-order questions. One of Keith's comments was, "I think this question is a higher-order question, but she didn't get the lead up to this point. She basically started them out without the necessary information." Andy commented twice in each of the video excerpts on higher-order questions. In the rock video excerpt Andy said, "Definitely a higher-order question for them."

Research Question 2

How do novice secondary science teachers' connect teachers' questions to the scientific principle?

Concise Findings

1. One participant, Stellah, attended to student thinking in her understanding that questions that challenge student ideas push students construct new vocabulary.
2. Three participants attended student thinking through their understanding that questions to challenge student ideas push students to use new vocabulary. First-year teachers were slightly more likely to notice student use and construction of vocabulary.
3. All seven participants attended to student thinking through their understanding that questions to challenge student ideas guide students to make a new connection to a scientific principle.
4. Two participants, both first-year teachers, misjudged student connection to the scientific.

Table 9 *Questions that challenge student ideas*

Participant	Teaching experience	Rock content knowledge	Weather content knowledge	Noticed student constructed vocabulary	Noticed student use of new vocabulary	Understanding of questions to challenge student ideas	Misjudged student connection to scientific principle
Stellah	6-12 months	Slight	Slight	√		√	
Keith	6-12 months	Slight	Somewhat			√	
Ally	6-12 months	Somewhat	Somewhat		√	√	√
John	6-12 months	Moderate	Moderate		√	√	
Andy	12-18 months	Slight	Slight			√	√
Payton	18-36 months	Slight	Slight		√	√	
Brock	18-36 months	Somewhat	Somewhat			√	

Questions to Challenge Student Ideas

Questions that challenge student ideas develop deeper understandings of science ideas. Questions that challenge student ideas will push students to make new connections and use new vocabulary. First, I will present the data related to participant attention to student thinking in the construction and use of new vocabulary in a meaningful way. Second, I will present the data that participants attended to student thinking with their understanding that questions that challenge student ideas required students to make connections to the scientific principle being taught. Finally, I will present the data that two participants misjudged student connection to the scientific principle.

Construction and Use of New Vocabulary

One participant, Stellah, attended to student thinking in her understanding that questions that challenge student ideas push students construct new vocabulary. Three participants, Payton, John, and Ally attended to student use of new vocabulary. First-year teachers were slightly more likely to notice student use and construction of vocabulary. The US4 Rocks video teacher challenged students with questions to make new connections and to form new vocabulary from their understanding of a concept.

Stellah

Stellah attended to student thinking in her understanding that questions that challenge student ideas push students to make a new connection and to use new vocabulary. Stellah gave evidence of her understanding of questions that challenge student ideas when she talked about student constructed definitions in the critical incident interview. Stellah commented that constructing definitions backwards was hard work for students, but motivating and created confidence. The following comment summarized her thinking about student constructed definitions:

> If the questions are "how do you think?" may not be something they know, they are still offering an opinion; maybe it was this, you mean you are telling me these little bubbles.. and then a lot of times he led them into coming up with a definition for vocabulary words. You tell me that term first, that's intimidating, but then gas bubbles? Ok and then what you said is actually this here and he gives them the term. And then, what is the term for that? actually you are right and we actually call that strata, there's a term for that, what's that? and gives them the term. Constructing the definitions backwards, that's motivating and helps with confidence; you know that's a hard word – but I already know what it means.

Students learn new knowledge when it is learned in a meaningful way and it makes sense. Stellah showed evidence of student thinking when she noticed the inductive approach used by the teacher in the US4 Rocks video excerpts that allowed the students to discover there was a scientific term for their understanding of concepts which connected that gap in knowledge.

In contrast to attending to vocabulary terms constructed with the inductive approach, Payton, John, and Ally noticed student use of vocabulary in a meaningful way. Payton said, "I like how the student just answered the question with academic vocabulary" And "I am really impressed the students are using their academic vocabulary answering questions" and "…she used academic vocabulary." John said, "Oh, good use of vacab by the students" and "Oh very good, more student use of vocabulary."

Ally not only noticed student use of new vocabulary, she attended to student thinking with her understanding how questions that challenge student ideas push students to make a new connection to the scientific principle. In the US4 Rock video excerpt (section 00:22-03:22) the teacher used questions to elicit, probe, and challenge student ideas to guide students in a discussion for identifying the characteristics sedimentary rock formation of layers, or strata. Ally attended to student thinking when she noticed the teacher pushing students to use new vocabulary, "So, one of the students says it is stuck together, and he asks what does that mean stuck together? So, he explains. So, the key word he was looking for was layers. He asked, what's the word for that? So, the student said that key word, strata." Ally attended to student thinking a second time when she noticed the teacher challenged another student to used new vocabulary,

> So he is telling them, setting up the scenario of an animal and he draws it on the board and the layers, so he asks them, knowing what you know now, what is going to happen to that animal? So the student answers the question what they think is going to happen and – its going to blend into the rocks it is going to go into the rocks, and he says that's a good answer but because they didn't say a specific vocab, he is always trying to relate to specific vocab, he asked what's the

word for that. So, another student makes the connection that the animal will become fossilized.

In summary, Stellah noticed questions to challenge student ideas resulted in student construction of new vocabulary with the inductive approach. Payton, John, and Ally showed understanding of questions to challenge student ideas with the use of new vocabulary in a meaningful way.

Connection to Scientific Principle

All seven participants attended to student thinking in their understanding of questions to challenge student ideas when they noticed at least one teacher question to challenge student ideas guided students to make a connection to the scientific principle. Two participants misjudged students connecting to the scientific principle. Questions to challenge student ideas will advance students in their understanding of a scientific principle by having them explain their understanding of the newly formed concept and show their ability to use vocabulary in a meaningful way (see Appendix B). The data is presented by science concept within each video, US4 Rocks, then US1 Weather.

US4 Rocks

In the US4 Rock video excerpt (section 03:30-04:10), the teacher asked the students what they think will happen to animal remains deposited in a river with sediments. Ally was the only participant that commented that a student made a connection to the concept of fossilization when she commented on a student response, "Student makes connection -animal will become fossilized." Ally also noticed the teacher was looking for a key word, strata when the teacher probed a student, "How do you know it's stuck together?" This finding is in opposition to participants that commented about the questions to challenge student ideas without giving evidence of student connection. Brock noticed the teacher was "getting them to think about what they actually know" and "expand on what they know and why they know that," but he did not comment whether or not the students made the connection. As well, John made the statement, “Kids are all involved, grasping the concept, they are definitely able to understand and identify what makes it a sedimentary rock,” but did not give details of the student responses.

Stellah, Ally, and Brock attended to student thinking with their evidence that questions to challenge student ideas connect students to the scientific principle.

Alternatively, John, Payton, Keith and Andy did not talk about teacher questioning to connect students to the scientific principle. While John stated “kids are grasping the concept”, he did not give evidence of that statement. He only stated “good answers from kids”. John noted that the teacher connected a lot of concepts but did not state how. Payton, Keith and Andy did not discuss how the teacher questions led to student understanding of the science concept, only noticed the questions were “higher order” and the teacher used “wait time” and “praise”. Payton did notice teacher and student use of academic vocabulary.

Three participants, Stellah, Ally, and Brock, showed evidence that teacher questions challenge student ideas connect to the scientific principle in this section of the US4 Rocks video excerpt. Ally was the only participant that explicitly noted the student statement that made the connection to the scientific principle.

