PROFESSIONAL DEVELOPMENT PROTOTYPE DESIGN FOR QUESTIONING AND DISCOURSE IN THE SCIENCE CLASSROOM

By

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Abstract

Teacher questioning has historically been an integral part of the learning process in the classroom (Roth, 1996). Teachers ask anywhere from 300 to 400 questions each day (Tienken et al., 2009). Of these, consistently close to 60% of questions asked by teachers in the classroom are factual or recall, 20% are procedural, and only the remaining 20% are higher-order thinking questions (Gall, 1970; Myhill, 2006). This pattern of teacher questioning has not changed despite changes in education standards that emphasize critical thinking and problem solving. A focus on questioning is especially significant in the science classroom. The nature of scientific inquiry offers a unique opportunity where students are constantly asking questions about the world around them. Further, they are encouraged to systematically answer these questions through discussion, evidence, and reasoning (Lustick, 2010). This critical process of scientific inquiry is typically facilitated in the classroom by teacher questioning. However, despite the need for better teacher questioning, teachers face contextual and pedagogical challenges as they attempt to change their questioning practices. The purpose of this mixed methods design study is to investigate teachers' learning needs and design a just-in-time, informal, online professional development prototype for middle school science educators that supports effective questioning practices to facilitate discourse in the inquiry-based science classroom. This was accomplished by utilizing 4 iterative phases of needs assessment, analysis, and design including literature analysis, semi-structured interviews, anonymous surveys, and user-testing. Findings of this study indicate that teachers need learning experiences about questioning practices that are focused on content and provide time for reflection and collaboration. Further, they would like to learn in informal, individual, self-paced environments with an option to engage with others. These findings inform the design of the prototype, The Question Connection

(www.questionconnection.com), as well as the current literature base on professional development, teacher questioning, and scientific inquiry instruction.

Key words: Teacher questioning, science, inquiry, professional development design

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Chapter 1: Introduction

Professional Development Prototype Design for Questioning and Discourse in the Science Classroom

Teacher questioning has historically been an integral part of the learning process in the classroom (Roth, 1996). Dating back to ancient Greeks, and reaching into today with the Socratic method, questioning has endured for its seemingly simple and effective utilization in the classroom (Lustick, 2010; Tienken, Goldberg, & DiRocco, 2009). However, asking questions is a deceptively complex process, resulting in one of the oldest and most misunderstood teaching methods.

Teachers have traditionally engaged in an Initiate-Respond-Evaluate (I-R-E) (Chin, 2006; Forbes & Davis, 2010) or "triadic" (Oliveira, 2010a) sequence of questioning that is teacher to student initiated and directed (Rop, 2002). However, this sequence of questioning and discourse typically results in factual recall and limited critical thinking by the learner. This type of questioning evolved from progressive era reforms. During the progressive era when schooling became mandatory, teachers were suddenly faced with the responsibility of teaching large groups of students (Hoteker & Ahlbrand, 1969). As a result, they relied on more efficient transmission models of teaching where teachers would give recitations about a topic and students would passively listen (King, 1993). However, more recent reform efforts to move education from a passive and individual domain to that of an interactive and social experience have forced educators to reconsider the traditional IRE questioning sequence. The goal of this shift in teacher talk is to move from "teaching by telling" or "questioning to evaluate" (Chin, 2007; Roth, 1996) to more sophisticated discourse practices such as argumentation and utilizing various feedback chains instead of evaluation (McNeill & Krajcik, 2008; Smith & Hackling, 2016).

A focus on questioning is especially significant in the science classroom. The nature of scientific inquiry offers a unique opportunity where students are constantly asking questions about the world around them. Further, they are encouraged to systematically answer these questions through discussion, evidence, and reasoning (Lustick, 2010). This critical process of scientific inquiry is typically facilitated in the classroom by teacher questioning. Scientific inquiry, as defined by the National Science Education Standards:

> Refers to the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Inquiry also refers to the activities of students in which they develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world. (National Research Council, [NRC], 1996, p. 23)

More recently, the Next Generation Science Standards (NGSS) go on to support a need for inquiry with the idea that:

> Students cannot fully understand scientific and engineering ideas without engaging in the practices of inquiry and the discourses by which such ideas are developed and refined. At the same time, they cannot learn or show competence in practices except in the context of specific content. (NRC Framework, 2011, p. 218)

Ideally, scientific inquiry in the classroom happens when students and teachers engage in discourse to socially construct knowledge based on their observations during hands-on and interactive inquiry-based science (Oliveira, 2010a, 2010b; Roth, 1996; Ruiz-Primo & Furtak, 2007). This hands-on and interactive process requires that students engage in more than observing science, but actually doing science in combination with actively constructing scientific knowledge and critical thinking skills (NRC, 1996). Further, research supports that "inquiry

begins with a teacher's ability to identify, use, and exploit quality questions that help achieve specific content and/or skill learning objectives" (Lustick, 2010, p. 496). And while research also supports the idea that inquiry does improve student learning outcomes (McNeill & Krajcik, 2008; Oliveira et al., 2013; Ruiz-Primo & Furtak, 2007), teachers still struggle with actually implementing inquiry in their classrooms.

Despite the importance of discourse in the science classroom, the move away from traditional IRE questioning has proven difficult. There are both contextual and pedagogical challenges involved with making this shift. Contextual challenges include lack of instructional time (Myhill, 2006), prescribed curricula (Watson & Young, 1986), unsupportive administration (Southerland, Sowell, & Enderle, 2011), and uncooperative students (Pea, 2012). In this high stakes era of education, there is an increased pressure on teachers to prepare students academically for standardized assessments or grade level promotion. This can deter teachers from utilizing discourse in the classroom because it is not seen as an efficient use of time. As a result, teachers do not invest the effort in learning new questioning skills that would support student discourse in the classroom (Oliveira, 2010a; 2010b; Forbes & Davis, 2010; Rop, 2002).

Additionally, pedagogical challenges also prevent teachers from improving their questioning practices. Teachers bring prior knowledge and beliefs about questioning and discourse to the classroom that may or may not support the social nature of scientific discourse (Rop, 2002). Even if teachers firmly believe in questioning and discourse in the classroom, they may find they are not adequately prepared to manage the new roles that come with it (Chen, Hand, & Norton-Meir, 2016). This results in well-intentioned teachers abandoning any pedagogical changes and falling back on more traditional IRE questioning sequences.

Like any skill, teachers need time and experience to develop their questioning practices in

the classroom. There are many books and scholarly articles about best practices as they relate to questioning in general (e.g. Quality Questioning: Research-Based Practice to Engage Every Learner by Jackie Acree Walsh and Beth Dankert Sattes) and even more when considering inquiry instruction in science specifically (e.g. Five Practices for Orchestrating Productive Task-Based Discussions in Science by Jennifer Cartier, Margaret Smith, Mary Kay Stein, and Danielle Ross). However, teachers are still struggling to use questioning effectively. In fact, the results of a large scale national study indicate that, "questioning was among the weakest elements of science instruction, with only 16 percent of lessons nationally incorporating questioning that seemed likely to move student understanding forward" (Pasley, Weiss, Shimkus, & Smith, 2004, p. 8). And while the available research on how to improve questioning practices is informative, it can be argued that teacher development in questioning is not something that teachers can simply read about and do, they will only get better at it through practice and high-quality mentoring (Roth, 1996).

Typically, formal learning about questioning and/or discourse facilitation occurs during teachers' pre-service education. Teachers typically participate in a combination of coursework and mentoring about questioning that can be superficial in nature (Lustick, 2010; Roth, 1996). Moreover, the focus of professional development opportunities for in-service teachers is usually at the discretion of school and/or district administrators (Harwell, 2003). And in an era of decreasing budgets and high stakes testing, the focus of professional development has narrowed, often at the expense of science content (Loukes-Horsley, Stiles, Mundry, Love, & Hewson, 2010). Further, even if professional development is focused on science, traditional single-day workshops are not effective learning experiences for teachers because they fail to provide consistent, follow-up support teachers need to make changes once they return to their classrooms

(Harwell, 2003). For teachers to make any lasting change they need support in content, reflection, and collaboration, all of which cannot be provided in only one day (Garet, Porter, Desimone, Birman, & Yoon, 2001; Lebak & Tinsley, 2010; Marshall et al., 2010; Scribner, 1999; Wolf, 1987).

Teacher questioning in science is an important area of study because science teachers need to be able to help students understand scientific phenomena. Typically, this is accomplished when teachers model scientific reasoning as well as how to ask researchable questions. It is important for students to learn how to ask questions to be successful in science. Thus, not only do science teachers need to learn general questioning skills as they relate to the classroom, but also specific questioning skills as they relate to science content. Helping students engage in explanation and argumentation in science may help them move away from the notion that science is a "static set of facts to science as a social process where knowledge is constructed" (McNeill & Kajcik, 2008, p. 54). As this important shift in science pedagogy is embraced, teachers will need to be prepared to craft meaningful and thought-provoking questions. And they will need professional development opportunities on questioning and discourse that are focused on content, provide time for reflection and collaboration, and are available for timely and ongoing support.

The purpose of this mixed methods design study is to investigate teachers' learning needs and design a just-in-time, informal, online professional development prototype for science educators that supports effective questioning practices to facilitate discourse in the inquiry-based science classroom. Specifically, this study will seek to answer the following research questions:

1. What do inquiry-based science teachers need to know about questioning practices that will help them facilitate learning discourse?

2. What components are needed in an online prototype to support immediate application of teacher questioning and discourse skills for inquiry-based science instruction?
3. How will the affordances and constraints of an informal online environment affect the design of this prototype?

This study utilized an iterative needs assessment and design process to answer these research questions and develop, The Question Connection (www.questionconnection.com), a just-in-time online prototype aimed at middle school science teachers who want to improve their use of questions in the classroom.

Chapter 2: Design Based Approach

The purpose of this study was to investigate teachers' learning needs around questioning practices in the middle school science classroom and then identify learning goals that address those needs in a just-in-time, informal, online professional development prototype that supports teachers' effective questioning practices and facilitates discourse in the inquiry-based science classroom. As science education moves into the era of Next Generation Science Standards, it is increasingly important that teachers have a thorough understanding of how to promote scientific inquiry through questioning and discourse. Because this is a design study, I completed several rounds of needs analysis and design. The concepts that inform the design approach for this study are; the principles of andragogy (Knowles, Holton, & Swanson, 1998), informal learning (Bell, Lewenstein, Shouse, & Feder, 2009), and the ADDIE model of design (Gustafson & Branch, 2002).

Principles of Andragogy

Andragogy is the study of adults' unique learning needs (Knowles et al., 1998). There are six assumptions that form the basis of Knowles' andragogical model of adult learning. These assumptions include: the need to know, the learner's self-concept, the role of the learner's experience, readiness to learn, orientation to learning, and motivation (Knowles et al., 1998). Andragogy is specific to adult learning principles and informs the needs analysis and design of this study because the learners in this study are all professional educators with diverse knowledge and backgrounds.

According to adult learning theory, adult learners are defined as those who are responsible for their own learning, have experience, and are autonomous (Brookfield, 1991). Further, Knowles' principle of self-concept supports the notion that adult learners should have

ownership over their own learning (1998). In this design study, the role of the teachers' experiences will be central in determining learning needs through interviews, surveys, and user-testing focused on direct teacher experience with questioning in the science classroom. Specifically, the content and design of the prototype will be heavily influenced by the results of iterative rounds of needs analysis and design where I identify learning needs, create learning goals, and then design the prototype to help users meet those goals. To further provide autonomy and ownership over learning, the prototype design is informal. There will be no required standards or assessments; and each teacher will be responsible for content acquisition, but also, the direction of their own learning experience.

Adults are also motivated to engage in learning experiences because of a purpose and a "need to know" (Knowles et al., 1998). Again, I utilized interviews, surveys, and user-testing to identify learning needs and gaps in knowledge that can be used to generate interest and a need to know. For example, one of the most intriguing questions I asked teachers was how many questions do you ask in one day? This question stimulated participants' thinking about what they actually do and generated interest and a need to know. Further, adult learning research suggests that adult learners prefer simple, straightforward, single topic courses about practical problems (Zemke & Zemke, 1996) in "informal, comfortable, flexible, non-threatening settings" (Queeney, 1995, p. 61). Thus, the focus of this prototype is on real life, practical problems that teachers face about questioning practices in their classrooms.

Informal Learning

In general, informal learning is characterized as free choice, learner driven and without high stakes assessments (Bell, Lewenstein, Shouse, & Feder, 2009). Further it is characterized as unsystematic, fluid in nature, and the learners represent a diversity of age, race, and groupings

(Hsi et al., 2004). For the purposes of this study, informal learning theory underlies the study design in three ways; range of learner experience, motivation to learn, and flexibility of learning.

The unsystematic and fluid nature of informal learning affords the accommodation of a range of learners (Hsi et al., 2004). Learners who engage in free-choice learning can vary widely in prior knowledge, from novice to content experts. While this study will focus on middle school science teachers, within this group there are a number of constructs that can vary widely including; years of experience, prior knowledge and beliefs, school district, state, curriculum, etc. For this reason, informal learning theory supports the selection of a wide range of teachers to inform the identification of learning needs during the needs analysis and the learning goals and content design in the design and development of the prototype.

The informal nature of the online prototype aligns well with the adult audience who will be self-motivated to learn and interact in the space. One of the affordances of free choice learning is that the learners must have some level of intrinsic motivation to engage in the learning. However, maintaining motivation can be a challenge in informal learning environments. Interestingly, higher motivation is not always correlated with higher learning in informal environments (Falk & Adelman, 2003). Sometimes, the most learning occurs when an unmotivated learner is surprised by material in the learning environment and compelled to engage and learn more. And while design research recognizes that in general learners need to be motivated intrinsically, there can also be designed elements that create a need to know for the learner (Edelson, 2001). Thus, it will be important to consider the level of teacher motivation to use this prototype and design elements that support a need to know.

Due to the informal and online nature of the prototype, teachers will be able to access the content from anywhere at any time. This flexibility provides teachers with control over not only

what, but how, when, and where they will learn. Additionally, time is the biggest limitation for continuing education (Gray, 2004; Queeney, 1995), thus, having access to a flexible, just-in-time prototype helps alleviate this dilemma. Finally, learners need multiple opportunities to organize and refine their learning before it can be useful (Edelson, 2001). The informal nature of this prototype will allow teachers to access learning in many ways and at different points in the learning process. One of the main failings of traditional professional development is that it does not provide continued support (Harwell, 2003). The informal and online affordances of this prototype will allow for continued and flexible learning that is built upon the teachers' experiences.

ADDIE

In this study I completed a portion of the ADDIE (Analyze, Design, Develop, Implement, Evaluate) model of design (Allen, 2006) through the development phase. ADDIE is a design process that encompasses a needs assessment and analysis (A) to determine any gaps in performance and identified goals. Then there is a design phase (D) where learning objectives and activities are identified. This is followed by the development phase (D) where the actual materials are developed based on the design specifications. Finally are the implementation (I) and evaluation (E) phases. The implementation phase is when the design is actually implemented and data collected so that the design can be evaluated and improved or modified. I did not implement or evaluate the final design as part of this study. I made this decision due to time constraints of the study and my desire to complete a thorough and multi-phased needs analysis, design, and development cycle.

Study Overview

In accordance with the principles of andragogy, informal learning, and the ADDIE

model, the design for this study included four iterative phases; each focused on needs analysis and each with distinct methodology, findings, and prototype design (see Table 1). Also, because each phase is distinct, I present each one in its own chapter describing its distinct methods, results, and discussion (Chapter 3: Phase 1; Chapter 4: Phase 2; Chapter 5: Phase 3; Chapter 6: Phase 4). While this format is atypical, it allows the reader to fully understand each phase in its entirety and how each subsequent phase built upon the analysis and results of the previous phases. The findings chapters are followed by Chapter 7, which discusses the overall findings including how the prototype meets the identified learning goals, next steps for development and implementation, and overall implications of this study for future research. Additionally, I obtained IRB approval (#16-041M) of all study related documents including recruitment flyers, email language, study protocols, and consent forms for Phases 2, 3, and 4.

Table 1

Research Phases

	Phase 1	**Phase 2**	**Phase 3**	**Phase 4**
Data (n=)	Literature (100)	Interviews (10)	Surveys (66)	User Testing (6)
Methods (ADDIE Phase Completed)	Literature review (Assessment) Initial Paper Prototype Design (Design)	Interview Protocol Design IRB Approval Sample Selection Data Collection Qualitative Analysis (Assessment) Refined Paper Prototype (Design)	Survey Protocol Design IRB Approval Sample Selection Data Collection Quantitative Analysis (Assessment) Website Prototype (Design & Development)	User Testing Protocol Design IRB Approval Sample Selection Data Collection Qualitative Analysis (Assessment) Refined Website Prototype (Design & Development)

Study Limitations

Even though the methodology of this study has been carefully crafted and considered there are still potential limitations. An ideal sample for this study would include a nationally representative sample of middle school science teachers. However, limits on time and resources mean I will focus on a smaller purposeful sample. And while this purposeful sample will provide a variety of rich information, it will not be generalizable.

The data collection procedures also have limitations. First, the needs assessment interview and survey will both rely to some degree on self-report. It is generally understood that self-report is not an accurate measure of actual needs (Karabenick et al., 2007) as people often erroneously assume they accomplish their everyday activities well (Queeney, 1995). In this case, since questioning is something teachers do every day, they may not truly understand where their practice is lacking. To help alleviate this, I will identify performance problems and determine the goals for the learning (Gustafson & Branch, 2002) and include direct assessment questions during different phases of the study.