Table 10 *First rock video question to challenge student ideas*

section 03:46-04:33	**Suppose an animal, the remains of an animal, got deposited in the river along with the sediments. So now we have an animal, you know, that could have been buried… a million years ago, 10 million years ago, 50 million years ago… What do you think's gonna happen to that animal?**
Ally	Student makes connection -animal will become fossilized
Brock	As far as different fossils being buried beneath each other, getting them to think about which fossils are older by where they are buried in the sediment layers. All students seem to be engaged and trying to determine the older fossil; what they actually know and expand on what they know and why they know that
John	Kids are all involved, grasping the concept, they are definitely able to understand and identify what makes it a sedimentary rock. That's good
Andy	Looking for a definition more than an idea
Keith	You can tell he is really stretching the students; they are all looking at their notes, they are all very eager to answer the questions as well. They are all looking through their notes
Payton	More challenging questions. More modeling, more drawing as he is speaking, I like how he is doing that to visualize what he is saying. Yea [to the student answer]

In the US4 Rock video excerpt (section 05:19-06:23), the teacher asked the students which layer of sedimentary rock is older and how they would know. Again, Ally noticed students made a connection to the scientific principle of superposition where the oldest layer is on the bottom, "so they are making the connection that the older fossil is further down in the strata". This is in contrast to talking about student thinking about concepts instead of noticing when students make the connection to the scientific principle. Brock commented students were thinking about the layers of sedimentary rock, "they are tying in different applications of thinking through sedimentary rock and linking different layers of sedimentary rock," but he did not explicitly state the evidence that students made the connection to the scientific principle.

Once again, John notices the teacher makes connections and kids are engaged and respond, but does not notice the students making connections from teacher questions. Payton, Andy, and Keith still talk about positive feedback, student engagement, wait time, and higher order questions. Although they do not talk about student connection to the scientific principle, they all notice the teacher asks probing and challenging questions. Keith noticed questions to challenge student ideas elicit student thinking, “very good questions to evoke thinking.”

Ally, a first-year teacher, was the only participant that attended to student thinking when she noticed the questions to challenge student ideas connected students to the scientific principle.

Table 11 *Second rock video question to challenge student ideas*

section 05:19-06:23	**Suppose we dig down further into the sedimentary rock, into a layer that's underneath it. Maybe this fossil of a fish is found in here, and maybe something like this is found below it. Which would you say is older?**
Ally	so they are making the connection that the older fossil is further down in the strata
Brock	Looks like he is relating biology and age of animals to the rock layers. Again using a lot of different techniques to associate and different visuals so they can understand.
Keith	He is asking very good questions to evoke thinking.
John	Now back into more questioning. Good explanation. Oh, that's amazing, another concept. Relative aging, superposition. Bringing a lot of concepts into one base visual, base example. Lots of engagement, lots of responses from the kids. They are thinking about it. They are completely engaged, digging deeper.
Andy	Walking around, asking a question, and if/then question, hierarchical question right there. Showed on board, the different layers, and depending on that, higher-order, connecting it back to the different strata; reminding them how this ties in with geology.
Payton	I think he is asking, he is asking a lot of questions, probing and challenging.

In the remainder of the US4 Rock video excerpt (section 06:59-15:03), the teacher asked the students how they know the rock he was standing on was not sedimentary rock. The teacher was looking for student evidence showing how igneous rock was formed. A question that has student's explain how something happens is a question to challenge student ideas (see Appendix B).

Questions to challenge student ideas push students to make a new connection and use new vocabulary meaningfully and all seven participants showed attention to student thinking in this understanding with their comments in this last section of the US4 Rocks video excerpt. The questions will have student s explain their thinking and give reasons their understanding of the concept. Ally was very explicit how the student showed her understanding of how igneous rock formed when she stated the complete sentence the student said, “So, the student made a really simple sentence: igneous rock forms when magma cools.” Payton, John and Keith also showed understanding that this challenge question asked students to explain their reasoning for how igneous rock forms in a concise sentence. They also noticed the question was answered correctly. Payton was the only participant to use the term challenge question when she referred to the question. Payton said, “Um, challenge question.” Payton also showed her understanding of questions to challenge student ideas when further stated, “What comes to mind is the higher order thinking because they have to figure out how to explain this in one sentence.” Payton then noticed the student created the sentence, “I am not sure she read that or if she said that on her own, but she um created, she had a sentence, she used academic vocabulary, and she used a complete sentence.” Further, John did not use the language for questions to challenge student ideas, but showed his understanding when he said, “Alright, now he is asking them to give him a definition, an explanation in just sentence, he is getting them to minimize, making sure they are clear and concise” and “Got lots of hands up now, maybe a dozen. And there it is, a student responded with the correct answer.” In the same way, Keith said, “So now he is asking them to explain in one sentence, which is pretty good, again a higher-order thinking ‘cause you have to explain the process,” and adds, “And then he gets the answer that he wanted.” Likewise, Andy and Brock modestly stated students replied, “Students are giving answers for how they think it is formed” and “So, getting a one sentence answer from a student he is looking to get students to expand on their answers having students generate their own theories.” Not only did Stellah comment that the teacher asked students to summarize their knowledge how igneous rock forms into one sentence, but she also noticed student use of newly constructed vocabulary, “So now they are using the vocabulary off their sheet for the first time.”

In this section of the US4 Rocks video excerpt, all seven participants give evidence that students made the connection to the scientific principle by summarizing their newly constructed understanding of how igneous rock forms and in one case, used newly constructed scientific terms. The participant statements are consistent with the purposes of questions to challenge student ideas.

Table 12 *Third rock video question to challenge student ideas*

section 06:59-15:03	**Now, if I'm standing on the top of a volcano, why am I not standing on sedimentary rock? Why do I have to be standing on another kind of rock that we're gonna call non-sedimentary at least for the time being? Why? Yeah, but how is it different than sedimentary rock? Think the way this rock-this rock forms. How did it form?**
Ally	So, the student made a really simple sentence: igneous rock forms when magma cools.
Payton	Um, challenge question What comes to mind is the higher order thinking because they have to figure out how to explain this in one sentence. Impressed the students are using academic vocabulary. I am not sure she read that or if she said that on her own, but she um created, she had a sentence, she used academic vocabulary, and she used a complete sentence.
John	Alright, now he is asking them to give him a definition, an explanation in just one sentence, he is getting them to minimize, making sure they are clear and concise Got lots of hands up now, maybe a dozen. And there it is, a student responded with the correct answer.
Keith	So now he is asking them to explain in one sentence, which is pretty good, again a higher-order thinking 'cause you have to explain the process then he gets the answer that he wanted
Andy	Students are giving answers for how they think it is formed
Brock	So, getting a one sentence answer from a student he is looking to get students to expand on their answers having students generate their own theories.
Stellah	He told them to summarize in one sentence and he set up the first part for them. So now they are using the vocabulary off their sheet for the first time.

US1 Weather

The US1 Weather video teacher asked, "What pattern do you notice about fronts and pressure centers?" (Section 03:39). A question to challenge student ideas will guide student thinking toward a deeper understanding, has them reconsider their thinking and make a new connection (see Appendix A). This question to challenge student ideas was posed early in the lesson immediately after the elicit question was not answered. Andy and Stellah only commented on the question without further discussion. Andy said that “she re-asked the question.” Similarly, Stellah said, “So she repeats their answer back to them in a different way, that way for more clarification on their answer.” These two participants do not provide evidence that they understand the question to challenge student ideas connects students to the scientific principle.

Two other participants, Ally and Payton, noticed the teacher posed the question to challenge student ideas. Ally said, “So she is asking them to make some sort of connection, what are you noticing between the low pressure and high pressure fronts, so make a connection.” Ally’s comment showed evidence that she understood a question to challenge student ideas was posed to have students make a connection to the scientific concepts in the class discussion. Payton simply stated, “She is continuously asking about what patterns they notice”, but did not expand on her comment. Asking students to notice a pattern is pushing students to make a new connection, therefore Payton also exhibits evidence that question to challenge student ideas elicit a deeper understanding to make a new connection with the scientific principle.

Noticing the question to challenge student ideas went unanswered by the students, Brock, John, and Keith all made suggestions for questioning. Brock said, “She needs to ask some different questions, she is not getting responses from students.” John suggested, “I would like this more if they were in twos or threes and trying to figure things out for themselves, to bounce ideas off.” Keith noticed “she did a little guiding questioning,” and suggested, “I would think that that should have started the system”

As the lesson progressed, the teacher utilized three balloons to illustrate warm, cold, and cooler air masses on a map displayed in the front of the room to explain the science concept to the students. Table 13 displays the US1 Weather video teacher reformulated the questions. The leading questions are not used to connect students to the scientific principle (see Appendix B).

Table 13 *US1 weather excerpt leading questions*

07:25 [teacher]	Here's the warm air. Here's the cold air. Here's the cool air. You see the hole in-between the three?
07:32 [student]	Yeah.
07:33 [teacher]	There's your low pressure center. It's where those big bubbles of air have a depression, or an area, or gap, that space.
07:42 [teacher]	That's the low. See? Yeah.
07:45 [student]	Yeah.
07:46 [teacher]	Ah, that's what you 're looking at. You're looking at the bubble of warm air, the bubble of cold air behind
07:46 [teacher]	Here's the front right here, right? The front of the air mass, Yes?
07:57 [teacher]	And then where they all meet up, where these bubbles of air meet up, that's where that low pressure center comes in
08:03 [teacher]	The high pressure is going to be this big bubble of cold air at the very highest point of it as far as pressure goes
08:14 [teacher]	It's not gonna ever have a front because it occurs in like in the middle of the air mass, Okay?
08:20 [student]	Okay.
08:20 [teacher]	Get it?
08:21 [student]	Yeah.
08:21 [teacher]	Ooh. Yes?

Payton, Stellah, and Ally noticed the reformulated leading questions posed by the US1 Weather video teacher and how the questions did not connect students to the scientific principle. Payton said, "I just noticed she said, OK, get it? But, that is not adequately assessing whether or not they actually understand, not for everybody, maybe from the ones she got a response from but …I was thinking that anyway that is something we sometimes do in the classroom to kids, un huh get it?" Stellah discussed the teacher questions and body movements,

> So the questions are confirmations of what they should have figured out on their own and what they kind of went through as a class. So "get it?" and then "do you see?" it's not really a question but that corresponds to nodding their heads and "Ok, we are going to move on and explain. She asks a lot of questions with her eyes and her head without, she stops and kind of moves her head and the students respond with "yes, I understand". That's pretty good.

Payton, Ally, and Stellah noticed the teacher elicited student agreement.

In the critical incident interview, Stellah commented further, "So that wasn't even verbally asking questions but the kids knew they needed to respond when she said 'Ok? Right?' And students would respond 'yes'."

John and Keith noticed the questions were not questions to challenge student ideas and offered suggestions. John stated, "She asks a lot of leading questions, too. I think we all do it, but I maybe try to through them in the wrong direction just to make them think." He suggested, "You've gotta make them think." Keith noticed the teacher did not ask questions to challenge student ideas and offered a suggestion when he said, "She is asking really basic recall questions she is not asking them understanding questions and it could have been easy she could have asked them what convection is and they would have had to explain, which is what high order is, and what does this mean?"

Oh the other hand, Ally and Andy misjudged the student reactions to the reformulated leading questions and incorrectly noticed the students made a connection to the scientific principle. Ally gave evidence that the US1 Weather video teacher posed questions she immediately answered, "So she is giving them information and asks 'did you notice that? Do you see what I see?' even though they didn't come to that conclusion." But, she also thought the students made the connection to the science concept when she said, “So she uses a visual aid to make the connection with the students, between the pressure low and high, Ahhh so they all got it.” The teacher made the connection for the students.

Similarly, Andy did not notice the reformulated leading questions and that all students did not make the connection to the science principle. Andy showed this misjudgment with his comment,

> Ok, now they finally figured out the low pressure center [teacher told them] and all the students are definitely in agreement or seem to be in agreement [you see the teacher and the back of two students heads, one student nods when she says “get it” while nodding her head, and the other student just looks, you cannot see any other students but hear a few].

Andy did not notice that the teacher told students the answer to the question and that only one of the two students that are visible nodded his head. Andy continued with this misjudgment, “Now she just reinforced the same thing again, kids are definitely giving the oohs and ahs, it is making sense [teacher doing the oohs and ahs (section 08:21)].

In summary, four participants noticed the questions asked by the US1 Weather video teacher were not questions to challenge student ideas. Payton and Stellah noticed the questions were leading questions that provoked student agreement. John and Keith noticed the questions were leading and recall questions, respectively, and offered suggestion for student thinking. Four of the seven participants noticed the leading questions the committee of experts identified as important for the participants to notice. First-year teachers were more likely to notice the leading questions. Ally and Andy, also first-year teachers, misjudged the conversation between the teacher and students and stated the students had made the connection to the scientific principle.

Brock merely made the statement, “Students are giving verbal responses in unison to try to understand.”

The evidence that participants attended to student connection to the scientific principle through teacher questions to challenge student ideas consisted of one participant who noticed student construction of new vocabulary terms, three participants who noticed student use of new vocabulary and all seven participants who noticed at least one challenge question connected a student to the scientific principle.

Research Question 3

What patterns emerge from novice secondary science teachers' thinking about the role of questioning during instruction?

Concise Findings

1. Five participants noticed the classroom culture in the classroom video excerpts. Two participants noticed that teacher questions can build student confidence. Four participants noticed teacher demeanor, and two participants noticed class diversity. First-year teachers were more likely to notice classroom culture than the more experienced teachers.
2. Two participants, Payton and Brock, shifted attention from the attention to student ideas to not attending to student ideas according to the language used in the teacher evaluation system used in their school district. The more experienced teachers were more likely to shift their attention and to learn from the video.
3. One participant learned as they viewed the U S4 Rocks video excerpt. Payton was a more experience teacher who learned from the video.
4. The participants teaching experience did affect some aspects of the sophistication of their think aloud protocols.
5. The participants' relative knowledge of the science content did not affect the sophistication of their think aloud protocols.

Table 14 *Participant attention to the role of questioning during instruction*

Participants	Teaching experience	Rock content knowledge	Weather content knowledge	Class culture			Participant shift in thinking	Participant learning
				Student confidence	Teacher demeanor	Student diversity		
Stellah	6-12 months	Slight	Slight	√	√			
Keith	6-12 months	Slight	Somewhat	√	√			
Ally	6-12 months	Somewhat	Somewhat			√		
John	6-12 months	Moderate	Moderate		√	√		
Andy	12-18 months	Slight	Slight					
Payton	18-36 months	Slight	Slight		√		√	√
Brock	18-36 months	Somewhat	Somewhat				√	

Class Culture

Other factors emerged from the protocol analysis of the video think aloud participants noticed: Student confidence gained through teacher questions, teacher demeanor, and lack of student diversity. Two participants attended to student confidence through teacher questions. Four participants revealed their attention to teacher demeanor and two participants noticed the lack of student diversity, in one of the classroom video excerpts. First-year teachers were much more likely to attend to aspects of classroom culture.

Student Confidence

Two participants, Stellah and Keith, commented on the US4 Rock video teacher building confidence in students. This data was not noted by the expert committee when reviewing the videos and was unexpected findings. I will first present Stellah's statements about student confidence and follow with Keith's statement about student self-efficacy.

Stellah

Stellah commented in her thinking that students would gain confidence from the teacher interactions with the students in the US 4 Rock video excerpt. When the teacher asked students how they would be able to spot sedimentary rock (00:00:43-00:01:15 elapsed time), a student replied that there must be deposition. The teacher replied that was certainly how sedimentary rock was made and restated the question. Stellah said, “So her answer is wrong and he told her it was wrong in a very nice way but he said good because it was something they all needed to know. So she will still have confidence to answer a question again.” Stellah supported her thinking in the critical debrief and tied student confidence to teacher questioning when she said, “so I think they are confident to talk because he does ask a lot of how do you think, or what do you think.” Stellah’s comment about student constructed definitions also supports evidence to noticing student confidence from teacher questioning, “Constructing the definitions backwards, that’s motivating and helps with confidence; you know that’s a hard word – but I already know what it means; those kids seemed happy in that class.”