Finally, my personal background and experience may impact the analysis of the data collected. I come from a family of research scientists and since I was a very young child I have developed an interest and affinity for all things science. This love of learning about science turned into a desire to help others learn science. As a professional elementary and secondary science teacher, I found that students learn best when they engage in inquiry and discourse. When we engaged in discussions in the classroom around meaningful questions, students made connections and built understandings together. As a science teacher I recognize that I view learning from a social constructivist and inquiry-oriented lens. Further, as a researcher, I am aware of these biases and while interpreting data, I will need to be sure that these biases do not

affect the design in negative ways. To help alleviate this, I engaged in peer debriefing and an external audit by a person not associated with the research who examined the methods and conclusions (Creswell, 2018). The auditor is a professional science teacher, holds a doctorate in science education, and provides professional development for science educators in school settings.

Chapter 3: Phase 1 Literature Review

Phase 1 of this study included a thorough review of the literature to identify teacher learning needs and then draft an initial prototype of the online design. First, I present the methodology of the literature review including steps taken to identify resources and my analytic procedures. Second, I present the findings of the literature review. And finally, I discuss how the results of the literature review helped me identify teacher learning needs and draft an initial prototype design.

Methodology: Literature Review

An initial search of the ERIC (Education Resources Information Center), Professional Development Collection, PsychCRITIQUES, and Social Sciences Full Text databases was done using the following terms: "science," "inquiry," "discourse," and "questioning." From this initial search, I identified a total of 122 sources. Because my goal was to do an exhaustive review I did not further limit this sample with additional search criteria. I read the abstracts/summaries for all 122 resources and discarded 55 resources that focused on student questioning practices rather than teacher questioning practices. I read and analyzed the remaining 67 resources in their entirety. During this process, an additional 33 articles and books were identified and added to the sample for a total of 100 resources for further review.

I analyzed the sources by first reading each source in its entirety and taking notes in an Excel spreadsheet. Descriptions of included references including my notes are found in Appendix A. Additionally, I captured my own thoughts and reactions to the readings in a separate document with emphasis on identifying themes that cut across the literature and relating them to my research questions. The themes and associated articles are described in Table 2.

Table 2

Literature Informed Themes about Teacher Questioning

Theme	Description	References
Importance (29)	The why: Why do we use questioning in the classroom? The interplay between inquiry, reform, and standards and how historically this has shaped (or not) the importance of teacher questioning in the classroom.	Bybee, 1985 Capps & Crawford, 2013 Gall, 1970 Garet et al., 2001 Hermann & Miranda, 2010 Kim & Chin, 2011 Klahr, Zimmerman, & Jirout, 2011 Lebak & Tinsley, 2010 Lustick, 2010 Marshall & Horton, 2011 Marshall, Smart, & Horton, 2010 McNeill & Krajcik, 2008 Myhill, 2006 NGSS Lead States, 2013 No Child Left Behind Act of 2001: Qualifications for Teachers and Professionals, 2004 NRC, 1996 Nystrand, 2006 Oliveira, 2010b Oliveira et al., 2013 Pasley et al., 2004 Pea, 2012 Rop, 2002 Ruiz, Primo & Furtak, 2009 Scribner, 1999 Southerland et al., 2011 Tienken, Goldberg, & DiRocco, 2009 United States National Commission on Excellence in Education, 1983 Wolf, 1987 Yeager, 2000
Practices/Barriers (36)	The what: What is actually happening in classroom practice? Traditional and reform practices of questioning practices and factors that promote and inhibit teacher questioning practices.	Brown, 2011 Burns & Myhill, 2004 Chin, 2004 Chin, 2006 Chin, 2007 Dillon, 1985 Forbes & Davis, 2010 Gall, 1984 Gall & Gillette, 1980 Ireland et al., 2012 Kassner, 1998

		King, 1993 Lustick, 2010 Lyle, 2008 Marshall & Horton, 2011 McGough &Nyberg, DATE McNeill & Krajcik, 2008 McNeill & Pimentel, 2010 Minstrell & van Zee, 2003 Myhill, 2006 NRC, 1996 Nystrand, 2006 Oliviera, 2010a Pea, 2012 Pasley et al., 2004 Reznitskaya & Gregory, 2013 Roth, 1996 Rowle & Ebbers, 2004 Scott, 1998 Southerland et al., 2011 Tienken, Goldberg, & DiRocco, 2009 Watson & Young, 1986 Wells & Arauz, 2006 Wragg & Brown, 2001 Wolf, 1987 Yilmaz, 2011
Professional Learning/Design (35)	The how: How are teachers supported in learning about and improving teacher questioning practices? Trends in professional development on discourse and questioning and how adult learning translates to an informal online space.	Allen, 2006 Bell et al., 2009 Brookfield, 1991 Capps & Crawford, 2013 Dillon, 1984 Edelson, 2001 Falk & Adelman, 2003 Forber & Davis, 2010 Garet et al., 2001 Gray, 2004 Hackling, Smith, & Mercia, 2011 Harris, Philips, & Penuel, 2012 Harwell, 2003 Hoeteker & Ahlbrand, 1969 Hsi et al., 2004 Ireland et al., 2012 Knowles et al., 1998 Lebak & Tinsley, 2010

	Liberman & Pointer-Mace, 2012 Loukes-Horsley et al., 2010 Marshall et al., 2010 McNeill & Krajcik, 2008 Nystrand, 2006 Oliveira, 2010a Oliveira, 2010b Oliviera et al., 2013 Parker & Hurry, 2007 Queeny, 1995 Ruebush et al., 2009 Roth, 1996 Schiller & Joseph, 2010 Scribner, 1999 Southerland et al., 2011 Wolf, 1987 Zemke, 1996

Findings: Literature Review

In an effort to fully understand teachers' learning needs about questioning in the inquiry-based classroom, I analyzed the literature and identified three themes about questioning and discourse practices in the classroom. First, I provide a historical context for science education reform that illustrates the importance and necessity of inquiry-based instruction and thus quality teacher questioning and discourse in the classroom. Next, I shift the focus to a more specific conversation about the role of questioning in the science classroom, including current practices and barriers to improved practice. Then, I present literature about the role of professional development in science education and questioning. Specifically, what the research has shown to effectively modify teacher practices through increased knowledge, reflection and collaboration.

Importance of Questioning in Science Education

Science education in the United States has undergone various reform efforts over the past 6 decades. Starting in the 1950's and 1960's international pressure with the launch of Sputnik in 1957 resulted in a national focus on science and science education (Bybee, 1985; Yager, 2000).

By the late 1960's several studies by national organizations such as the National Science Foundation (NSF) resulted in curricular recommendations for improving science education. The goal of these recommendations was to involve all students in science and have them experience science as scientists do, through inquiry (Yager, 2000). This early attempt at incorporating inquiry in the science classroom however was unsuccessful throughout the 1970's for two reasons. First, textbooks and traditional teaching methods still dominated classroom practice and change proved difficult (Yager, 2000). Second, a steady decline in student assessment and national interest in science education resulted in a stall of science education reform (Yager, 2000).

The 1983 publication of *A Nation at Risk* highlighted the declining student assessment results throughout the 1970's, prompting a new effort towards science education reform (United States National Commission on Excellence in Education, 1983). This time, the focus was on creating cohesive national standards in science education with a focus on scientific literacy (NRC, 1996). The American Association for the Advancement of Science (AAAS) led the way with the publication of two reform documents: *Science for All Americans* (1990), and *Benchmarks for Science Literacy* (1993). Also, in the early 1990's the National Research Council (NRC) coordinated a committee dedicated to designing national science standards which were released in 1996.

The National Science Education Standards that were released by the NRC were grounded by 4 important principles; "science is for all students, learning is an active process, school science reflects the intellectual and cultural traditions that characterize the practice of contemporary science, and improving science education is part of systemic education reform" (NRC, 1996, p. 19). Further, the standards emphasize the importance of inquiry in the classroom:

> Inquiry is central to science learning. When engaging in inquiry, students describe objects and events, ask questions, construct explanations, test those explanations against current scientific knowledge, and communicate their ideas to others. They identify their assumptions, use critical and logical thinking, and consider alternative explanations. In this way, students actively develop their understanding of science by combining scientific knowledge with reasoning and thinking skills (NRC, 1996, p. 2).

Following the release of these standards, an emphasis on inquiry in the science classroom led to an important shift in research, teacher preparation, and practice. Over the next 15 years much of the research on science education focused on inquiry in the science classroom. This focus resulted in articles about defining what inquiry looks like in the classroom (Capps & Crawford, 2013; Rop, 2002), teachers' inquiry practices and limitations (Kim & Chin, 2011, Pea, 2012; Rop, 2002; Southerland et al., 2011), and whether or not inquiry is an effective method for teaching science (McNeill & Krajcik, 2008; Oliveira, 2010b; Ruiz-Primo & Furtak, 2009).

In general, the research has found that defining inquiry is easier in theory than in practice. Teachers are often able to describe inquiry in an ideal sense, but they fail to make the connection to the realities of their practice (Capps & Crawford, 2013). As the research on what qualifies as inquiry has developed, there is less of an emphasis on one type of inquiry and more of a focus on inquiry as a continuum from open to guided (Hermann & Miranda, 2010; Oliveira et al., 2013). On one end of the continuum, open inquiry follows a more professional scientific approach where a student asks their own question about scientific phenomenon and then designs their own investigation to answer this question (Oliveira et al., 2013). While on the other end of the continuum, guided inquiry encourages students to investigate more focused science questions as determined by the teacher and/or curriculum (Oliveira et al., 2013). Regardless of the type of

inquiry, a broader view of what inquiry looks like in the classroom has helped teachers better situate their knowledge, beliefs and practices of inquiry in the realities and limitations of the institution of traditional K-12 schooling. Thus, inquiry instruction has shifted from an all or nothing perspective to allowing for a spectrum of inquiry approaches aimed at improving understanding (Pasley et al., 2004). Specifically, teachers can plan science instruction ranging from full, open inquiry to a more guided approach that still leaves room for mandated school curriculum, standards, and objectives. This shift has made inquiry instruction more accessible for teachers, thus allowing them to begin the process of actually incorporating more inquiry into their classrooms.

As teachers work to implement more inquiry, researchers have looked at what is actually happening in classrooms. In some cases, teachers feel comfortable with inquiry; however, for the vast majority, this conceptual and practical shift proves difficult to make. Teachers struggle with time constraints (Rop, 2002), unsupportive administration (Southerland et al., 2011), unmotivated students (Pea, 2012), and limited understanding of how to implement inquiry (Kim & Chin, 2011). Over time the research began to uncover ways in which teachers could improve their practice through increased content knowledge, reflection, and collaboration (Garet et al., 2001; Lebak & Tinsley, 2010; Marshall, Smart, & Horton, 2010; Scribner, 1999; Wolf, 1987). At the same time, teacher preparation and national certification standards began to call for highly qualified teachers, translating to higher content knowledge requirements for science teacher candidates (No Child Left Behind Act of 2001: Qualifications for Teachers and Professionals, 2004). Even though teachers still experience struggles with implementing inquiry, as a result of this larger systemic change, there is more support for teachers to acquire content knowledge, which in turn can help them improve their practice of implementing inquiry in the classroom

(Pasley et al, 2004).

Over the years there has been debate about whether or not inquiry is an effective method for teaching science. Some have argued that inquiry can actually decrease learning in science due to the fact that students do not have a sufficient knowledge base to ask meaningful questions (Klahr, Zimmerman, & Jirout, 2011). However, reform-minded educators argue that socially constructing knowledge through discourse is essential to learning and understanding science (Oliviera et al., 2013). While it can be difficult to prove that inquiry leads to increased learning, there are several studies that have demonstrated that a more conceptual understanding of science as a result of inquiry instruction leads to increased knowledge and better assessment scores (McNeill & Krajcik, 2008; Oliveira et al, 2013; Ruiz-Primo & Furtak, 2009).

Most recently a new era of science education reform began with the release of the Next Generation Science Standards (NGSS) in 2013. Again, students in the United States are struggling to demonstrate basic levels of proficiency in science on national assessments and are not competitive internationally (NGSS Lead States, 2013). And while the National Science Education Standards from 1996 have proven to be robust, it was time for updates that incorporated new knowledge and understandings of science education (NGSS Lead States, 2013). The NGSS are different from previous standards in three ways: performance, foundations, and coherence (NGSS Lead States, 2013). Previously, standards described what students should know and understand, however this led to confusion with respect to assessment. The NGSS however outlines performance standards that demonstrate knowledge and understandings. Secondly, the NGSS incorporates three dimensions for each performance; a core idea, a science and engineering practice, and a crosscutting concept (NGSS Lead States, 2013). Finally, there are connections to other disciplines and also the Common Core State Standards. Thus, while

many of the principles of the National Science Education Standards are still relevant, the NGSS have added new and important layers of assessment, engineering, and connections that will help teachers as they continue to improve classroom practice.

The importance of inquiry in the evolution of standards and education reform highlights the importance of teacher practices in the science classroom, including teacher questioning skills. The goal of science instruction throughout the years has evolved to include students participating in inquiry experiences so they can explain scientific phenomenon through argumentation and reasoning. As a result, teachers need to be prepared to craft meaningful and thought provoking questions that will inspire and guide students as they engage in this inquiry process.

Questioning in Science Education: Practices and Barriers

Direct instruction, which includes questioning, is still the most commonly used practice in the classroom not only here in the United States but around the world (Myhill, 2006). There are some who argue that questions can inhibit learning and their use in the classroom should be limited (Dillon, 1985; Gall, 1984). However, others counter that well-crafted questions can inspire learning, "independent of whom they teach, skilled teachers question in distinctive ways: they raise a range of questions, they sustain and build arcs of questions, their inquiries are authentic, they inquire with a sense of respect flail decency" (Wolf, 1987, p. 3). At stake is not perhaps the question itself, but rather how it is used and in what context. Traditionally, question sequences in the classroom have been used as a way to evaluate students. In these sequences teachers initiate a question (I), which is usually factual in nature, they wait for a student to respond (R), and then they provide a short evaluation (E) (Chin, 2006; Wells & Arauz, 2006; Watson & Young, 1986). However, traditional IRE sequences have been shown to not only stifle discourse (Dillon, 1985; Rowle & Ebbers, 2004) but also limit critical thinking (Watson &

Young, 1986), both of which are important to inquiry-based science instruction (NRC, 1996).

Instead of using questions to evaluate, constructivist questioning is about scaffolding student thinking and providing feedback in lieu of evaluation (Chin, 2006; Minstrell & van Zee, 2003). Additionally, asking students questions is one way for teachers to know what students understand and how they organize information (Yilmaz, 2011). This shift in questioning practice mirrors that of science education in general. It is important that students understand science more conceptually than factually (Marshall et al., 2011; Pasley et al., 2004). A conceptual knowledge of science allows students to engage in critical thinking and problem solving as opposed to rote memorization (Marshall et al, 2011). However, to craft meaningful questions, teachers need to master a number of constructs. They need to understand the specific content, common misconceptions of the content, general child development, socio-cultural context, prior knowledge, experience, and understanding of their students. They also need to have a firm understanding of the situation(s) that are best situated for various types of questions and what responses they typically evoke. This is a tremendous amount for teachers to consider. Further, this is to craft just one question, let alone handle the in-situ response and ensuing discussion.

Understanding how to effectively question students in a classroom setting also requires educators be familiar with theoretical constructs of learning. One important construct is the use of language in learning. Both cognitively and culturally, language is a powerful product of, and tool for, learning (Myhill, 2006). Cognitively, the focus is on how language is processed for learning. Meaning, students not only learn by listening, but they also learn by talking. In fact, much of the research has focused on how the more students talk, the more they actually learn (McNeill & Krajcik, 2008). Further, critical thinking skills associated with discussion result in more meaningful learning than more traditional fact-based dialogue typical of most classroom

talk (Lustick, 2010; McNeill & Kajcik, 2008).

Learning is a cognitive, social, and cultural experience (Burns & Myhill, 2004; Lyle, 2008; Nystrand, 2006; Oliviera, 2010a). Language plays an important role in how students interact in the classroom, "what counts as knowledge and understanding in any given classroom is largely shaped by the questions teachers ask, how they respond to their students, and how they structure small-group and other pedagogical activities" (Nystrand, 2006, p. 400). More specifically, language serves as a means to communicate what the students know and understand about what they are learning as well as build and refine new knowledge (Myhill, 2006). Further, it allows students to try out different identities and methods of communication such as argumentation and evidence-based reasoning (Brown, 2011). Moving students through this process requires thoughtful scaffolding, which can be accomplished utilizing specific focus questions (Lustick, 2010; Scott, 1998). Ultimately, effective interaction around well-crafted questions can result in deep and meaningful learning in the classroom.

Throughout the day, teachers use questions to accomplish a variety of tasks. As mentioned previously, in some cases the questions are procedural, such as "who is here today?" However, the vast majority of questions (about 80%) in the classroom revolve around content. Teachers typically ask questions so they can understand what students know and have learned. The types of questions teachers ask in the classroom have been the topic of research for many years, and typically referred to as question typology. The most notable typology referred to in the literature is Bloom's taxonomy (Lustick, 2010; Tienken et al., 2009). Bloom's taxonomy offers teachers a framework that helps them develop higher order thinking questions in a range of levels from knowledge to evaluation. Questions can also be organized in other ways such as, "subject matter mastery, issue oriented, problem solving, simple motivation" (Gall & Gillette,

1980), or "inference, interpretation, transfer, questions about hypotheses, and reflective" (Wolf, 1987). Regardless of the huge variety of questions, most teachers pose simple, factual questions that only exercise a student's recall (Gall, 1970; Myhill, 2006). Unfortunately, this results in more of a recitation than discussion, thus limiting any meaningful learning (Dillon, 1985), as well as failing to realize the full potential of a question.