Keith

Keith also noticed the US4 Rock video teacher building student confidence. He stated, “And even though he is not giving correct answers right away, he is not making students feel wrong, he is allowing the students to feel good about themselves in answering the questions, and he is reinforcing the students’ correct answers.”

Stellah and Keith both suggested that teacher interactions with students can improve student confidence.

Teacher Demeanor

John was the only participant to comment on the teacher demeanor in the weather video excerpts. John commented on the teacher's demeanor, "I don't like how she talks to the kids necessarily, you have to be a little kinder, more patient than that." He also stated, "I still just don't like her demeanor, she is still kind of condescending." John also noticed possible teacher bias, "Ah, there's one, he has his hand up, he is adorable, oh she is not calling on him though, I don't know if she hates him because he is red headed or if she is using wait time. Ah, she is using wait time."

Three participants commented on the rock video teacher's demeanor, Payton Keith, and Stellah in the US4 Rocks video excerpt. Payton commented once on the patience of the teacher, "He seems to be very patient in guiding them to the answer." Keith and Stellah both commented on the teacher support to student responses. Keith said, "He is not crushing the students' responses" and "even though he is not giving correct answers right away, he is not making students feel wrong, he is allowing the students to feel good about themselves in answering the questions."

Similarly, Stellah talked about the teacher building student confidence. This was discussed in the previous section on building confidence. An example of Stellah's comments was, "…I think they are confident to talk because he does ask a lot of how do you think or what do you think." Stellah also noticed the teacher called on students that did not raise their hands, "so you have to be paying attention to the questions he is asking and the information he is talking about." Stellah commented while viewing the video about how the teacher reminds students of what they know and supported this notion in her critical incident debrief, “reminding them we know this, we know this you guys already know this”. Stellah discussed how students are not afraid to answer questions in this class because the teacher uses student answers in meaningful ways, “nobody is giving up on answering questions, which is tough to do, usually kids quit after being wrong a couple of times, but he keeps taking his wrong answers and rephrasing.” She says, “…he uses their wrong answers in meaningful ways.”

Four participants noticed the teacher demeanor in the video excerpts. This is another factor that was not discussed by the expert committee. Evidence is captured in the think aloud that three participants noticed the rock video teacher displayed patience and a good rapport with his students. Evidence is also noted from one participant that the weather video teacher was condescending to her students and may have presented some student bias.

Student Diversity

Two participants made a comment about the student diversity in the US4 Rocks video. Ally’s first comment in the think aloud was, “Right off the bat, this teacher does not teach in a very diverse classroom, most of them look African American so that is right off the bat. I don’t see another student of a different ethnicity in the classroom.” John also referred to the same classroom with, “Interesting student composition”. Both participants noticed the uniform student composition in the classroom. The other five participants did not make any comments about student diversity.

Participant Shift in Thinking

During the think aloud activity, two participants, Payton and Brock, shifted attention back and forth between attention to student ideas and language used in the teacher evaluation system used in their school district. Both participants were more experienced teachers.

Brock used the term “feedback” in the US1 Weather video (sections 03:11 – 3:55), “She is not really giving much feedback to her students at all,” and “I think some guiding questions might help a little and get some feedback from students.” This is also the same time he notices the teacher is waiting for answers from students and uses the language “wait time”, “She is practicing wait time to try and get more students involved.” Brock then shifts his thinking to what the students are thinking, although he still talks about student “response”. Brock said “Again, asking the same question and not getting any response from students.” Brock noticed further student thinking in his statements, “Ok, she is asking a different question, trying to work on that to figure out the difference,” and when he said, “So a student is volunteering an answer he thinks and she is having him expand on his answer.”

Payton also used language that corresponded to the teacher evaluation system used in her school district. Payton shifted her thinking back and forth between attention to the teacher evaluation language and student thinking throughout the US4 Rocks video excerpt. An example was her first comment using the terms “feedback” and “academic vocabulary.” Payton said, “He’s giving, he asked a question and gives feedback that I like how he is using academic vocabulary and I like how the student just answered the question with academic vocabulary.” Payton added, “Gave them positive feedback.” Payton then shifted to attention to student thinking when she noticed, “He is asking probing questions.” Payton continued to attend to student thinking when her next few statements showed she noticed the challenging question posed, “He is asking them challenge questions like “how do you know it is stuck together?” and how the question elicited student understanding of science vocabulary, “Challenge questions try to give vocab that um content specific vocab.” Then Payton shifted her thinking back to the language that corresponded to the teacher evaluation system again, “He is giving the students positive feedback, it seems he has a good report with the students and they are really engaged.”

This is different from another participant, Andy, who attended to student thinking in his explanations of the teacher questions with the use of the language that corresponded to the teacher evaluation system used in his school district consistently throughout both videos. Andy used the terms, “feedback”, “praise”, “wait time,” “higher order questions”, “If/then questions”, “engaged” and “rhetorical questions” several times throughout both video excerpts.

Both participants shifted their thinking from attention to student thinking to language that corresponded to the teacher evaluation system used in the school districts where the participants are employed.

Participant Learning

One participant learned as she viewed the US4 Rocks video excerpt. Payton showed evidence that she learned from the US4 Rocks video excerpt. In the think aloud protocol, Payton talked about teacher and student use of academic vocabulary several times. At the beginning of the think aloud Payton said, “He’s giving, he asked a question and gives feedback that I like how he is using academic vocabulary and I like how the student just answered the question with academic vocabulary. The question was a question to elicit student ideas and prior knowledge from the previous day's lesson on sedimentary rocks. The student answered the question using the term "deposition". When the teacher drew diagrams on the board and showed models and visuals to attend to student understanding, Payton said, "More modeling, more drawing as he is speaking, I like how he is doing that to visualize what he is saying." When students and the teacher discussed the difference between the terms lava and magma, Payton commented, "I am really impressed the students are using their academic vocabulary answering questions." At many points in the think aloud, I encouraged Payton to keep talking by asking "what are you thinking?" Payton replied during one instance, "I am thinking about what type of question he is using right now. I like how he is drawing and modeling, I am kind of engaged in what he is saying." In answering this question again late in the video excerpt, Payton summarized her engagement in the US4 Rocks video excerpt by saying, "Um…I am thinking, I am learning much more through this video than the previous." When the think aloud time allowance ended, Payton asked to continue to watch the video in its entirety, in which she did complete watching the video.

Evidence from Payton's comments in the US4 Rock video excerpt displayed data that Payton learned from the video excerpts. Payton was a more experienced teacher.

Participant Teaching Experience

The participants teaching experience did affect some aspects of the sophistication of their think aloud protocols. This data was captured at the beginning of the study in a survey. Teachers with more experience showed naïve understanding of the purpose of questions to elicit student ideas and attended to student thinking more than teachers with less experience. Of the four first-year teachers, only two showed understandings of questions to elicit student ideas. Of the second- and third-year teachers, they all showed understanding. However, participants lacked of detailed purpose of the questions and student thinking about the questions. Teachers with more experience were more likely to learn from the video and shift their attention from student thinking to aspects of classroom culture. Teachers with more experience also were more likely to attend to feedback and praise, while teachers with less experience referred to questions as "lower- and higher-order" questions. First-year teachers were more likely to notice class culture than the more experience teachers

Participant Subject Matter Knowledge

Data did not show any effect on the participant think aloud protocols due to number of years teaching or relative science content knowledge. This data was captured at the beginning of the study in a survey. Even though participants held bachelor degrees in science fields, the critical incident debrief revealed little variance in participant knowledge about the concept of weather and the concept of rocks. One participant, John, said he taught these topics in his middle school science classroom, but his think aloud protocol did not reveal he attended to student thinking about the topics any more than other participants. Most participants did not have formal coursework on the topic of weather and rocks and only remembered a few weather symbols, if any, and little detail on the topic of high and low pressure systems and sedimentary, igneous, and metamorphic rocks.