The reasons for this failure to effectively utilize questioning in the classroom is a result of many factors. Broadly these factors can be divided into two categories, contextual factors and pedagogical understandings (Ireland, Watters, Brownlee, and Lupton, 2012; Southerland et al., 2011). Contextual factors include things like limited instructional time, prescribed curriculum, unsupportive administrators, and uncooperative students while pedagogical factors include teacher beliefs about teaching and learning and their own teacher preparation experiences. Lack of instructional time (Forbes & Davis, 2010; Myhill, 2006; Oliveira, 2010b) is the main contextual factor limiting questioning and discourse in the classroom. While teachers may be willing to negotiate the locus of control in a student-centered dialogue, they find that as a result it is difficult to accomplish all that is planned or required for the day. This classroom issue is tied closely to the school curricula as teachers feel pressured to prepare their students for the next class or year (Myhill, 2006). Textbooks can also add to the problem. Questions in textbooks often reinforce the low level, factual questioning that is predominant in the classroom (Watson & Young, 1986).

Besides instructional time, lack of student participation is the main contextual reason teachers abandon questioning and discourse in the classroom (Gall & Gillette, 1980; Pea, 2012; Wolf, 1987). As questioning and discourse practices change from traditional recitation to more discussion focused, both teachers and students may struggle with their new roles (McNeill &

Pimentel, 2010). Students are not used to talking for the majority of class time and teachers struggle to talk less (Gall & Gillette, 1980). Further, students may be unsure of how to engage in discussion and lack content knowledge sufficient for discussion (Wolf, 1987). Additionally, teacher beliefs are predictive precursors to classroom practice (Forbes & Davis, 2010). If a teacher does not believe in the benefits of questioning and discourse, then they will not employ these tools in practice. Further, even if questioning and discourse is a pedagogical priority for teachers, they may find that they are not adequately prepared to question students and facilitate discourse (Oliveira, 2010a) resulting in a gap between what teachers know they should do and what actually happens in practice (McNeill & Krajcik, 2008; Reznitskaya & Gregory, 2013).

Teachers need practical, theoretical, and pedagogical knowledge to ask higher-order thinking questions in the classroom. In science classrooms, they also need a thorough understanding of content knowledge and the role of inquiry, reasoning, and argumentation in science teaching and learning. Further, teachers need to be aware of pervasive patterns of factual and rote questioning and evaluation practices teachers typically use in the classroom. Teachers also need to understand how to update questioning practices to align with the goal of higher-order thinking by students, despite contextual and pedagogical factors like limited instructional time and personal beliefs, that are often barriers to improved teacher questioning practices.

Professional Development in Science Education

Over the years professional development has served to address the gap between teacher knowledge of questioning and their practice. In general, professional development for teachers consists of one-time workshops either during the school year or over the summer where it is removed from their school and/or classroom context. There is an abundance of evidence that supports the notion that this is not effective (Garet et al., 2001; Harwell, 2003; Lieberman &

Pointer-Mace, 2010). Further, teachers in the United States have considerably less time for planning and/or developing their own knowledge during the school day as compared to teachers in other countries (Lieberman & Pointer-Mace, 2010). With only about 5-6 hours per week (Lieberman & Pointer-Mace, 2010), teachers are not able to capitalize on what has been shown consistently in the literature to actually increase teacher knowledge: time for reflection, collaboration, and content knowledge (Garet et al., 2001; Lebak & Tinsley, 2010; Marshall et al., 2010; Scribner, 1999; Wolf, 1987).

Teachers simply need more time to develop their own understandings and improve their practice. Teaching science especially requires considerable conceptual development on the part of the teacher. Learning how to adjust individual teaching methods to meet inquiry-based standards means that teachers may have to abandon pre-conceived notions about how science is taught in the classroom (Southerland et al., 2011). Often teachers' ideas about science instruction are a result of their experiences as a student, which may have adhered to a more traditional recitation format. Having the time to reflect on their practice and how it is impacted by their knowledge and beliefs is critical. Taking this time to reflect individually as well as collaboratively is shown to help bridge the gap between knowledge and changing actual practice (Lebak & Tinsley, 2010; Scribner, 1999).

Learning to teach science from an inquiry-based perspective also requires teachers to have a solid mastery of content and desire to improve their practice (Lebak & Tinsley, 2010; Scribner, 1999). Teachers are better able to adjust classroom questioning and discourse when they have strong content knowledge as well as an informed understanding of the inquiry process. Flexibility of questioning and discourse in the science classroom is important as students may require more or less scaffolding depending on the content and their personal experiences (Forbes

& Davis, 2010). Studies about inquiry instruction suggest that teachers improve their inquiry instruction when they are immersed themselves as students in inquiry learning environments (Capps & Crawford, 2013; Ruebush et al., 2009).

Teachers' questioning skills is an area that is not often addressed by in-depth teacher training (Lustick, 2010). This may be a result of two reasons. First, "its obviousness has obscured its central role" in the learning process (Hoeteker & Ahlbrand, 1969, p. 224). Teachers are often surprised that their practices, especially their questioning practices, are more traditional than they thought (Schiller & Joseph, 2010). They spend so much time questioning that they rarely stop to consider if they do it well. Second, questioning and fostering discourse in the classroom is hard to do (Dillon, 1984). There is no standard way to question and no question is universally good (Oliveira et al., 2013; Roth, 1996). Further, even with a quality script and/or the same curriculum, not all teachers will be good at questioning (Harris, Phillips, & Penuel, 2012; McNeill & Krajcik, 2008). They may find that quality questioning takes too much time and effort and will ultimately fall back on more traditional questioning practices (Wolf, 1987).

Teachers need explicit instruction in questioning and discourse facilitation to improve their practice (Hackling, Smith, & Mercia, 2011; Oliveira, 2010a**;** Parker & Hurry, 2007). This instruction needs to include both a cognitive perspective, including question typologies, as well as a social perspective of questioning, including classroom power structures (Oliviera, 2010b). Professional development should be flexible, to adapt to teacher and student needs (Forbes & Davis, 2010) and include time for reflection and peer collaboration (Garet et al., 2001; Lebak & Tinsley, 2010; Marshall et al., 2010; Scribner, 1999). Videos are one tool that has been shown to be effective for professional development in questioning and discourse (Lebak & Tinsley, 2010; Oliviera, 2010b). Videos provide opportunities to capture actual practice, observe others

practice, and collaboratively reflect on questioning practices.

Much of what is known about good questioning and discourse facilitation is privately held by skilled teachers in their classrooms (Dillon, 1984; Nystrand, 2006). Education practitioners, scholars, and researchers have long called for de-privatization of practice as a way to build communities and grow instructional practice (Dillon, 1984; Lieberman & Pointer-Mace, 2010); however, such change has been difficult given time limitations (Lieberman & Pointer-Mace, 2010) and norms of autonomy that dominate the teaching profession (Leiberman & Pointer-Mace, 2010). One way for teachers to connect and share knowledge as well as make their practice public is through the use of digital spaces (Lieberman & Pointer-Mace, 2010). In this way, teachers can view and share best practices as well as weed out practices that are no longer effective. And while theory helps to create common understandings, theory alone does not help teachers change their practice (Ireland et al., 2012; Scribner, 1999). Thus, teachers need to learn content and theory as well as connect and share experiences to best be prepared to change their questioning practices.

Discussion: Teacher Learning Needs & Prototype Design

Based on this initial analysis of the literature, I started to identify teachers' learning needs and design the initial paper prototype that would become the online prototype. I started by examining and describing the three themes identified in the literature; 1) importance of questioning in teaching and learning science 2) questioning practices and barriers to questioning practice, and 3) professional learning opportunities and professional development design. From the themes I then identified four initial learning needs for teachers about questioning and discourse in the science classroom that align with these themes (Table 3). First, I identified a need for teachers to learn about the importance of questioning in the classroom setting including

history and background of this practice. Second, I found there was a need for educators to reflect on their practice and be able to collaborate by evaluating their questions in a private and/or public space. I also found that teachers needed tools and frameworks to overcome barriers and improve their practice with respect to planning questions and developing good feedback strategies for inquiry and productive discourse. And finally, to support teachers' professional learning and provide access to timely and shared knowledge, I identified a need for general resources about questioning.

Table 3

Literature Informed Learning Needs

Learning Need	Literature Theme	Description
Information	Importance Practices/Barriers	General information about the importance of teacher questioning in the classroom setting including the history and background of this practice
Tools	Practices/Barriers Professional Learning/Design	Various tools and frameworks to be organized in one place that can help educators write questions and develop good feedback strategies
Self-Assess	Practices/Barriers Professional Learning/Design	Various tools to help teachers self-reflect/self-assess their questioning practice
Resources	Importance Practices/Barriers	Comprehensive list of references about teacher questioning practices, like articles, books, videos, websites, etc.

Understanding general information about how questioning is situated in teaching and learning as well as science and science instruction is an important learning need for the prototype to address. The literature provided a historical perspective of questioning as well as its significance in the science classroom. Some of the most basic patterns about questioning practices were identified in this part of the analysis, like number of questions asked each day and types of questions asked. I suspected that this information was something that most teachers

were not aware of, yet they would be interested to learn more about. Further, the information from the literature about the importance of questioning and its persistent patterns in practice provided a concrete way for teachers to self-assess their own knowledge and practice. For example, they could keep track of the number and type of questions they ask in one day of teaching as a way to start learning about their practice.

Further, in my experience I found that there are many great resources that already exist on questioning and discourse. However, they are not organized in an easily accessible space focused on science educators, thus my goal was to curate a selection of resources that is readily available for just-in-time learning about questioning and discourse in the science classroom. More specifically, I wanted teachers to be able to plan for discourse; including steps for writing good questions and also learn strategies about giving feedback so that they could start to break the habit of consistently using IRE questioning sequences.

Based on the learning needs identified, the initial learning goals were drafted in a paper prototype and are depicted in Figure 1. The paper prototype served as a quick sketch depicting preliminary ideas about website layout and design. Specifically, the paper prototype depicts an initial design that will meet the identified learning needs. Further, the paper prototype is intended to evolve through multiple rounds of design and increase fidelity of the final digital prototype (Brown & Green, 2016).

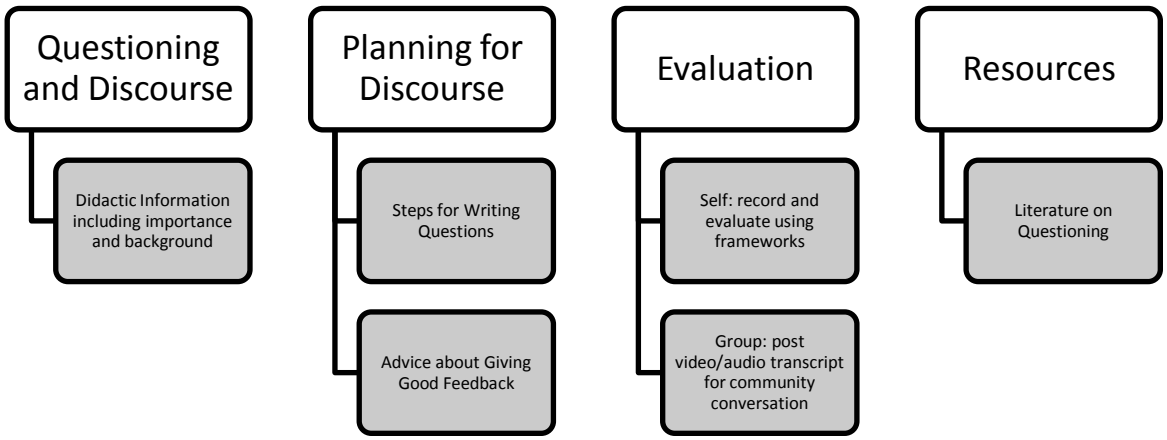

Figure 1. Literature informed prototype design that incorporates learning needs

Chapter 4: Phase 2 Interviews

Phase 2 of this study builds on Phase 1 with participant interviews and redesign of the prototype. First, I present the methodology of the interviews including sample selection, data collection and analysis. Second, I present the findings of the interview analysis. And finally, I discuss how the results of the interviews helped me refine teacher learning needs and the prototype design.

Methodology: Interviews

Interviews enabled me to gather a variety of perspectives that could augment and refine my understanding of teachers' learning needs with regard to questioning in middle school science. I completed interviews with 10 middle school science teachers, student teachers, supervisors, and university professors. The semi-structured interview protocol incorporated findings from the literature review completed in Phase 1 (Appendix B). The protocol focused on themes derived from the literature analysis, yet still allowed for the exploration of new ideas. Further, the interview protocol also asked for information about: demographics, knowledge of questioning practices, perceived needs, and preferred learning styles.

I utilized a purposeful selection approach (Creswell, 2018), identifying specific individuals from my professional network with the purpose of acquiring a variety of demographics. Participants were then recruited for an interview using an email flyer (Appendix C) I sent to the director or supervisor of the school, district, or program to forward to potential participants. A total of 20 institutions were contacted in five states about participating in this study and 15 individuals responded in two states. Due to the exploratory nature of this phase of the study and the stated goal of a variety of teacher and educator experience, I was more interested in the diversity of the sample and not statistical representation (Gyllenpalm, Wickman,

& Holmgren, 2010). I wanted to interview teachers with a range of experience from novice to experienced and also supervisors and professors. Of the 15 individuals, 10 individuals from seven different institutions in two states participated. The other five participants did not participate due to scheduling conflicts. Participants represent a wide range in many descriptors including age, education level, and experience teaching and/or supervising. Table 4 provides details on Phase 2 participant demographics.

Table 4

Phase 2 Interview Participant Demographics

Participant	Gender	Age	Education Level	Position	Total Years Experience
1	F	21	High School	Student Teacher	0
2	M	47	Master's Plus Credits	MS Science Teacher	17
3	M	39	Master's	HS Science Teacher & Instructional Coach	12
4	F	42	Associate's	Student Teacher	0
5	F	52	Master's Plus Credits	District Supervisor	20
6	M	68	Master's	University Faculty & Author	38
7	F	21	High School	Student Teacher	0
8	F	52	Master's	MS Science Teacher	20
9	F	27	Master's	MS Science Teacher	6
10	F	50	Master's Plus Credits	District Supervisor	28

Using the interview protocol, I conducted interviews with the participants to discern their knowledge of questioning and discourse and identify perceived learning needs. The interviews were semi-structured and digitally recorded for accuracy (Creswell, 2018). Interviews were conducted via telephone (9) or face to face (1) when possible. The interview data were analyzed following traditional qualitative methods (Creswell, 2018). First, I prepared the data for analysis by transcribing each interview. Then I systematically read through all the data including my

notes taken during the interviews. During the reading process I was able to get a general sense of the data and also take notes on my reactions and thoughts on participant responses.

Next, I deductively coded the data using my research questions and the themes identified in Phase 1 (Patton, 2002). The initial coding process yielded 78 codes and subcodes. I used a hand coding process with paper notes that I could move around on a vertical surface. I took the original 78 codes and continued to re-read the data and re-group codes until they were condensed into eight main codes and 13 subcodes organized by research question (See Table 5). The data were coded one more time with the finalized codes so I could utilize the data to make design changes and determine the next phase of needs analysis.

Table 5

Phase 2 Interview Codes by Research Question

Question 1	**Question 2**	**Question 3**
1. Awareness of research on questioning practice 2. Awareness of personal philosophy and beliefs a. Learning in general b. Questioning purpose 3. Awareness of Classroom Practice a. Goals of instruction b. Instructional practice c. Questioning practice	1. Prototype needs reported a. Design components b. Questioning knowledge c. Questioning skills 2. Prototype needs based on Question 1 a. Tools to examine personal beliefs b. Tools to help align goals and practice	1. Affordance 2. Constraint 3. Design Considerations a. Time/Autonomy b. Purpose Alignment c. Productive Experience

In an effort to increase the validity of the data, I utilized several approaches. First, to simply check for accuracy of representation, I had each participant review their transcript and make any changes as necessary. Second, I consulted with an external auditor (Creswell, 2018). I invited a professional teacher and researcher who is not associated with the project to read through the transcripts and codes and provide feedback and comments. This person helped

clarify connections in the data with the research questions and provided an objective view of the project as a whole. Specifically, they asked me to clarify how my findings answered my research questions and how these findings translate to identified teacher needs and the learning goals of the prototype.

Findings: Interviews

Based on the literature review, I structured the interview to determine if the learning needs I identified in Phase 1 aligned with the identified learning needs of educators in the field and/or identify new needs I had not considered. In this section, I explain the findings from the interviews and how these findings confirmed and broadened the themes identified in the literature review; 1) importance of questioning in teaching and learning science 2) questioning practices and barriers to questioning practice, and 3) professional learning opportunities and professional development design.

Importance of Questioning in Science Education

Participants confirmed the importance of questioning and questioning practices and its central role in the classroom. One veteran teacher commented on the importance of his questioning practices in the classroom, "questioning is at the core of teaching and education and learning and I think that students are not going to learn unless they have questions in their mind that they feel need to be answered." Another veteran teacher agreed, "it's where the whole thought process starts...I mean a question, you ask them a question and have them answer it." Student teachers also recognize the importance of questioning. One commented, "it is a way to make connections to their prior knowledge, prior units that we've done, and really build connections." Participants also confirmed that questioning is especially important in science as one student teacher noted, "in science you want them to be curious, it's a discipline that is based

on curiosity so you want them to ask questions." Additionally, when I asked participants to describe their goals for teaching and questioning, they offered detailed descriptions using terminology like; "scaffolded questions and leading questions," "guiding questions," "inquiry," "open ended," "higher level." According to study participants, science as a content area, necessitates curiosity and questioning, leading the participants to recognize the importance of questioning in instructional practice.

Questioning in Science Education: Practices and Barriers

Participants also described examples of questioning practices and what it should and should not look like. A young teacher in an urban school said, "I very very rarely ask questions that are like yes or no...higher order level questioning is huge in my classroom, I'm always asking...why questions or what do you think questions to get them really thinking." These ideas carried throughout the responses. Most of the educators commented that they try to steer away from "yes, no questions" and strive to ask more "thinking," "guided," or "scaffolded" questions. In general, the participants seemed very aware of their questioning practices in the classroom.

Further, the descriptions of teaching practice were rich with ideas on personal philosophy and beliefs about learning in the classroom. From the literature review, personal philosophy and beliefs were identified as a possible barrier to practice. However, interview participants expressed beliefs that encouraged questioning and discourse. For example, one student teacher described learning in the classroom as, "hands-on, there should be conversation, talking, there should be inquiry...when you give them the opportunity to explore like that on their own rather than just take knowledge from the teacher, I think it is worth more for them." Many of the participants expressed similar ideas including a desire to lead interesting, student driven classrooms. They described this with comments like, "get kids excited about science," "to find a

way to make science interesting," "inquiry-based," "hands-on, and fun," "science identity development," and "an interest and love for science." Participants expressed personal beliefs not associated with barriers, but rather, beliefs served to encourage quality questioning practices.

Professional Development Needs

Participants reported both content learning needs and design delivery needs. Participants self-reported that they need the prototype to be: convenient, interactive, and content specific. However, in addition to these self-reported needs, the findings from the analysis implied that they also need tools for self-assessment and planning.

Participants confirmed the need for the prototype to be convenient because they have limited time for professional learning as indicated by the literature review. One novice teacher commented that she would like something she could, "go at my own pace" and do "at 11:30 at night," "something I can pop in and out of." All participants mentioned that they would prefer the structure of the prototype be an informal, "online tutorial." They want to access the information when they have time and can fit it into their schedule.

Participants also want the prototype to be interactive. One novice teacher talked about a desire to connect with an instructor so they could "get feedback" about their practice, while another veteran educator wanted to connect with other teachers and "learn from each other." Other participants also talked about how they would like to interact with the content of the prototype. For example, they would like to read or watch something and then write a response to what they learned. Overall, each participant mentioned at least one way they would like the prototype to be interactive, expanding on what was learned from the literature review.

Another theme expanded on by participants was specificity. They want content, examples, and videos to be specific to science. Participants mentioned their own learning about

questioning, but it usually happened during professional development in a general sense, or in another subject altogether. What participants want to see are "examples of questions" and "testimonials" on questioning practices in science. Most of all, participants want videos. One veteran teacher explained:

> To be able to watch someone...little video clips of a classroom, because inquiry is so big now and I feel lost, like I don't know what I am doing, it could be that I have been doing it all along, but it could be that I haven't, so... to see...a science teacher with excellent science questioning techniques would be very helpful.

Every participant immediately mentioned videos of others teaching as the resource they would like to find on a prototype about teacher questioning.

In addition to these self-reported needs, tools for self-assessment and planning were implied as a need for educators. Two supervisors mentioned that they would hope to find these tools, but others did not. This was not surprising as people are not always aware of what they need. From the literature, it is known that teachers are generally unaware of the number and types of questions they ask, they spend little if any time reflecting on their questioning practice. Further, it has been shown that quality questioning is supported by question planning prior to classroom instruction. Therefore, I asked direct assessment questions that would help me identify needs participants may not realize they have. These needs were identified by both what participants said and also, in part, what they did not say.

Although participants were able to describe their practice and beliefs about their questioning practice in a very clear and articulate way, when I asked direct questions, all participants struggled. Interestingly the one question that threw everyone off the most was "How many questions do you ask in one day?" One veteran teacher remarked, "Oh my gosh! If I had a

dollar for every question I asked, I could retire. A lot, I mean I couldn't really put a number on it." Another veteran teacher added, "I would think I ask a lot, but I have never counted them up." Others who took a guess reported that it is probably somewhere around 100, but they were not sure, and surprised at themselves for not knowing. One such teacher commented, "it's weird to think about...I think it's way more than 100 per day."

Another direct assessment question I asked was whether participants planned questions ahead of time or asked questions spontaneously in the classroom. All experienced and veteran teachers did not plan ahead of time. Instead the lesson plan and questions were "in my head" as a result of "experience" with the content and anticipated student experiences with the lesson. However, supervisors and novice teachers talked more about the need to plan. They mentioned, "being prepared" and "having a back-up."

Discussion: Teacher Learning Needs & Prototype Design

When designing learning experiences it is important to align the goals and objectives with learning needs; not overlook necessary learning experiences participants need to meet the identified goals; and result in improved knowledge, skills, and performance (Queeny, 1995; Silberman & Auerbach, 2006). Findings from the interview participants informed the design process in two key ways. First, I was able to confirm and broaden my understanding of teachers' learning needs. Second, I used this understanding to create learning goals and revise the prototype design accordingly.

To align the goals of the prototype with identified learning needs, I first reconsidered the learning needs identified in Phase 1 considering the new information from the interviews. The learning needs identified in Phase 1 were: 1) importance of questioning in the classroom setting including history and background of this practice; 2) reflect on practice and be able to

collaborate by evaluating questions in a private and/or public space; 3) make tools and frameworks available to teachers for planning questions and developing good feedback strategies; And 4) share a comprehensive list of references about teacher questioning practices. The original prototype form Phase 1 that depicted the design to meet these learning needs is shown in Figure 1 (p. 32).

However, based on the analysis of the interviews, I determined that teachers do in fact have a strong sense of the importance of questioning in the classroom. And, while they are somewhat reflective about their practice, it is more general than the literature suggests it should be. Interview participants were able to describe their practice in general terms, but struggled to give specifics when asked about the number and types of questions they ask. Additionally, the interviews also confirmed the need for tools and frameworks that can help teachers plan their questions. This was evidenced by the fact that question planning seems to be tied to experience with more experienced teachers planning fewer questions than novice teachers.

Following the ADDIE model of design, I identified learning needs in Phase 1 and then modified these needs in Phase 2 as part of the needs assessment and analysis (A) phase of the ADDIE model. Further, as a result of Phase 2, I began to identify learning goals based on learning needs as indicated in the design (D) phase of the ADDIE model. The 3 new learning goals for the prototype that align with the learning needs identified in Phase 1 and refined in Phase 2 include:

1. Assess personal questioning practice
2. Plan for and write questions
3. Share information and/or experiences with others

Further, I created a set of design questions that would continue to drive the design process:

1. How does a teacher's background and professional setting affect needs?
2. What are teachers' perceptions of their questioning practice?
3. What are the realistic time constraints for participants?
4. How can I make the design adaptable for a variety of needs with respect to content* and delivery**?

   *Content: What do participants need to learn about teacher questioning practices?

   **Delivery: How will participants interact with website? What tools do they need to be successful at interacting with the website?

Finally, I also made changes to the paper prototype to reflect the newly identified learning goals. The new goals are represented in the revised paper prototype design (Figure 2).

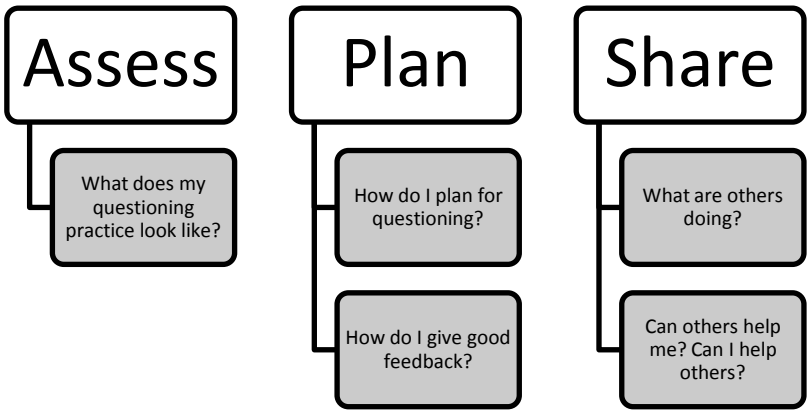

Figure 2. Interview informed paper prototype design based on new learning goals

Chapter 5: Phase 3 Survey

Phase 3 of this study builds on Phases 1 and 2 and uses the results from an anonymous survey to redesign and digitize the prototype. First, I present the survey methodology including sample selection, data collection and analysis. Second, I present findings from my descriptive statistical analysis of the survey responses. And finally, I discuss how the survey results helped me refine teacher learning needs and the prototype design.

Methodology: Surveys

In an effort to gain more specific information about teacher learning needs that will inform the development of prototype materials, I created a survey protocol (Appendix D). The anonymous survey was designed to collect information related to teacher demographics (Q 2-10), questioning practices (Q#11-16), professional learning opportunities and time constraints (Q#17-22), content needs specific to teacher questioning practices (Q#23-36), and preferred content delivery mechanisms in an online space (Q# 37-45).

The survey was closed response meaning participants had to choose from existing responses. Unlike an open-response survey, which seeks to gather new ideas, a closed response design asks participants to select a choice from a predetermined list, which helped me narrow decisions about the prototype design. At this point in the ADDIE process, I needed information that would inform the development (D) of specific activities and content that will help users meet the identified learning goals. I asked participants to describe the level of importance of certain design components. For example, "How important is it that a website about teacher questioning practices is connected to Common Core Standards?" However, because I was concerned that participants would describe everything as "important" or "not important" I also asked participants to rank these same topics, which proved useful for making design decisions. For

example, 73 % of respondents noted that it is moderately to extremely important that "a website about teacher questioning practices provide suggested books and articles about teacher questioning", which would lead me to focus on this in the design. However, 56% also ranked this as the least important resource that would help them implement and/or change their questioning practice when compared to other options. This process helped me understand the relative value of various design components and make design decisions that reflect both reported and relative values.

Participants for Phase 3 were recruited using purposeful sampling of possible school districts, colleges, and universities with a population of middle school science teachers and supervisors, pre-service science teachers, and university professors. However, because this phase of the research was anonymous, I did not "select" participants. Additionally, to capture a larger sample ($50<n<100$) I posted the survey to the NSTA (National Science Teachers Association) General and Middle School Science list servs. As a result, 94 people completed partial surveys and 66 completed the entire survey. Demographics of the 66 completed participant surveys are summarized in Table 6.

Analysis of the survey results included descriptive statistical analysis to determine percentages, means and ranges of the demographic information and closed responses (Creswell, 2018). While this type of analysis does not identify statistical relationships between data points, it does help to describe the participant group as a whole and facilitate identification of priorities and next steps for online prototype design and development.

Table 6

Phase 3 Survey Participant Demographics

Gender		Age		Education Level		Check all that apply Position		Grade(s)		Subject(s)		School Location		Size		Type	
Female	54	20-29	5	High School	0	MS Science Student Teacher	1	Six	28	Biology	26	Urban	27	Small	35	Public	48
Male	12	30-39	20	Associate's	0	MS Science Teacher	56	Seven	39	Chemistry	16	Suburban	31	Medium	22	Charter	4
Trans-gender	0	40-49	12	Bachelor's	10	Science Supervisor	4	Eight	46	Physics	14	Rural	8	Large	9	Private	6
Other	0	50-59	18	Master's	14	University Professor	8			Earth Science	27					Religious	7
Prefer not to answer	0	60-69	10	Master's + Credits	31					General	46						
		70+	1	Doctorate	11					Other	14						
Total	66		66		66		69		113		143		66		66		65

Findings: Surveys

A total of 66 completed surveys were collected. The majority of survey respondents were female (82%) middle school science teachers (81%) between the ages of 30-39 (30%) and 50-59 (28%). They mostly teach 8th grade (40%) General Science (32%) and have at least a master's degree (21%) with more having a master's degree plus credits (47%). They teach in mostly small (53%), urban (41%) or suburban (47%) public schools (74%).

Participants reported that they ask an average of 33 content questions (ranging from 5-240) in one day of teaching and the percent of questions planned range from 0 to 100. Only two participants reported that they did not plan any questions and one reported that they planned all their questions. The remaining responses are fairly evenly split: less than 50% of questions planned (23 responses), about 50% (19), and more than 50% (20).

The majority of respondents (96%) consider themselves to be somewhat to very knowledgeable about teacher questioning with the majority of these selecting moderately knowledgeable (41%). Initial learning about teacher questioning practices mostly occurred in formal learning environments; pre-service coursework (38%) and professional development (32%). However, the majority of participants do not rely on these methods when they have a question about their own practices. Instead they rely on colleagues (35%) and academic research (21%). And, when asked to complete the sentence, I find questioning to be... they responded that questioning was "essential" (48%).

With regards to professional learning opportunities, respondents reported an average of 11-15 hours available from their employer for professional development (PD). Additionally, about half of the respondents can self-select their PD about 50% of the time. However, in the past year, 23 respondents (35%) have not participated in PD about questioning at all and 27

participants (41%) were only able to participate for 1-5 hours. And while participants consider learning about questioning to be a moderate (52%) to high (35%) priority, opportunities for PD on questioning in the past year are non-existent; 0 hours (38%) or limited; 1-5 hours (39%).

Participants responded that there is a need for both shorter (1-30 minutes) and longer (45 minutes to more than 1 hour) sessions about teacher questioning (42% and 41% responses respectively). They also indicate that learning about questioning practices should focus on specific content (i.e. Biology, Chemistry, etc.) (65%) over more general practices (11%) or grade specific questioning practices (24%). The survey participants also preferred to connect with other teachers about content (38%) or state and content (52%), but not only by state (6%).

Respondents also ranked preferences on content for the website (Figure 3). Respondents reported that they consider "tools to plan questions for classroom discussions" the most important (48% ranked this #1) over "tools to self-assess questioning practices" (37% ranked this #2), "resources on teacher responses and feedback" (29% ranked this #3), "alignment with teacher evaluation models" (44% ranked this #4), and "connections to common core standards" (48% ranked this #5).

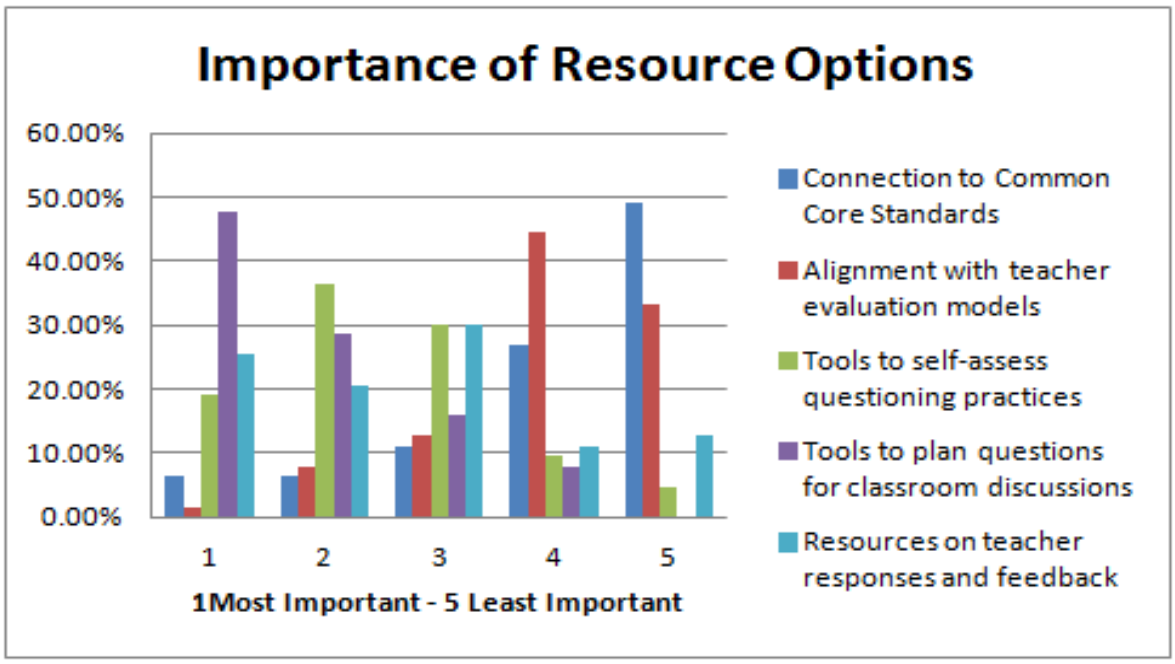

Figure 3. Importance of resource options 1

In a separate ranked question, respondents reported preferences about available website resources (Figure 4). These include (in order of ranking from 1 most important to 5 least important): Videos of teachers modeling questioning techniques (35% ranked this #1); sample questions used by teachers (35% ranked this #2); informational videos on questioning techniques (38% ranked this #3); sample lesson plans/units used by teachers (27% ranked this #4), and suggested books and articles about teacher questioning (56% ranked this #5).