Summary

This chapter was organized to address each of the research questions which guided this study. Data were analyzed to determine novice secondary science teachers' understanding of the purpose of teachers' questions and the appropriateness of questioning strategies for facilitating student learning. The first research question presented the factors participants attended in the think aloud protocols: student thinking through teacher questions, connection between teacher questions and student thinking, communication patterns, and teacher instruction. The second research questions presented data that supported participants attended to student thinking through their understanding that challenge questions connect to a scientific principle. The third research question presented four emergent themes. Classroom Culture, Shifts in teacher instruction from attention to student thinking to the language of the teacher evaluation system in the participant school district, participant learning from the think aloud video excerpts and no effect of participant teaching experience and relative knowledge of the science content in their think aloud protocols. Discussion of these findings, conclusions, and recommendations for future research are provided in Chapter 5.

CHAPTER FIVE: CONCLUSION AND DISCUSSION

Introduction

The purpose of this study was to determine novice secondary science teachers' thinking about the relationship between student thinking and teacher questioning strategies. This chapter contains a report on the analysis of the data obtained from the protocol analysis, critical incident debriefings, and field notes. Information for the participants on their teaching experience and subject matter knowledge were reported.

The results of this study were intended to inform secondary science pedagogy faculty of novice teacher thinking about the relationship between teacher questions and student thinking. This chapter includes a discussion of the findings of this study and recommendations for practice. Also included are additional questions for future research that may impact secondary science programs.

Research Question 1

What factors do novice secondary science teachers' attend to in the instructional environment when considering the effectiveness of a questioning strategy?

Concise Findings

1. Attention to student thinking. One participant, Stellah, elaborated on student thinking in both video excerpts.
2. Three participants noticed the questions to elicit student ideas reviewed the previous lesson in the rock video excerpt. Five participants attended to student thinking with their understanding of questions to elicit student ideas. Teachers with more experience showed understanding and attended to student thinking in questions to elicit student ideas more than first-year teachers.
3. All participants showed understanding of questions to probe student ideas. Six participants attended to student thinking with their understanding of questions to probe student ideas. One participant consistently identified each question type by the language taught in the science methods course. There were no noticeable differences between first-year teachers and more experienced teachers.
4. Attention to communication patterns. Three participants noticed the communication patterns between the teacher and students.

5. Attention to teacher instruction. All participants paid attention to teacher instruction, especially wait time and student engagement. Teachers with more experience showed attention to feedback and praise. One first- and one second-year teacher referred to the questions as “lower-order” and “higher-order” questions. Teachers with little teaching experience are more likely to refer to questions as “lower-“and “higher-order” questions.

Research Question 2

How do novice secondary science teachers’ connect teachers’ questions to the scientific principle?

Concise Findings

1. One participant, Stellah, attended to student thinking in her understanding that questions that challenge student ideas push students construct new vocabulary.
2. Three participants attended student thinking through their understanding that questions to challenge student ideas push students to use new vocabulary. First-year teachers were slightly more likely to notice student use and construction of vocabulary.

3. All seven participants attended to student thinking through their understanding that questions to challenge student ideas guide students to make a new connection to a scientific principle.
4. Two participants, both first-year teachers, misjudged student connection to the scientific.

Research Question 3

What patterns emerge from novice secondary science teachers' thinking about the role of questioning during instruction?

Concise Findings

1. Five participants noticed the classroom culture in the classroom video excerpts. Two participants noticed that teacher questions can build student confidence. Four participants noticed teacher demeanor, and two participants noticed class diversity.
2. Two participants, Payton and Brock, shifted attention from the attention to student ideas to not attending to student ideas according to the language used in the teacher evaluation system used in their school district.
3. One participant learned as they viewed the US4 Rocks video excerpt.
4. The participants teaching experience did affect some aspects of the sophistication of their think aloud protocols.

5. The participants' relative knowledge of the science content did not affect the sophistication of their think aloud protocols.

Discussion of Findings

Teacher attention is shaped by reform priorities, standards and assessments, local professional communities, and institutionalized norms of student and teacher relationships. Some researchers have posited a developmental trajectory for teachers and I am still seeing some evidence that the more experienced teachers were able to notice a few things more than the novice teachers. This study suggests novice teachers learning is framed by the priorities of the public school system. All participants attended to teacher instruction, especially wait time and student engagement. Participants also focused on feedback, praise, and higher- and lower-order questions. Although one participant elaborated on student thinking, and participants were able to attend to student thinking at a naïve level, most participants focused on instructional delivery using the language of the teacher evaluation system. School culture and the way teachers are now assessed may scaffold and support these teachers to have a more nuanced and sophisticated understanding of questioning and student thinking than has previously been reported for novice/beginning teachers. While some aspects of school culture and assessment may be problematic- e.g. wait time, feedback, praise, higher-order questions, etc.-on the whole it seems to be leading them in the right direction.

An interpretation of the results regarding the participants' attention to student thinking indicated one participant, Stellah, elaborated on student thinking in both video excerpts. This was surprising because she was one of the least experienced teachers in the sample. One participant, Payton who was a more experienced teacher, consistently identified each question type by the language taught in the science methods course.

These findings were similar to the findings of previous researchers (Levin, 2008; Levin, Hammer, & Coffey, 2009) that novice teachers can attend to student thinking early in their teaching and that teachers will more likely attend to student thinking if the focus of student thinking is taught in pedagogy courses (Levin, 2008; Levin, Hammer, & Coffey, 2009) or in a professional development program (Roth, Garnier, Chen, Lemmens, Schwille, & Wickler, 2011). The participants in this study were also provided the procedural knowledge to attend to student thinking with questions to elicit, probe, and challenge student ideas, but it was not determined the participants learned these understandings in the pedagogy course.

Levin and his colleagues (2008, 2009) found eight of nine novice science teacher participants were successful at attending to student thinking by reflecting ideas back to the class, and in asking students to repeat or elaborate on their ideas. In the present study, all seven participants attended to student thinking by noticing questions to probe and challenge student ideas had students expand on their ideas and connect their understanding to the science concepts.

Roth and her colleagues found that in-service fourth, fifth, and sixth grade teachers implemented a beginning level of attention to student thinking by using more probing and challenging questions to engage students in reasoning about their data. Participants were also challenged to apply new ideas in different contexts and to make connections through synthesizing and summarizing after learning how to reveal, support and challenge student thinking through questions that elicit, probe, and challenge student ideas.

In this study, the use of think aloud methods allowed me to see more direct evidence of participant understanding of questioning in science class. I was able to notice that participants' understood more and less than may have been captured by other research methods. They seemed to understand more because I was able to attend to their thinking about the purposes of the questions in the video excerpts. Participants in this study showed understanding that questions needed to make students think, inductively construct new vocabulary terms, use new vocabulary terms in a meaningful way, build student confidence, probe student ideas, and make connections to the scientific principle. These abilities have not been reported in prior research (Roth, et. al.; Levin, 2008; Levin, Hammer, & Coffey, 2009). I was also able to see they understood less. This study's findings showed participants with more teaching experience noticed the questions to elicit student ideas, but the level of attention to student thinking about the question was naïve. This was shown by the participants' ritualistic attention to student thinking by noticing and discussing the teacher questions in the video excerpts would lead to responses and thinking from the students, but participants did not show understanding of the purposes of the questions in a deep way. Often they would be able to identify the question types and sometimes comment on the purpose of the questions, but deep understanding of the purpose of the questions and attention to student thinking about the questions was lacking. Participants showed they understood the general purposes of the questions, but they often had a fairly naïve understanding of the pedagogical purpose of the questions. This was especially true of the questions to elicit student ideas. For example, participants knew the question purpose was to elicit a variety of answers from many students and participants commented that students responded, but student thinking about the questions were not discussed. Five out of seven participants noticed the purpose of questions to elicit student ideas and three out of seven participants noticed the question reviewed the previous lesson in the rock video excerpt. This was an interesting finding because Roth and colleagues (2011) found that their teachers improved on all student thinking strategies except time spent on eliciting student ideas.