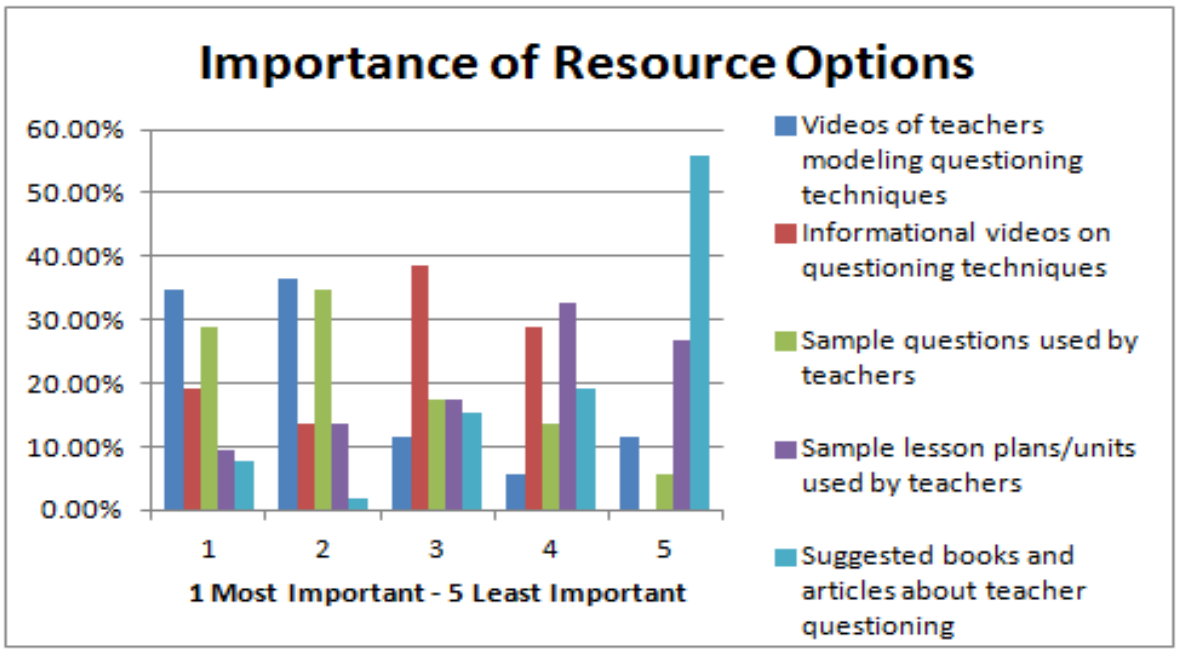

Figure 4. Importance of resource options 2

When it comes to website delivery, respondents reported that they would like an informal, self-paced, online learning environment; however, 27 respondents indicated they would like little or no instructor involvement and 33 wanted an instructor available. While participants responded that the opportunity to practice questioning and receive feedback was moderately important, it was unclear whether respondents prefer feedback from an instructor or a peer and whether they prefer a public or private feedback space.

Further, while the majority of respondents have never posted a video of their teaching (79%), they are split on whether or not they would in the future. Of the 66 participants, 29% said it was unlikely, 26% were neutral, and 27% were likely, with 14% reporting it would be extremely unlikely and 5% would be extremely likely. What is more clear is that participants believe it is moderately to extremely important to provide tutorials about how to record classroom conversations (64%) and also tutorials on how to upload and share videos on a website (47%).

Discussion: Teacher Learning Needs and Prototype Design

Information from the survey allowed me to further develop the prototype design and transition the prototype from paper to the online learning format. Specifically, I needed to align the teachers' learning needs with the goals and objectives of the prototype, taking into consideration the affordances and constraints of the online format. For example, the online nature of the prototype allows for a broad range of participants and easy access. Participants would be able to consult at any time with others in remote locations thus affording an easily accessible, "just-in-time" learning environment that fits into their busy schedules (Queeney, 1995). However, the online nature of the prototype also creates possible constraints. There could be limitations regarding access to technology and/or needs that cannot be met utilizing an online format, such as observations and immediate feedback from peers and/or an instructor.

Based on the survey results, I confirmed that most teachers recognize the importance of questioning as "essential"; however, they have not had many opportunities to learn about teacher questioning and are interested in learning opportunities. Further, they confirmed the need for an informal, self-paced, science content focused prototype. The survey participants also confirmed that they need tools to plan questions, want opportunities to collaborate with peers, and they need access to videos of quality questioning practices in science classrooms. These findings confirm what was identified in Phase 1 in that teachers need explicit instruction in questioning and discourse facilitation to improve their practice (Hackling, Smith, & Mercia, 2011; Oliveira, 2010a**;** Parker & Hurry, 2007). Further, professional development should be flexible, to adapt to teacher needs (Forbes & Davis, 2010) and include time for reflection and peer collaboration (Garet et al., 2001; Lebak & Tinsley, 2010; Marshall et al., 2010; Scribner, 1999). Also, videos are an effective tool for professional development in questioning and discourse (Lebak &

Tinsley, 2010; Oliviera, 2010b).

In addition to confirming previously identified needs from Phase 1 and Phase 2, the survey results broadened the scope of identified teacher learning needs. Participants clarified their collaboration needs with an option to interact with others, including instructors and/or peers. However, the results were mixed about a need for feedback from other prototype users. Also, the survey revealed that while most teachers want to view videos of other teachers, they are not comfortable sharing their own videos and would be unlikely to post videos of their teaching. Further, general resources like books and articles as well as connections to student learning standards and teacher evaluation models were identified as least important for improving questioning practice.

The goal of this phase of the research was to continue to with the ADDIE process and revisit and modify the identified learning needs (A) and learning goals, activities, and content (D) identified in the needs assessment and design stages in Phases 1 and 2. Further, the survey results were used to begin the process of developing (D) actual content and materials. Based on these results, I revised the design questions to include:

How can I make the design adaptable for a variety of needs with respect to content and delivery?

1. Content:
    a. What makes the sample activities easy to follow and applicable for immediate use? Are there too many or too few activities?
    b. Are the tutorials clear and easy to follow? Why? Why not?
1. Delivery:
    a. How does the focus of the home page layout affect motivation to enter the site?

b. What makes the most sense for the organization of shared tools and samples? For example, should they be embedded in the page they are about? In a separate area? Should they be in both? Is there a preference for curated or open material? Why?

To help create a working online prototype, I hired a website designer. I made this decision for two reasons. First, while I designed the content, I do not have computer programming expertise or technical and logistical knowledge necessary for website design like registering a domain etc. And, while I could learn these skills, it would take considerable time and perhaps not reflect a high professional standard. So, with the goal of having a functioning online prototype, I felt it was best to hire a professional website designer to guide aspects where I lack expertise.

At this point in the design process, I decided on a name and general layout of the prototype. I went back to the goals and objectives: assess questioning practice, plan for and write questions, and share information and/or experiences with others, which lead me to the name: The Question Connection (www.questionconnection.com). This name best reflects the purpose of the website: a place where educators can learn about questioning practices and connect with each other to share information and resources.

Also, I designed the original concept for the home page to align with the identified goals (Figure 5). However, I added a section to provide a self-guided or assisted option to enter the site from home page (Figure 6). I wanted users to be able to interact comfortably with the website. Also, the survey results were mixed with regard to feedback. So I created a space where users can select feedback preferences. If they don't want feedback they can work in self-guided mode and those who want feedback can select assisted.

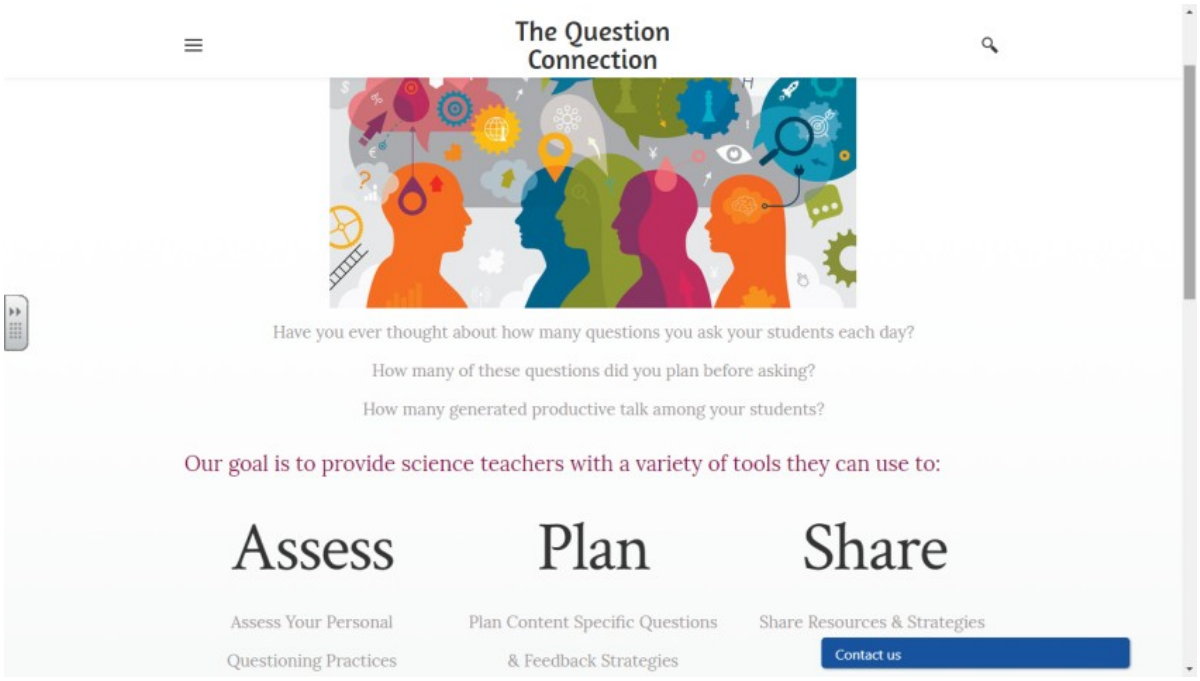

Figure 5. Original concept Home page

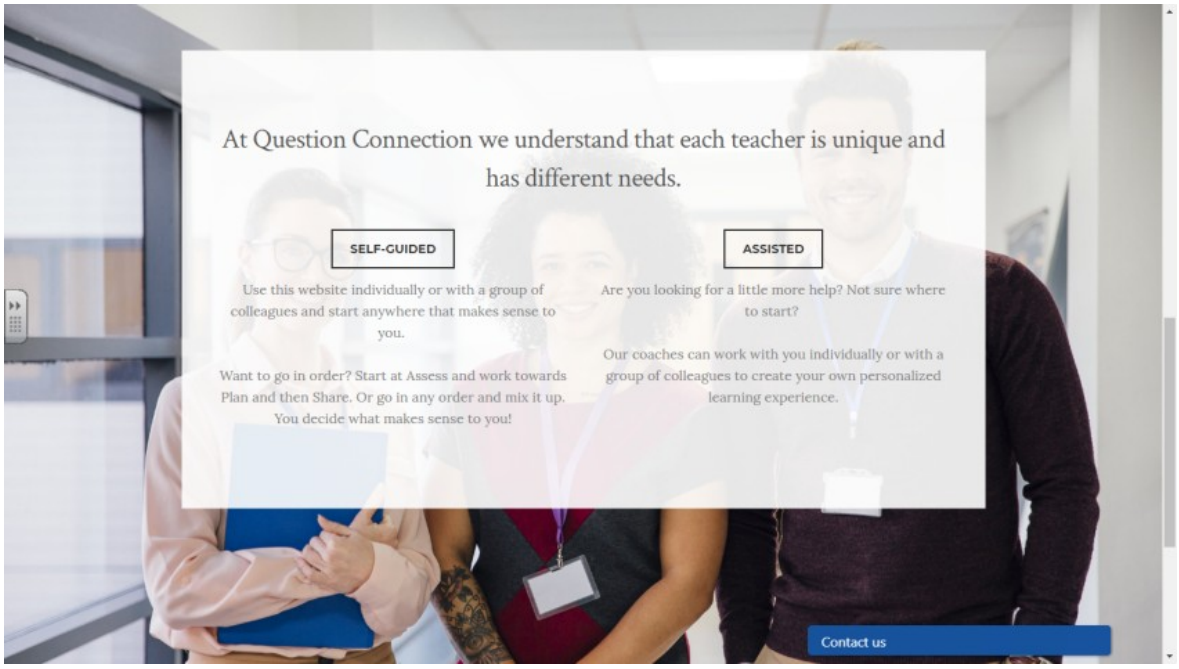

Figure 6. Home page website entry options

Given the participants survey responses, I knew the tutorials and information needed to

be clear, simple to follow, and immediately useful. Originally, I designed the Assess and Plan pages to include written information, however, it quickly became apparent that this amount of text could be overwhelming (Figure 7 & Figure 8). As a result of viewing the written text on the Assess and Plan pages, I decided to change the prototype once more to eliminate the written text and instead include narrated PowerPoints that play as video content under Assess (Figure 9) and Plan (Figure 10).