The think aloud used in this study provided insight into what the participants were thinking about questions to challenge student thinking and provided data about the decision process. All novice participants understood the purpose of making connections to the science principle or to use new vocabulary in a meaningful way. Similar results were found by Roth and her colleagues (2011). But, the think aloud methods in this study revealed some participant thinking about the purposes of the questions to challenge student ideas in a naïve way. In some instances, participants would use terms consistent with questions to challenge student ideas to describe the teacher question. Examples were comments that the teacher had students make a connection, or comments that showed participants noticed the students were making a connection. In other instances participants were correct in identifying the question type and purpose, and also noted the students reacted to the question. In this case, participants did not discuss the substance of the student responses that the question intended to evoke. Additionally, two participants, first-year teachers, showed understanding of the question purposes in the rock video excerpt also misjudged student understanding of the question to challenge student ideas in the weather video excerpt.

In contrast to the studies above, more detailed attention to student thinking was revealed in the analysis of one participant's think aloud and critical incident interview. According to Berliner's stage model of teacher development, Stellah would be a competent teacher who can determine what is and what is not important. Stellah was a teacher with 6-12 months experience who showed consistent understanding of the purposes of questions to elicit, probe, and challenge student ideas, as well as elaborated on student thinking about the questions. Stellah also did not attend to classroom management or terms such as “praise”, “feedback”, and “higher-order questions”. Berliner (1988) discussed the general theory of stages (Dreyfus & Dreyfus, 1986) as teacher’s progress from novice to expert teachers. This model predicts that novice teachers will be able to attend to tasks such as “give praise for right answers”, “wait time”, “higher order questions”, and “feedback”, as well as attend to classroom management. As they progress to the second stage, advanced beginner, the teachers will begin to conform to whatever rules they are taught to follow. Similar to Berliner’s findings, all of the participants in this study attended to wait time and some participants used the terms “feedback”, “praise”, and “higher-order questions”, but in contrast, this study’s data showed participants did not discuss classroom management or see questioning as a means of classroom management. In addition, participants who had more teaching experience, 18-36 months, used the terms “praise” and “feedback”. All of these findings might be influenced by the teacher education model, which is a good thing. However, participant reference to higher-order questions may be challenged to learn how questions are categorized into higher- and lower-order question categories such as Bloom’s taxonomy.

Instead of school culture leading teachers to less sophisticated practices and understandings, the data in this study strongly suggest that the participants’ school culture and the ways participants are now being assessed may actually be supporting them a bit. This data also provides evidence that participants' attention is shaped by reform priorities, standards and assessments, local professional communities, and institutionalized norms of student and teacher relationships which may create barriers for teacher learning (McNeil, 1986). But in contrast to prior research, these influences may be positive or developmentally supportive. The think aloud methods in this study revealed participant use of vocabulary terms "wait time", "praise", "feedback", student engagement, and "higher-order questions". These parts of instruction were emphasized by the participants correspond to the participant teacher evaluation system in quality of instruction (Berliner, 1988; Danielson, 2007; Marzano, 2007). These findings also support the argument that a number of researchers have argued that teacher attention is largely organized by aspects of educational institutions (Jenkins, 2000; Rop, 2002; Settlage & Meadows, 2002).

Focusing on engagement of students in their school evaluation system (Danielson, 2007; Marzano, 2007), most participants were aware of engaging students and saw how the teacher's questioning can either support or fail to support engagement. While they may have a nuanced vocabulary of different question types as seen in Bloom's revised taxonomy (Krathwohl, 2002), such as asking higher-order questions, they did at least see the importance of asking "higher-order" questions.

Implications for Future Research and Practical Implications

The use of a think-aloud technique as an approach to capture teacher thinking about student thinking in science has not been fully explored in science education. This study used think aloud methodology to capture teacher thinking about questions that will elicit student ideas, probe students for a better understanding of their ideas, and challenge students to connect new ideas and understandings that will help students make the connections to the scientific principle through socially constructed science discourse. The analysis showed the value of directly examining participants' understanding of the relationship between questioning and student thinking using protocol analysis. The use of think aloud methods allowed the insight into participant decision making about teacher questions and student thinking. The detail of Stellah's thinking showed the think aloud was an effective method in determining what participants were thinking about the questions.

Few studies offer findings indicating that thinking aloud is appropriate for capturing teacher thinking about science classroom practice. Given all novice teachers have a need for attending to student thinking as a component of effective teaching, it would follow that using think aloud as a method of instruction may be an effective way of teaching pre-service teacher candidates how to attend to student thinking in pedagogy courses. This method is already widely used in reading (Baumann, Jones & Seifert-Kessell, 1993; Davey, 1983; Wade, 1990). Davey and Wade used think aloud methodology to determine strategies needed for students weak in comprehension. Bauman and colleagues used the think aloud methodology to determine which reading strategies students use, monitor and control their own comprehension processes to add strategies to their instructional model for verifying, retelling, rereading and clarifying meaning in reading. The think aloud technique would also be useful in comparing novice secondary science teacher's attention to student thinking to expert secondary science teacher's attention to student thinking.

All seven participants in this study showed evidence of attending to teacher questions. But the attention the participants paid to student thinking was not constant. Shifts in two participant's attention were closely associated with shifts in framing of interactions. In particular, we may need to help novice teachers be concerned with the interactive nature of socially constructed science understandings of the scientific principles through science discourse (Scott, 1998; Vygotsky, 1978).

A future study for teacher candidates to develop a lesson to pose questions to elicit, probe, and challenge student ideas to students in the virtual classroom, track the questions asked and student responses for analyzing, correcting, and re-teaching would provide the experiences needed that will help them understand how students think (NRC, 2012). A think aloud may be useful when participants are analyzing the transcripts from the virtual classroom experience to capture their thinking about student ideas.

Research following the participants in this study would be of interest to see how they continue to develop. Future cohorts of the RTP[3] program with teacher candidates and novice teachers from our other programs will give further insights into teacher thinking about questions to elicit, probe, and challenge student ideas.

This study has some practical implications for how teacher educators teach novice teachers in the science education pedagogy course. Also, this study demonstrated the use of think-aloud as an instructional strategy was useful in the desire to improve questioning strategies to attend to student thinking in novice secondary science teachers, but what teachers noticed in the videos may or may not be direct evidence of what they do or are able to do in their own classrooms.

Conclusion

This study described novice secondary science teachers' thinking about the purpose of teachers' questions and the appropriateness of questioning strategies for facilitating student learning. Although one participant elaborated on student thinking, and participants were able to attend to student thinking at a naïve level, most participants focused on instructional delivery using the language of the teacher evaluation system. School culture and teacher assessment may support teachers to have a more refined understanding of questioning and student thinking than has previously been reported for novice/beginning teachers. School culture and assessment seems to be leading them in the right direction.

APPENDIX A: PROTOCOL INSTRUCTIONS

THINK ALOUD PROTOCOL INSTRUCTIONS

In this study I am interested in what you are thinking as you watch and listen to the classroom videos with attention to teacher questions. In order to do this, I am going to ask you to "THINK ALOUD" as you watch the videos. What I mean by think aloud is that I want you to tell me EVERYTHING that you are thinking from the beginning of the video to the end of the video. I would like you to talk aloud CONSTANTLY from the time you begin the video until the end of the video. I do not want you to feel as if you have to plan what you are going to say or that you have to explain what you have said. Act as if I am not in the room and you are here speaking out loud and viewing the videos by yourself. It is important that you keep talking at all times. If you are silent for a length of time, I will prompt you to keep talking. Do you understand what I have asked of you?

Good.

Now let's begin by practicing on a sample video clip. Remember to think aloud as you view the video. Pay attention to the kinds of questions the teacher asks and the verbal and nonverbal responses of the students. I don't want you to plan out what you say or try to explain to me what you are saying. Just act as if you are alone in the room speaking to yourself. Tell me everything that you are thinking from the moment you begin viewing the video clip. Good.

Now I want to hear how much you can remember about what you were just thinking from the time you viewed the video clip until the video ended. I am interested I what you can actually REMEMBER rather than what you think you must have thought. If possible, I would like you to tell about your memories in the sequence as they happened while you were viewing the video clip. Please tell me if you are uncertain about any of your memories. I don't want you to explain, just report all you can remember thinking about when viewing the video clip. Now, tell me what you remember. Good.

Now I will give you one more practice video clip before we proceed to the main activity. I want you to do the same thing for this video clip as you just did. I don't want you to plan out what you say or try to explain to me what you are saying. Just act as if you are alone in the room speaking to yourself. I want you to think aloud as before as you pay attention to the kinds of questions the teacher asks and the verbal and nonverbal responses of the students, I will ask you to report all that you can remember about your thinking. Any questions? Here is your next video clip. Good.

Now I want to hear how much you can remember about what you were just thinking from the time you viewed the video clip until the video clip ended. I am interested in what you can actually REMEMBER rather than what you think you must have thought. If possible, I would like you to tell about your memories in the sequence they happened while you were viewing the video. Please tell me if you are uncertain about any of your memories. I don't want you to retell the video, just report all you can remember thinking about when viewing the video clip. Now, tell me what you remember. Good.

Now we are ready to move onto the videos. During each video, you will continue to use the same protocol as you did for your two sample videos. Pay attention to the kinds of questions the teacher asks and the verbal and nonverbal responses of the students. Tell me everything that you are thinking from the moment you begin viewing the video. As you think aloud, please feel free to write on the transcripts. When you finish with one video, I may ask you to remember what you were thinking while viewing the video. If I am not going to ask you this, I will simply tell you to view the second video. This will be your cue to view the second video. Remember to think aloud as you view the video. Tell me everything that you are thinking and doing from the moment you first begin viewing the video.

APPENDIX B: BSCS STeLLA STRATEGIES

BSCS

A SCIENCE EDUCATION CURRICULUM STUDY

Strategies to Reveal, Support, and Challenge Student Thinking

STeLLA STRATEGY 1

ASK QUESTIONS TO ELICIT STUDENT IDEAS AND PREDICTIONS

Student thinking will be revealed by questions and activities that elicit students' prior knowledge, experiences, and predictions relevant to the learning goal. Before studying about food webs or the ways the surface of Earth changes, how are students already thinking about the occasions in their daily lives when they encounter plants and animals, rivers and streams, and the erosion of soil? What are their personal theories about how plants get their food, how a bird gets the energy to fly, and how mountains are formed? What do students predict will happen to matter when it decomposes? What do they think about why the surface of Earth has such variations-high places, low places, flat places, river valleys?

A question or activity designed to elicit students' initial ideas and predictions is addressed to multiple students (the whole class or a small group) and results in a variety of different student ideas, rather than one "right answer." The goal of these questions/activities is to learn about students' prior knowledge, misconceptions, experiences, and ways of making sense-whether their ideas are scientifically accurate or not. The more you can understand how students are thinking about science phenomena and ideas, the better you can adapt your instruction in future lessons to challenge their misconceptions and to support them in changing their ideas toward more scientific, evidence-based understandings.

Questions that elicit student thinking also play a role in engaging students in the topic of study-helping them to see the links between their own ideas and the science they will learn in the lesson. Students are also able to see that different people have different ideas. This sets up a "need" to find out which ideas are best.

Predictions can often be used effectively to elicit students' initial ideas. You'll want to take note of these ideas as they can *later* be challenged by the use of a "discrepant event." A discrepant event is an observation or piece of information that does not match a student's prediction. For example, students may predict that seeds will not grow in the dark. Observing seeds germinating in the dark is a discrepant event that challenges students to rethink their ideas. You'll learn more about questions that challenge student thinking when you study STeLLA Student Thinking Lens Strategy 3.

Questions that elicit student ideas should be phrased in everyday language that will make sense to the students, even before they begin a unit of study. If the teacher asks, "What do you think photosynthesis is?," most students will have nothing to contribute. In contrast many students will be able to respond to a question that asks, "How do you think this plant gets its food?" It is best to avoid using scientific terminology when eliciting student ideas. Instead, think of an everyday connection and everyday words that students can explore.

When used?

Used when a new idea is going to be introduced (often at the beginning of a unit or lesson)

Used to set up a "discrepant event" at any point in the unit of study

Teacher response to student ideas

- Make it clear to students that you are not going to tell which ideas are right or wrong at this point. Give your reasons for this. Students will remain confused if they are unclear about which ideas they are hearing from their peers are "right" from a scientist's perspective and which ideas are just interesting ideas. For example, you might say,

  - "Right now, we are just getting out our ideas. For now, these are just our predictions about _____. Later, we will gather some evidence to see if we can support or challenge any of our predictions."
  - "As you listen to different ideas, think about which ideas you agree with and which you do not agree with. Think about your reasons. Do you have evidence to support your idea? Do you have evidence to challenge someone else's idea?"

- Ask questions to gain more understanding of how students are thinking.

Examples of questions that elicit a variety of student ideas

About food webs

- Do we need the sun in order to get our food?
- How do you think plants get their food?
- Do plants need energy to grow? If so, how do they get their energy?
- Where does a bird get the energy to fly?
- If a squirrel dies in the forest and is not eaten by another animal, what eventually happens to its body? How does that happen?
- How does a tiny seed turn into a huge tree?

What happens to all the dead leaves that fall off the trees in a forest?

BSCS

A SCIENCE EDUCATION CURRICULUM STUDY

Strategies to Reveal, Support, and Challenge Student Thinking

STeLLA STRATEGY 2

ASK QUESTIONS TO PROBE STUDENT IDEAS AND PREDICTIONS

Throughout the lesson, you, as the teacher, should take every opportunity to ask questions that probe student thinking. These are questions directed to one student who has already provided an answer or offered an idea. The teacher then follows up with this same student to probe his or her thinking. Sometimes a teacher asks a sequence of questions that probe the thinking of the same student before moving on. These questions should not introduce new language or new science ideas; rather the goal is to build on ideas already presented by the student. This probing of an individual student's thinking can take place during whole class discussion, during small group work, or as students work individually.

The purpose of asking probing questions is to get more information about a student's thinking and understanding. It is not designed to teach new ideas or to "lead" students to a correct answer. The question can ask the student to give more information ("Tell me more.") or it can ask a student to clarify his/her thinking ("Did you mean... ?"). Like questions that elicit student ideas, questions that probe student thinking help you learn about students' prior knowledge, misconceptions, experiences, and ways of making sense. The more you can understand how students are thinking about science ideas and phenomena, the better you can adapt your instruction to challenge their misconceptions and to support them in changing their ideas toward more scientific, evidence-based understandings. You have to know what students are thinking in order to challenge and guide their thinking effectively!

Questions that probe a student's thinking are useful for both the teacher and the student. For the teacher, asking questions to probe student thinking allows you to learn more about students' prior knowledge, misconceptions, experiences, and ways of making sense. This will help guide you in making decisions while teaching your lesson(s). But these questions are important for students as well. When asked questions that probe their thinking, students explore, share, and clarify their own ideas. Students also benefit from listening to other students' ideas. Similar to how you want students to listen to others' responses to elicit questions, you want students to listen for ideas that they agree or disagree with and to think about their reasoning.