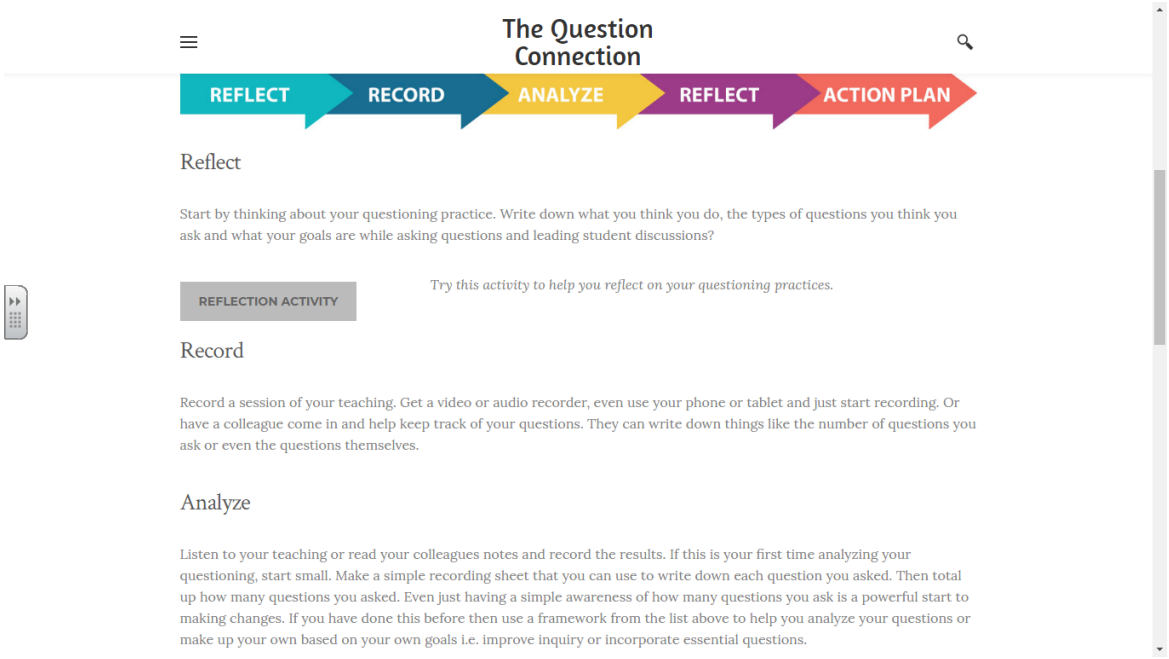

Figure 7. Assess page with text

Figure 8. Plan page with text

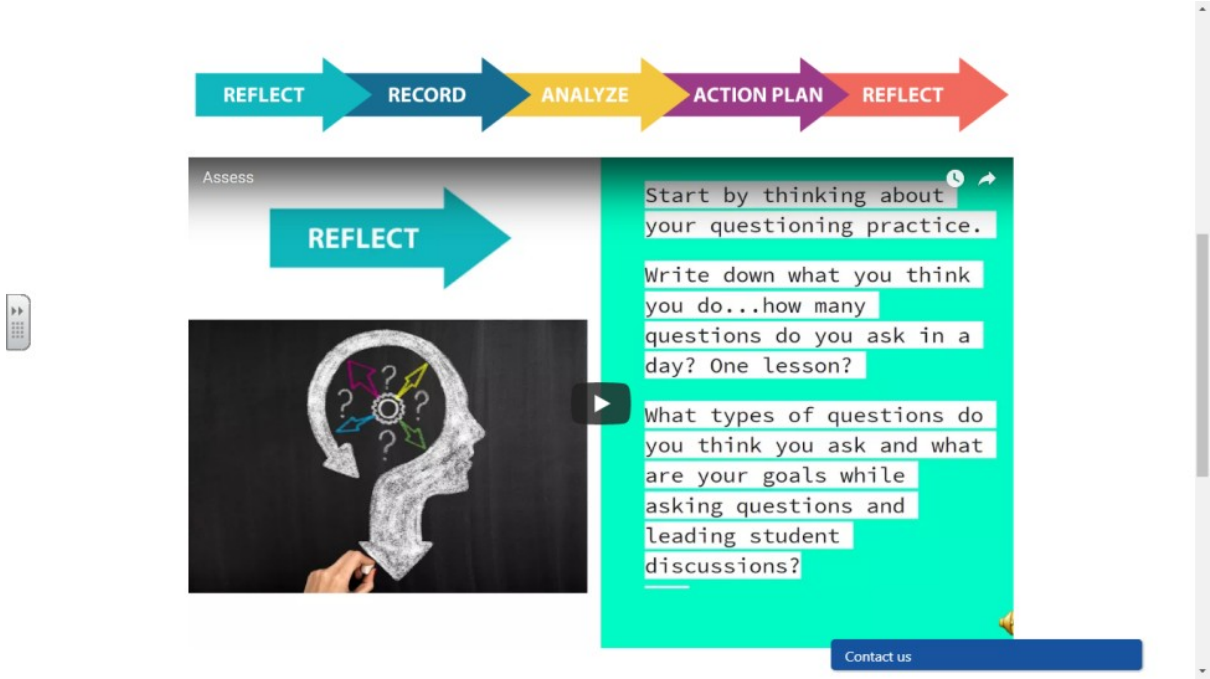

Figure 9. Assess page with video

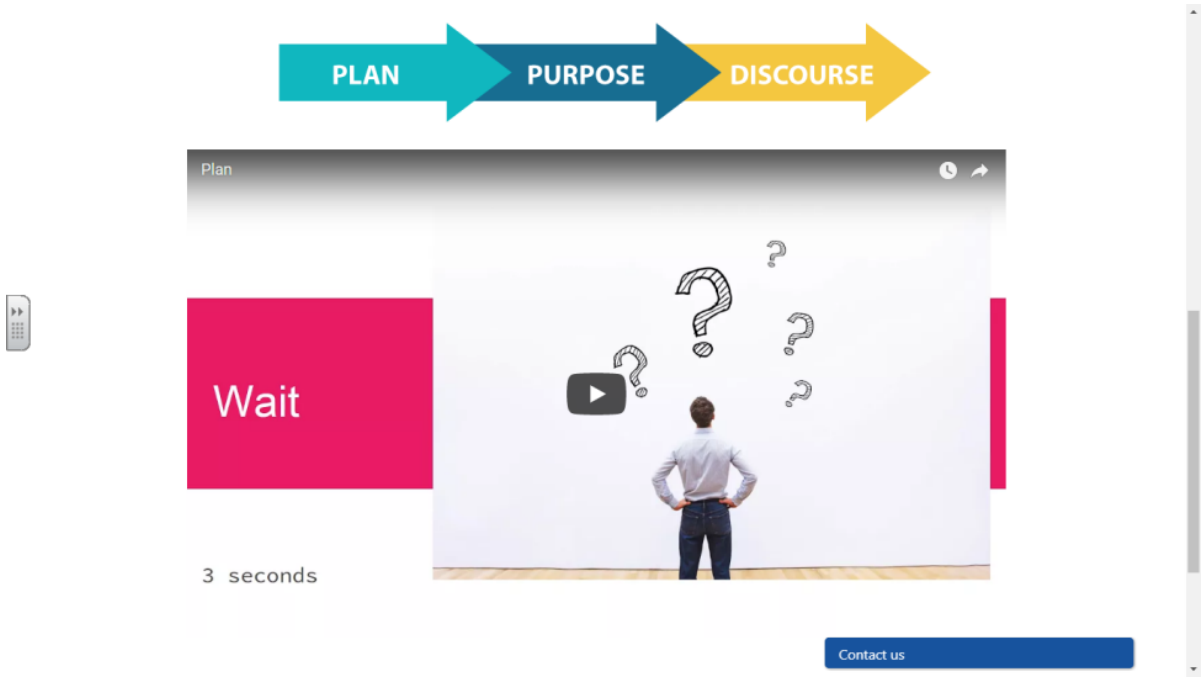

Figure 10. Plan page with video

Finally, based on the identified teacher learning need to create a content focused design, I created two options for the organization of shared material as well as a general resources page. I wanted to further investigate participants' definition of content and organization preferences. For purposes of user-testing, I called these options Share 1 and Share 2. In Share 1 (Figure 11) content was organized by modality; sample questions, videos and transcripts, and general resources. And Share 2 (Figure 12) was organized by discipline; biology, chemistry, physics, earth science, general science, and STEAM (Science, Technology, Engineering, Art, and Math). The general resources page, called Resources (Figure 13) included frameworks, books, articles, websites, and tutorials. Originally, I did not include a Resources page in the design based on its low priority ranking from survey results. However, before I removed it, I decided to test its purpose and usability with the users.

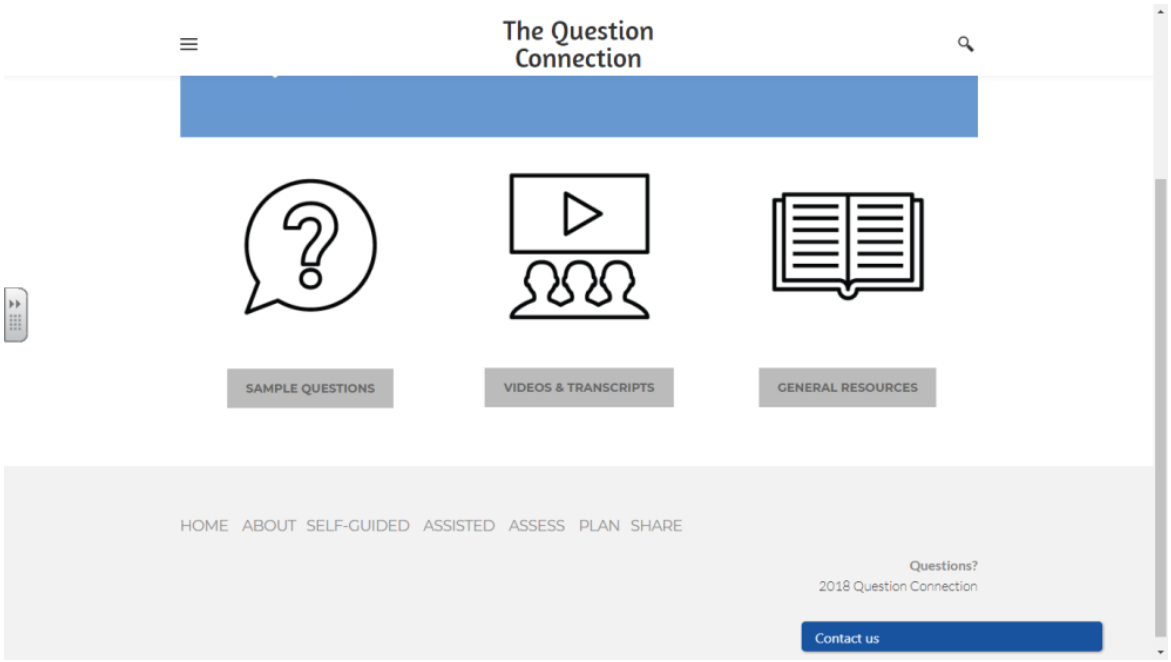

Figure 11. Share 1 page

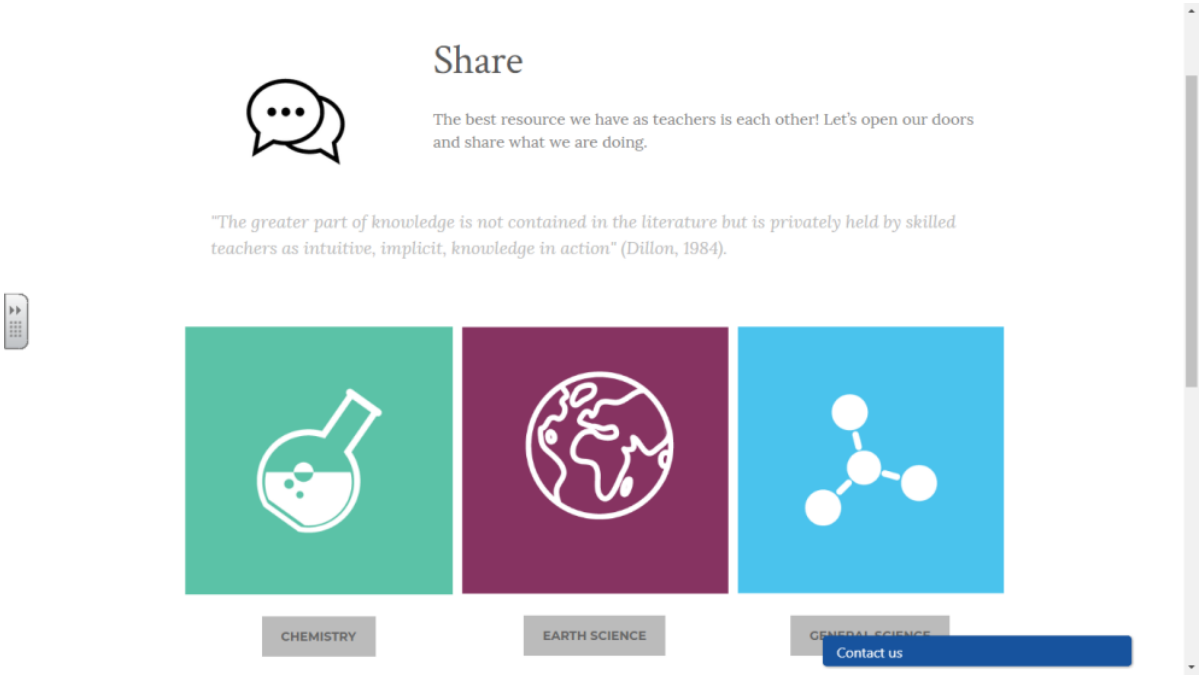

Figure 12. Share 2 page

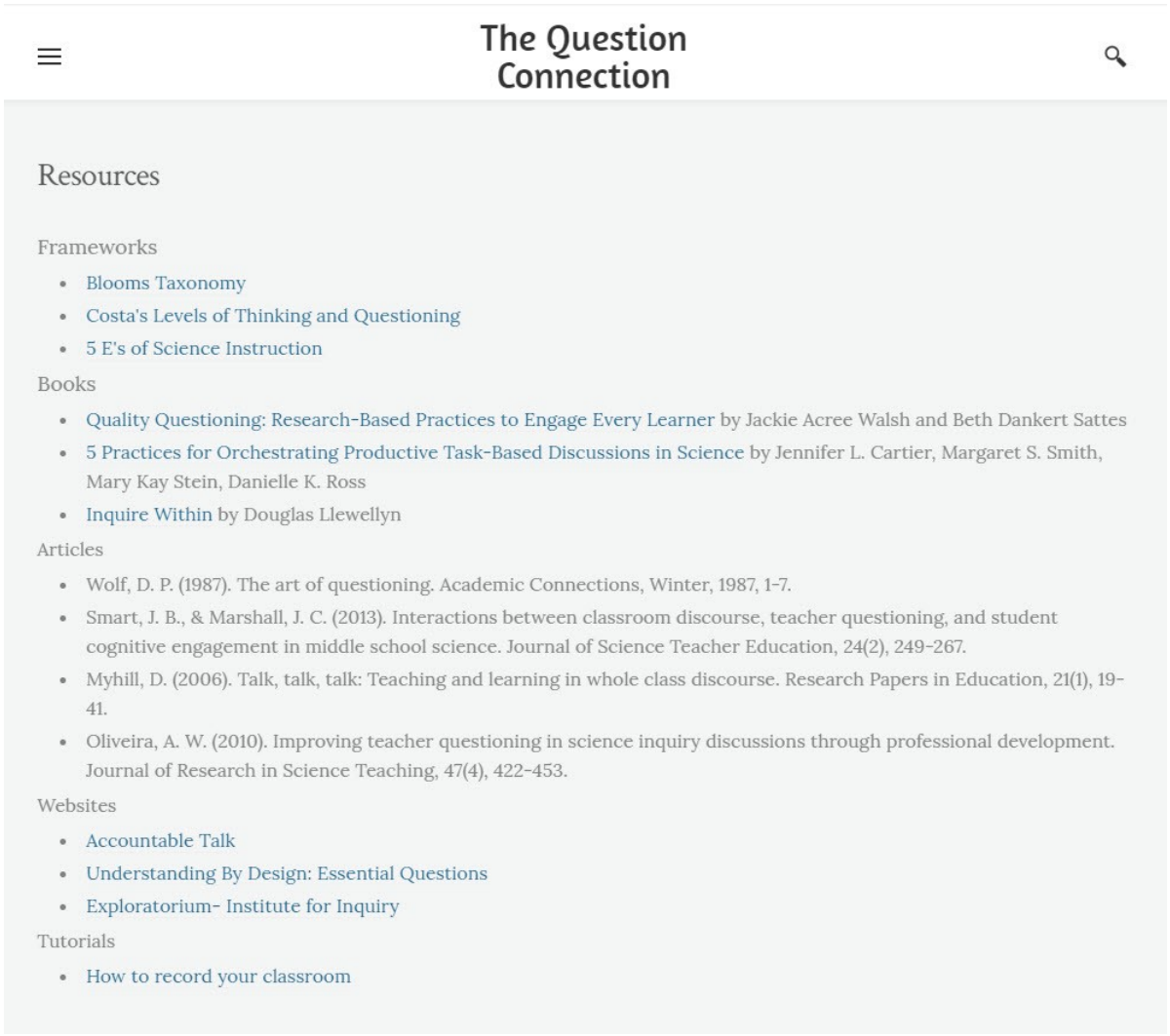

Figure 13. Resources page

Chapter 6: Phase 4 User-Testing

Phase 4 of this study, user-testing, builds on Phases 1, 2, and 3 and informs redesign of the prototype. First, I present the methodology of the user-testing including sample selection, data collection, and analysis. Second, I present the findings of the user-testing. And finally, I discuss how user-testing results helped me refine teacher learning needs and the prototype design.

Methodology: User-Testing

Once the working prototype was completed, I collected additional data through two rounds of user-testing with one round of design modifications in between rounds. Participants for Phase 4 of this study were recruited from the original group of 10 interview participants. Of the 10 contacted, seven responded and five ultimately participated. The remaining two were interested but had to cancel because of time conflicts. Also one new participant was recommended by a previous participant for a total of six participants, three for each round of user-testing. Demographics collected for the participants included gender, age, level of education completed, current positions (teacher, student teacher, etc.), grades, subjects taught, and school setting (i.e. size, relative location, and type). Demographics of the six participants are summarized in Table 7.

Table 7

User-Testing Participant Demographics

Participant	Gender	Age	Education Level	Position	Grades	Subjects	Location	Type	Size
1	F	50-59	Master's	MS Science Teacher	7	Chemistry	Suburban	Public	Medium
2	F	50-59	Master's Plus Credits	District Supervisor	K-12	All	Suburban	Public	Large
3	M	70+	Master's Plus Credits	University Faculty & Author	6-8	General	Urban	Public	Large
4	M	50-59	Master's Plus Credits	MS Science Teacher	8	Biology/Physics	Suburban	Public	Medium
5	F	20-29	Master's Plus Credits	MS Science Teacher	7-8	Biology/General	Urban	Public	Small
6	F	40-49	Master's Plus Credits	MS Science Teacher	6	Earth Science	Suburban	Public	Large

During user-testing, participants engaged in concurrent think aloud (CTA) (Cooke, 2010) in response to a semi-structured user-testing protocol (Appendix E). A CTA is when users verbalize their thoughts while using the computer prototype to navigate the site. The user-testing protocol had five scenarios designed to test the usability of the prototype and the impact of the design on identified learning needs. The five scenarios for the first round of user-testing addressed: 1) general online learning experiences and overall first impressions of The Question Connection, 2) availability of self-guided and assisted options, 3) ease and usefulness of Assess and Plan page information, 4) preference for Share page options, and 5) Resources page organization and openness of Share page content. These sessions were video and audio recorded and were conducted by video conference via Go To Meeting (4) or in person (2). In person, I was able to watch the participant use the website on a shared computer. During the videoconferences I had the participant share their computer screen with me, so I could see what they were doing on my computer screen.

The data analysis in Phase 4 focused on identifying themes for content design modification and usability needs as well as identifying themes for future research. To accomplish this, I took extensive field notes during and after user-testing. I took additional notes while reviewing all video and audio recordings. After the first round of user-testing, I modified the prototype design as well as the user-testing protocol, adapting the original scenarios. Specifically, scenario four, the Share page scenario was revised to focus on the usability of the new layout and include a "post" feature. Additionally, scenario one, now included reactions to the new About page. The second round of user-testing was completed with participants # 4-6 as described above and followed the same procedure and analysis as the first round.

Findings: User-Testing

Findings from both rounds of user-testing interviews resulted in three general themes about content and prototype usability: purpose, interaction, and organization of material. Each theme is subsequently described using examples from user-testing scenarios. Descriptions of how these themes impacted the design of the prototype after both rounds are described in the following section.

Purpose

Participants talked about purpose as it relates to overall design and feel of the prototype, the purpose of different resources and activities, and also the purpose behind the creator of the prototype. When asked what they would expect to find after hearing the name, The Question Connection, participants had a variety of responses. Some wondered, "Is it science? For teachers? For kids?" and "What does it connect to? Classroom practices? The types of questions teachers ask?" While others remarked, "A place where teachers can come and gather information, reinforce plans they already have, like a community" and "Connection signifies community based." This indicates that the name hints at the purpose, connecting to a community; however, the focus on middle school science community is not obvious.

As participants navigated the resources and activities, they continued to comment on the purpose of the prototype. Specifically, they wanted the purpose of the prototype and activities to be clear and easy to find. In general all participants, teachers and supervisors, have limited time and want clear learning goals presented quickly rather than searching for information. One supervisor noted, "I'm a little impatient, I don't have a lot of time to watch the video," while one teacher agreed, "I am a super impatient person and I just want the resources." Many reported enjoying the prototype's simplicity: "I like the cleanliness of it, it is not busy, so busy I don't know where to go" and "It's clean, I don't feel overwhelmed, not too much information on each

page." They also identified a need for more information, to clarify the purpose of some resources and activities. For example one teacher asked, "Is this what the video is about?" and another asked for more information about questions in general on the Assess and Plan pages to "get the premise of what's going on here."

Overall participants agreed that they want to connect with the person behind a website so they can better understand the purpose of the prototype. One person noted, "I like the voice, but want to connect with the person; I would like a split screen with the person talking." Another said, "It's nice to see a face; it's more user friendly." After the About page was added another participant commented ,"it makes me more comfortable, feels like I am talking to a real person." These comments suggest that the website's overall purpose is better understood and more accessible when connected to a real person.