When used?

Used after a question designed to elicit student ideas and predictions

Used after a question designed to challenge student thinking

Used frequently throughout the lesson

Examples of general questions that probe student thinking

- Tell us more about that.
- What do you mean when you say...?
- Tell me more about how you think that happens.
- So you are saying [paraphrase student response]. Tell me how I'm getting it wrong.
- Tell me how you are thinking about that.

- Can you put that idea into a complete sentence?

Examples of content-specific questions that probe student thinking

About food webs

Scenario: Teacher and students are looking at an aquarium that contains plants and fish.

T: What do you predict will happen to this plant if it dies? (ELICIT)

S: It will fall to the bottom and it might turn into soil.

T: Tell me more about that. (PROBE)

S: The dead plant would decay.

T: What causes the dead plant to decay? (PROBE)

S: It just becomes rotten and then turns into soil.

T: So, you are saying that nothing helps the plant to decay. It decays all by itself? (PROBE)

S: Yes, the dead plant would decay and turn into soil.

BSCS

A SCIENCE EDUCATION CURRICULUM STUDY

Strategies to Reveal, Support, and Challenge Student Thinking

STeLLA STRATEGY 3

ASK QUESTIONS TO CHALLENGE STUDENT THINKING

Throughout the lesson, you, as the teacher, should take every opportunity to ask questions that probe and challenge student thinking. Questions that probe student thinking reveal how students are thinking, without trying to change their thinking. In contrast, questions that challenge student thinking try to help the students change their thinking and develop a deeper understanding of the science ideas. Thus, questions that challenge student thinking are designed to push students to think further, to reconsider their thinking, to make a new connection, and/or to use new science vocabulary.

Learning to ask good challenge questions will take some time and conscious effort. The goal is to get students thinking harder while also scaffolding or guiding their thinking towards more scientific understandings.

Care must be taken to avoid questions or hints that lead students to the "right" answer without challenging them to really think. Such "leading" questions often come in a "fill-in-the-blank" or "yes-no" format, accompanied with hints so that students can frequently guess the right answer.

- Does energy get recycled? (S: Yes) It does?? (S: I mean no.)

- What is underneath the continents and the oceans? (S: the Earth's core) Yes, but something else is closer to the continents. (S: Hmmm) What do you put your food on when you eat dinner? (S: Oh! Plates) What kind of plates? (S: They move.) It starts with a "t." (S: Oh yeah, tectonic plates)

Questions that challenge student thinking do not ask students to simply state a vocabulary term but rather ask them to use science vocabulary and science ideas in a meaningful way. Challenge questions avoid leading directly to the right answer and focus instead on guiding student thinking toward a new concept or deeper understanding. It’s not an easy task for us as teachers to shift our focus from helping students get the right answers ("leading") to challenging students to think, reason, and to develop or clarify their thinking.

When used?

Used anytime during the lesson except when you are trying to elicit students' initial ideas and predictions about a science idea or concept.

Examples of general questions that challenge student thinking

- Add some of the new ideas we've been talking about to your explanation.
- Explain how that happens.
- Why does that happen?
- How does that relate to the ideas we've been studying?

Examples of content-specific questions that challenge student thinking

About food webs

T: When you look at our forest food web, what can you say about the connection between the bird and the snake?

S: The snake eats the bird.

T: Tell me more about that. (PROBE)

S: Well, the bird is food for the snake.

T: Why do you think the arrow points from the bird toward the snake? (CHALLENGE)

S: The arrow shows that the bird gives energy to the snake when the snake eats it.

T: Where did that energy come from? (CHALLENGE)

S: Well, it came from the bird.

T: How did the bird get the energy? (CHALLENGE)

S: From the food that it ate-like seeds and worms.

T: Where did the seeds and worms get the energy?

SN: All the energy originally came from the sun, which the producers used to make food.

T: Ok, so the snake got energy from the bird and that energy originally came from the sun.

What will happen to the energy that the snake gets from the bird? (CHALLENGE)

SN: The energy gets passed on when the snake is eaten by the hawk.

T: Tell me more about that. (PROBE)

SN: I disagree, not all of the energy gets passed on, just some'

T: Who agrees or disagrees? Does the snake pass on all of the energy to the hawk, or just some? Be ready to give a reason for your answer. (CHALLENGE)

APPENDIX C: BSCS PERMISSION

BSCS

A SCIENCE EDUCATION CURRICULUM STUDY

BSCS Permission Form

Request Date:	30 January 2013
Requested By:	Gwynn Crittenden University of Central Florida Science Education Doctoral Student gwyndolyn.crittenden@ucf.edu
Description:	STeLLA Strategies 1, 2, and 3 (elicit, probe, challenge questions)
For Use In:	Requestor's dissertation: for participants in proposed dissertation study to read and learn about elicit, probe, and challenge questions
Use Requirements:	Materials may be used for requestor's dissertation only (one-time use) and may not be published or shown in any other context. Materials must be used as-is and in their entirety. Source (see credit line below) is to be acknowledged in relation to the materials. Requester is to provide an electronic copy of the dissertation materials that include the BSCS materials, emailed to sluce@bscs.org.
Credit Line:	BSCS. (2012, March 30). *STeLLA Strategies 1, Ask Questions to Elicit Student Ideas and Predictions; 2, Ask Questions to Probe Student Ideas and Predictions; and 3 Ask Questions to Challenge Student Thinking*. Materials from *Videocase Lesson Analysis for Improved Teacher Practice*, workshop at NSTA, Indianapolis, IN.

BSCS
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Web Site: www.bscs.org

Signed: Stacey Luce

Stacey Luce
Production Coordinator
31 May 2013

APPENDIX D: IRB APPROVAL

University of Central Florida

University of Central Florida Institutional Review Board
Office of Research & Commercialization
12201 Research Parkway, Suite 501
Orlando, Florida 32826-3246
Telephone: 407-823-2901 or 407-882-2276
www.research.ucf.edu/compliance/irb.html

Approval of Human Research

From: **UCF Institutional Review Board #1**
FWA00000351, IRB00001138

To: **Gwyndolyn Crittenden**:

Date: **May 23, 2013**

Dear Researcher:

On 5/23/2013 the IRB approved the following human participant research until 5/22/2014 inclusive:

Type of Review:	Submission Correction for UCF Initial Review Submission Form Expedited Review
Project Title:	Novice Secondary Science Teachers' Understanding of the Purpose of Teachers' Questions
Investigator:	Gwyndolyn Crittenden
IRB Number:	SBE-13-09406
Funding Agency:	
Grant Title:	
Research ID:	N/A

The scientific merit of the research was considered during the IRB review. The Continuing Review Application must be submitted 30days prior to the expiration date for studies that were previously expedited, and 60 days prior to the expiration date for research that was previously reviewed at a convened meeting. Do not make changes to the study (i.e., protocol, methodology, consent form, personnel, site, etc.) before obtaining IRB approval. A Modification Form **cannot** be used to extend the approval period of a study. All forms may be completed and submitted online at https://iris.research.ucf.edu .

If continuing review approval is not granted before the expiration date of 5/22/2014, approval of this research expires on that date. When you have completed your research, please submit a Study Closure request in iRIS so that IRB records will be accurate.

Use of the approved, stamped consent document(s) is required. The new form supersedes all previous versions, which are now invalid for further use. Only approved investigators (or other approved key study personnel) may solicit consent for research participation. Participants or their representatives must receive a copy of the consent form(s).

In the conduct of this research, you are responsible to follow the requirements of the Investigator Manual.

On behalf of Sophia Dziegielewski, Ph.D., L.C.S.W., UCF IRB Chair, this letter is signed by:

Signature applied by Patria Davis on 05/23/2013 03:40:45 PM EDT

IRB Coordinator

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