Interaction

Interaction emerged as a theme in two ways: with whom and how. As mentioned above in relationship to purpose, participants expressed a desire to connect with the person behind the content of the prototype. This theme persisted as they wondered who they would be talking to with the "chat live now" option and the "question form" on the Assisted page. They expressed a need to learn more about me as the creator and potential coach. Additionally, they wanted to interact with other teachers and build a community. Participants reported, "it's good to be able to post and get feedback" and "the more community the better." At the same time, some thought it could be too open, saying "when it is open to the masses, you are not sure if you are getting accurate information...it has to be monitored" and "it should be vetted information, not teachers pay teachers." These comments indicate that some teachers prefer peer learning experiences, while others want more formal information from research and experts.

Participants also appreciated the choice of interaction presented in the prototype. For example, in response to finding the Assisted option on the Home page they commented, "oh wow, cool, assisted or guided" and "oh that's nice, I like structure... and like to be told what to do." Others who prefer to be self-guided appreciated not being forced to receive assistance. They stated, "I would expect to be totally bored while someone takes me through step by step when I could do it myself" and "I am self-guided; I don't want to be bothered by assistance." Having the option to be self-guided or assisted was an important learning need for participants. Participants also commented on the timeliness of interactions. For example on the Assisted page, they were concerned about how long it would take to hear back from someone after filling out the "question form." Participants reported, "generally I steer away from waiting; I love the chat live now option" and "if I have a question right now I could get an answer and not have to wait." Being able to connect with others, if and when you want, to get feedback, and in a timely fashion were all highlighted as important learning needs during interaction with the prototype.

Organization and Usability of Content

To assess whether content organization facilitated usability I asked participants about three facets of the prototype design. First, I asked participants to view and assess Share 1 and Share 2. I also asked participants to assess the usability of content presented in a video in contrast to content presented via narrative text on the Assess and Plan pages. And finally, I asked participants to assess the usefulness and feasibility of sample videos.

Unanimously all agreed that the Share 2 page layout, which organizes material by science discipline, is the preferred method of organization. They also agreed that the information presented in Share 1 is useful and I should "combine them." The prototype should have the Share page first broken out by discipline (i.e. Earth Science) and then by modality (i.e. Sample

Questions). These results reinforce the idea that the prototype design should be content focused.

Overall, content organization was clear and engaging for participants. After selecting self-guided on the home page one participant stated, "beautiful, it's simple and highlights what I was interested in on the homepage." Remarking on the headings Assess, Plan and Share, another teacher noted, "productive talk, good verbage, gets my attention." Participants also were intrigued by the overall content. "I don't care how long you have been teaching, you need to reassess." Another said, "I'm interested, what kinds of questions do I ask? How many do I ask? The wait time…" and "I want to try videotaping myself, it's made me question my questioning." However, there were mixed reactions to content presentation on the Assess and Plan pages. Some enjoyed having material presented in a short video. One teacher commented, "perfect! Too many words, I don't want to read that, so a video is better," and another noted, "it breaks up the monotony of reading." However, others mentioned that four minutes is too long and they would have preferred text they could "skim through faster." And one teacher wanted a little of both. She liked the video, but also wanted text and resources that could enhance the content of the video.

The need for sample videos was confirmed in each phase of this study. It was presented first in the literature review and has persisted as an identified need throughout the interviews, survey, and now user-testing. All participants agreed that carefully selected videos are necessary for learning about teacher questioning. They want to see both "good" and "bad" example videos that are narrated so they are sure to notice what is important about questioning. However, they also all agreed that the reality of posting videos is complicated. Most mentioned legal concerns about posting videos of their teaching and all talked about the vulnerability of doing it. One teacher commented on posting a video, "It's a big thing, teachers don't have that comfort level of sharing their work with one another. It's part of society. Teachers get so much backlash about

how awful they are, so why put themselves out there." Another teacher added, "your career is on the line...there would be hesitation about putting everything out there." And while they are "skeptical" of "canned" videos they felt at this time, "even if it is not as organic, it is better if the video has been vetted...teachers would feel safer."

Discussion: Teacher Learning Needs & Prototype Design

After the first round of three user-tests, I identified three areas that needed re-design based on the collective participants' learning needs. These changes included; condensing and restructuring the Share and Resources pages (Figure 14), building out additional options for the Assisted page (Figure 15), and creating an About page for users to connect with a person and learn more about the purpose of the prototype (Figure 16).

As previously mentioned I presented two Share page options to the first group of user-testers. Because they all agreed, after the first round of user-testing I changed the Share page so it became combined Share 1 and Share 2. Share 2 became the new first layer of the Share page. Selecting a discipline, now brought the user to the next layer, the original Share 1 page. By combining the two pages into one sequence, participants were able to focus sharing content first by discipline and then modality. This change created a more usable space where people did not have to "weed through all the biology stuff" as one participant remarked. At this time, I also added the comment boxes under Sample Questions and Resources so participants could experiment with the functionality of creating a post in each discipline. Further, I condensed the Resources page material into the Share pages. The original Share and Resources pages seemed to be competing with each other about the same type of material. Moving the content from the Resources page into the Share page under each discipline and keeping the Sample Questions and Video options reduced the competition between the two pages.

Also, as a result of the first round of user-testing, I changed the Assisted page to include a "chat live now" feature. The first three users all commented that they would be less likely to use the original "question form" and that they would like to have their queries answered in the moment. Even though the "chat live now" button is not activated, I added it to get feedback in the second round of user-testing.

The final change I made after the first round of user-testing was to add an About page. Again all users wondered about the purpose of the prototype and the "person" behind it. I designed a brief "bio" and attached a picture so participants could connect with me and put a face and overall purpose with the prototype.

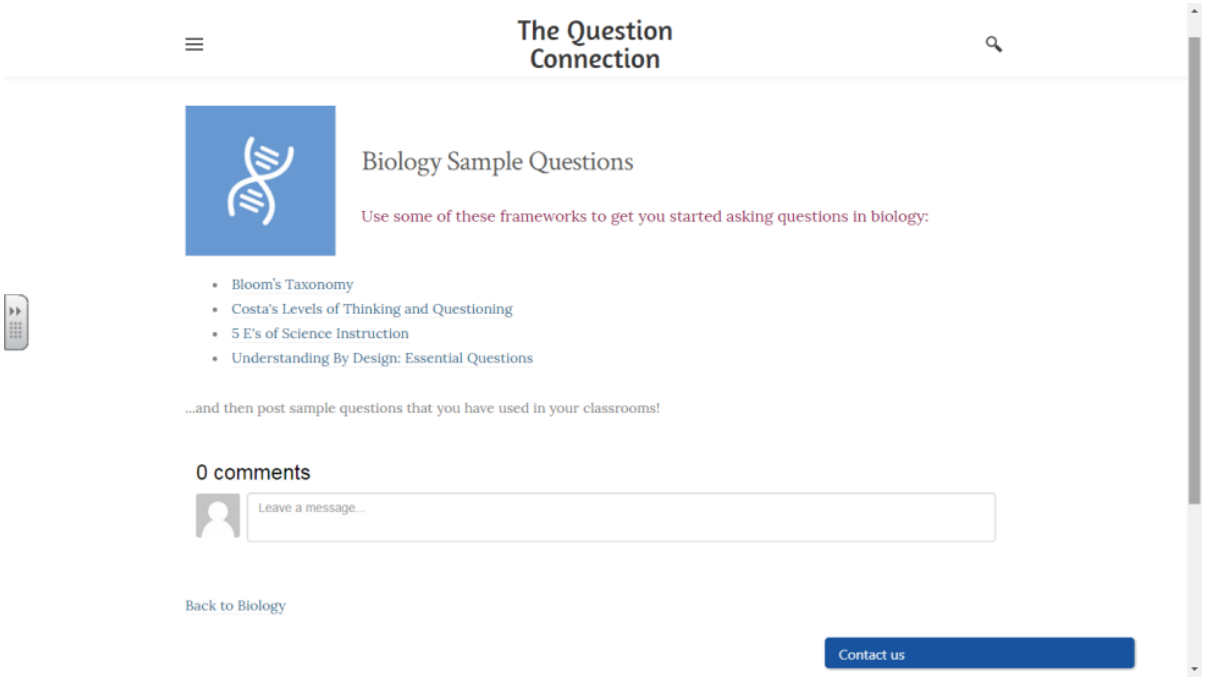

Figure 14. Restructured and condensed Share and Resource page

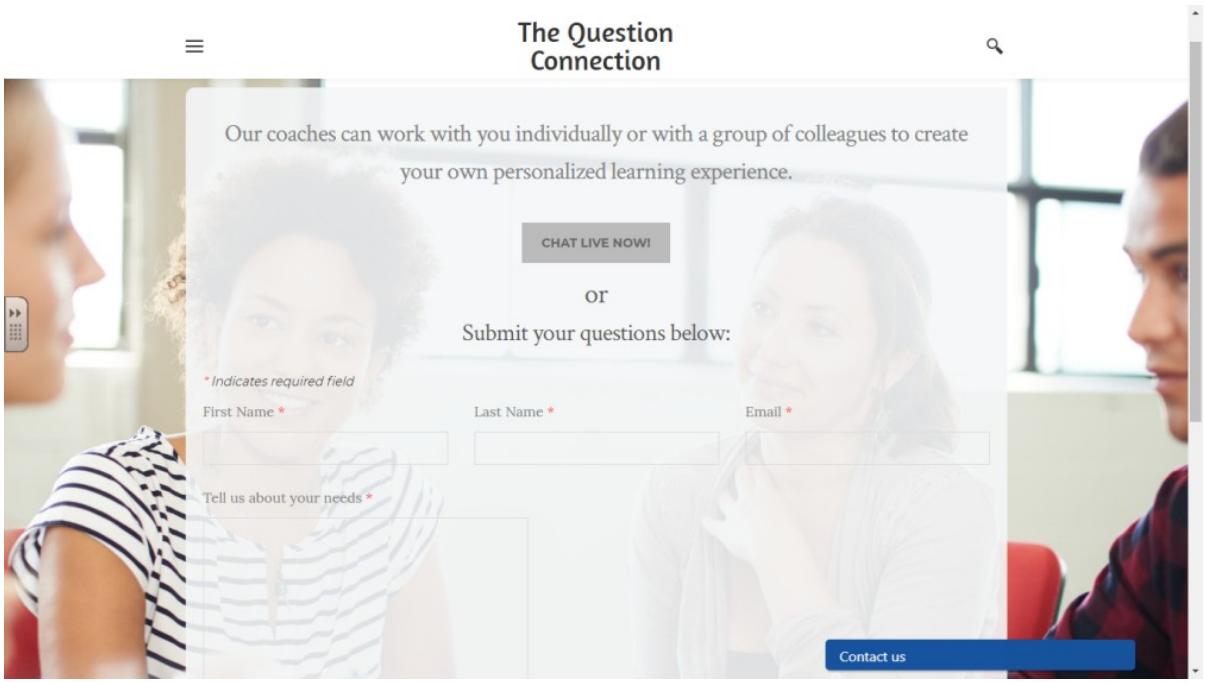

Figure 15. New Assisted page options

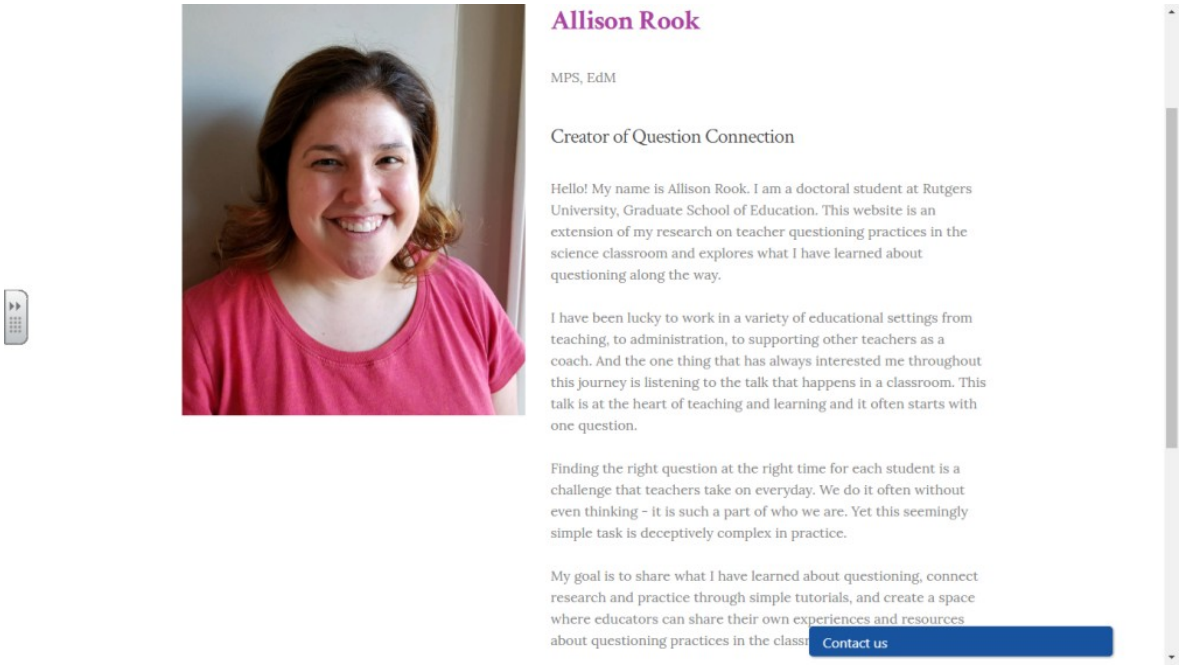

Figure 16. New About page

After the second round of user-testing, I refined the Assisted page once more to clarify the purpose of connecting (Figure 17). I also added more explanatory annotation and resources to

the Assess and Plan pages including tools, frameworks, and books and articles (Figure 18 and Figure 19). Finally, I built out the Sample Questions option for each content area page, see example in Figure 20. This helped to further organize material and also link to NGSS by utilizing headings from the standards.

During the second round of user-testing, participants still agreed that having the "chat live now" option was a good idea. However, they were confused by why both the "chat live now" and "question form" were on the assisted page. It was clear by their reactions to this page that these options needed to be clarified. Thus, after the second round of user-testing I restructured the page and added simple language to distinguish the purpose of each option.

I also added more information and content to the Assess and Plan pages. Participants reported that the purpose was still unclear, asking, "what is the video about? Where are the tools that will help me assess and plan?" In response, I added an introduction to each video on the Asses and Plan pages and I also added tools and frameworks to the bottom of the page so they are more readily accessible than when they were buried in the Share page. Based on the feedback, I wanted to make selected resources available for just-in-time learning yet prevent people from immediately going to a Resources page without working through the learning activities.

Finally, I further organized the Sample Questions sharing page by NGSS topics. Users noted a preference for organizing material by topic within a discipline. So for example in Earth Science they could find lessons on Space Systems. I decided to utilize the topics identified in NGSS as a starting point as it would be familiar to a wide range of educators all over the country.

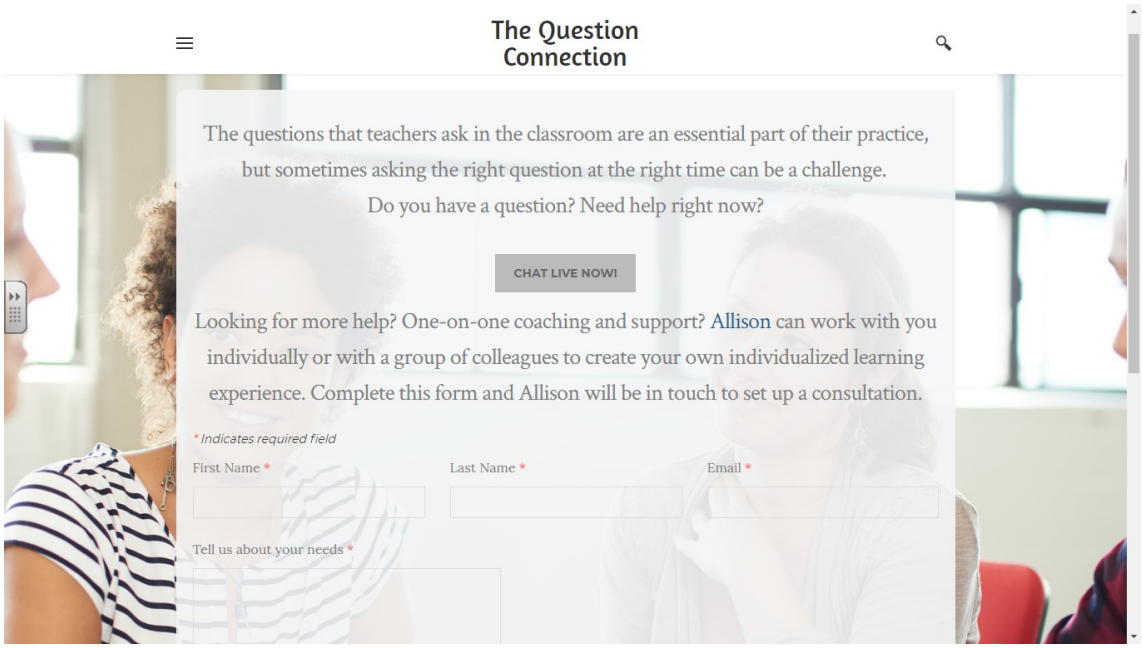

Figure 17. Assisted page with clarification

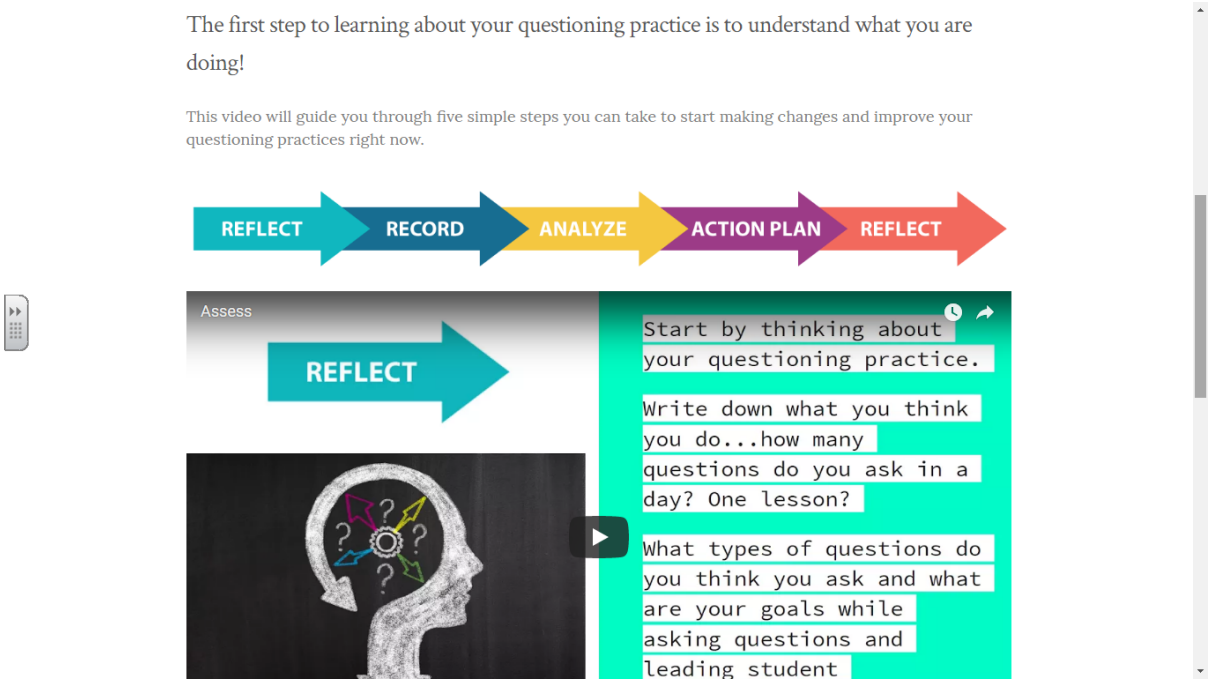

Figure 18. Example of purpose clarification on Assess page

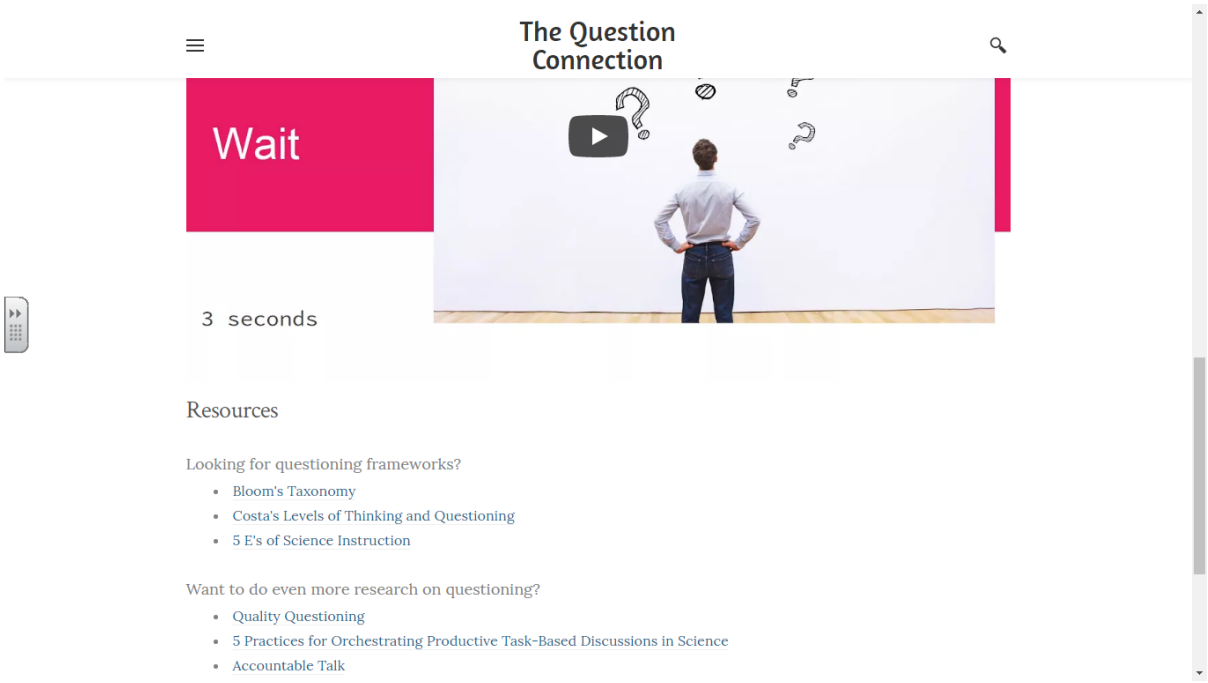

Figure 19. Example of added resources Plan page

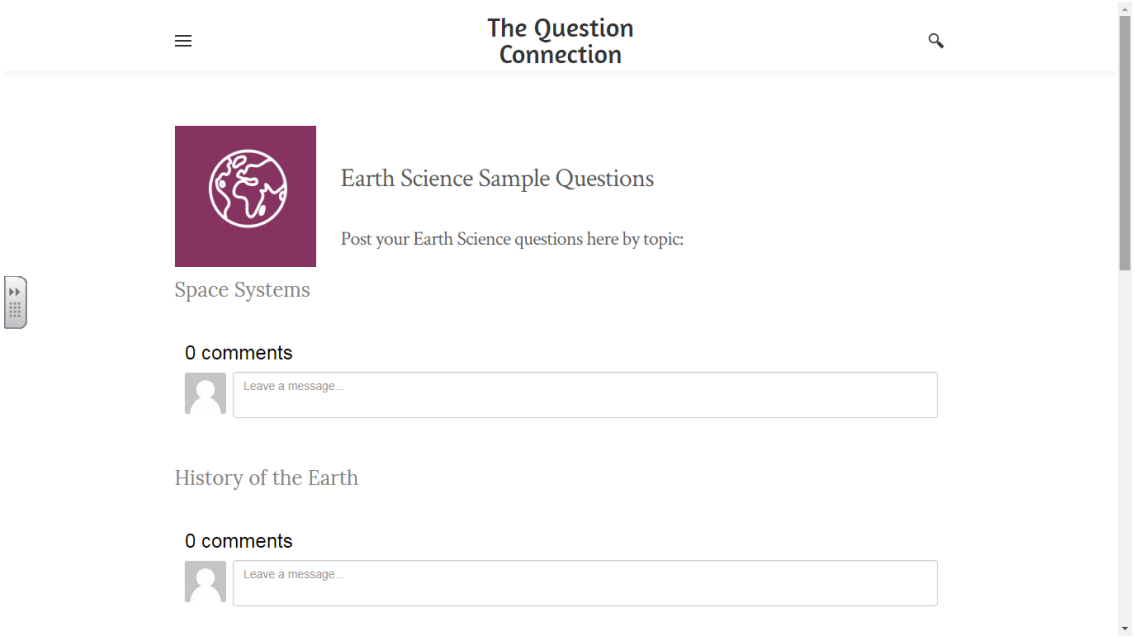

Figure 20. Example of Sample Questions page

Chapter 7: Overall Prototype Design, Next Steps, and Implications

The purpose of this design study was to investigate teachers' learning needs and design a just-in-time, informal, online professional development prototype for science educators that supports effective questioning practices to facilitate discourse in the inquiry-based science classroom. Specifically, this study investigated the following research questions:

1. What do inquiry-based science teachers need to know about questioning practices that will help them facilitate learning discourse?
2. What components are needed in an online prototype to support immediate application of teacher questioning and discourse skills for inquiry-based science instruction?
3. How will the affordances and constraints of an informal online environment affect the design of this prototype?

To accomplish my goal of investigating these research questions, I followed a multi-phased iterative needs analysis and design process. The process included an analysis of existing literature, interviews with selected middle school science educators, anonymous surveys, and user-testing of the working prototype. This process is depicted in Figure 21.

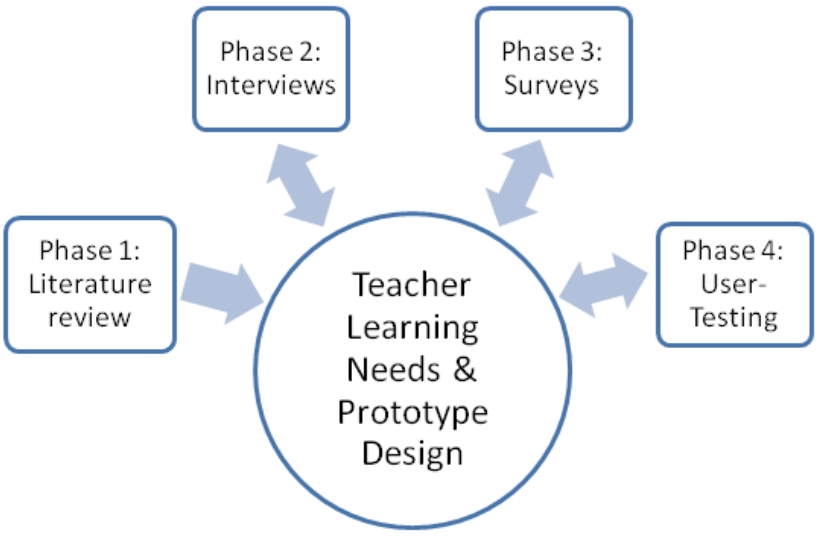

Figure 21. Iterative needs analysis and design process

In this section, I take a comprehensive look at the overall prototype design and how it meets the identified learning goals. First, I describe the alignment of the prototype design with the identified learning goals. This is followed by a discussion of next steps for the design and development of The Question Connection. And finally, I conclude with a discussion of the implications for future research.

Alignment of Learning Needs, Goals, and Design

As a result of four iterative phases of needs analysis and design, I identified three learning goals for teachers about questioning and discourse: 1) reflect on and ASSESS their own questioning practice, 2) PLAN for and write quality thinking questions, and 3) SHARE with others by sharing information and/or experiences. I also learned that teachers would like to learn about questioning and discourse in an online format that is informal, self-paced, and an individual experience with the option to collaborate with others. Thus, this lead to the basic layout of the online prototype design including the following pages: Home, About, Self-Guided, Assisted, Assess, Plan, and Share. In this section, I present the design of the prototype by page and explain how each page addresses the learning goals that emerged from the four-phase needs analysis.

The Home page of The Question Connection was designed to convey a look and feel of science teaching including themed graphics and images of diverse teachers. It also includes a set of questions to orient the user to the prototype content and pique their interest about the available learning opportunities. I also highlighted the three main learning goals: Assess, Plan, and Share with icons that are used throughout the prototype. The purpose of using the icons is to provide a quick, cohesive, recognizable visual for easy navigation by the user. Additionally, I built in user preference options, Self-Guided and Assisted, with explanations of each option so that users can

select their level of engagement with an instructor or "coach". These options were also added to the main menu for easy accessibility and navigation. Figures 22 and 23 depict the final design of the Home page.

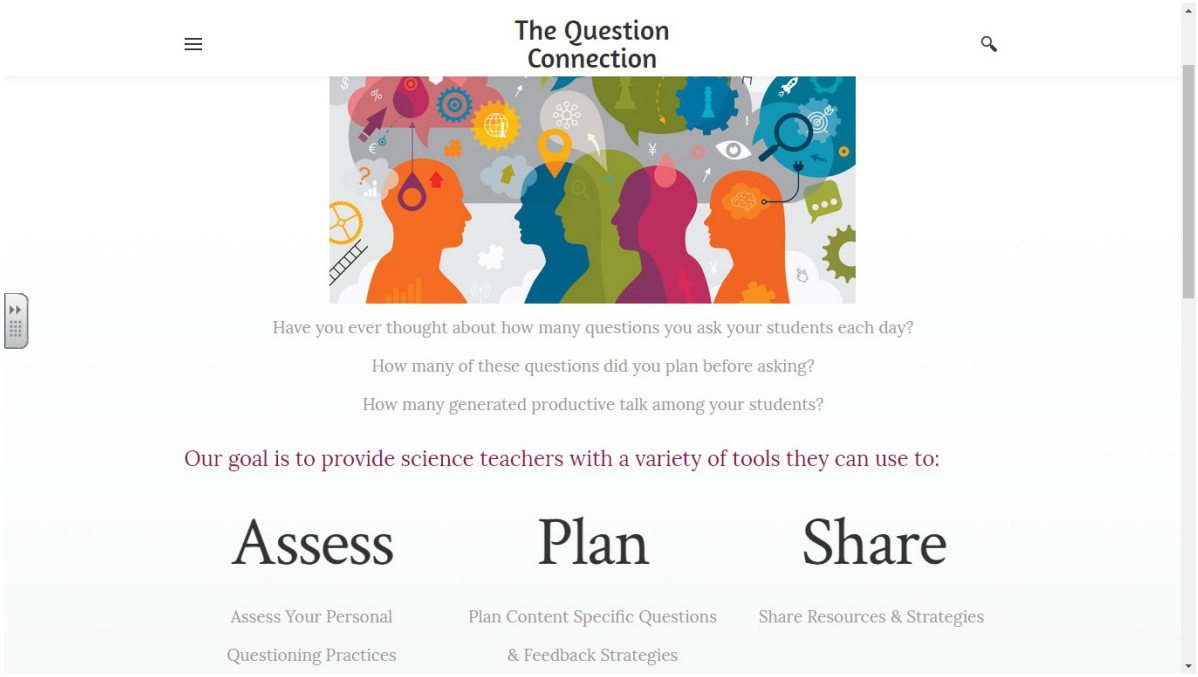

Figure 22. Final Home page design

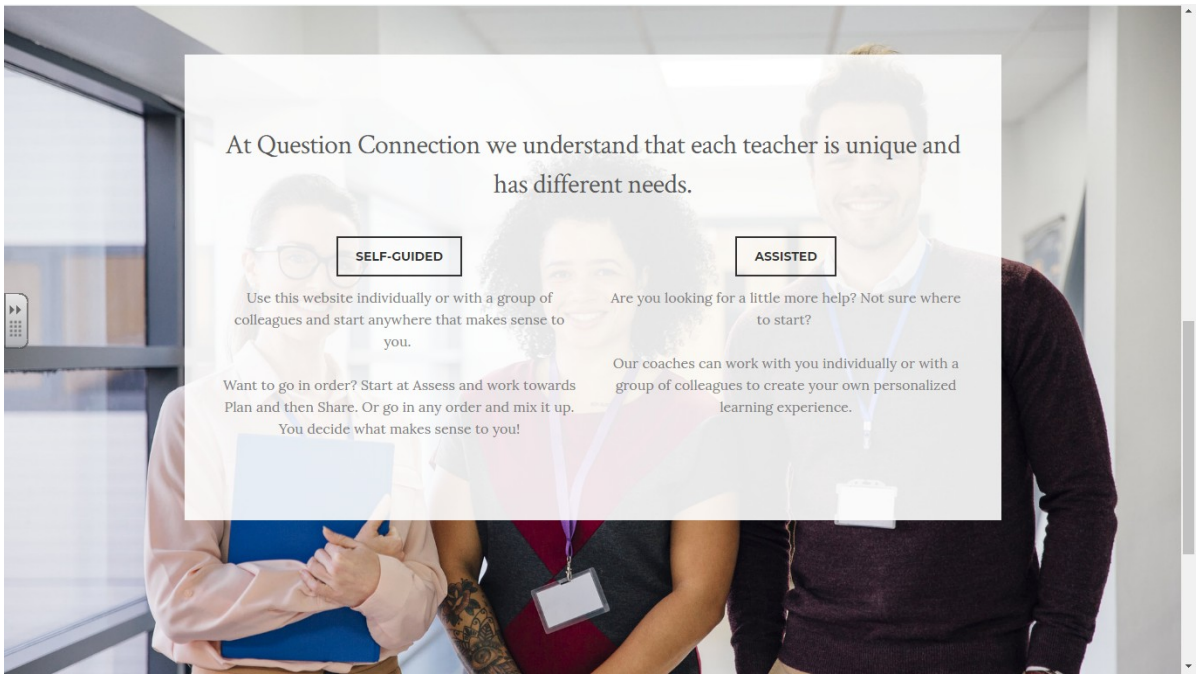

Figure 23. Final Home page design continued

The About page was added after the first round of user-testing. I had identified that teachers needed to collaborate to better learn about questioning and discourse, however, user-testing highlighted that users wanted an option to engage with a "coach" and also to know about the coach's background and expertise. While the first prototype design included an Assisted option, it did not state who would actually assist users. Instead it was a "question form" that users filled out and then wait to be contacted. And while they liked the option to connect, they wanted to know with whom they would actually be talking. Thus I created an About page that briefly describes my professional background, my goals for the prototype, and it includes my picture to make it more personable and relatable. Figure 24 depicts the final design of the About page.

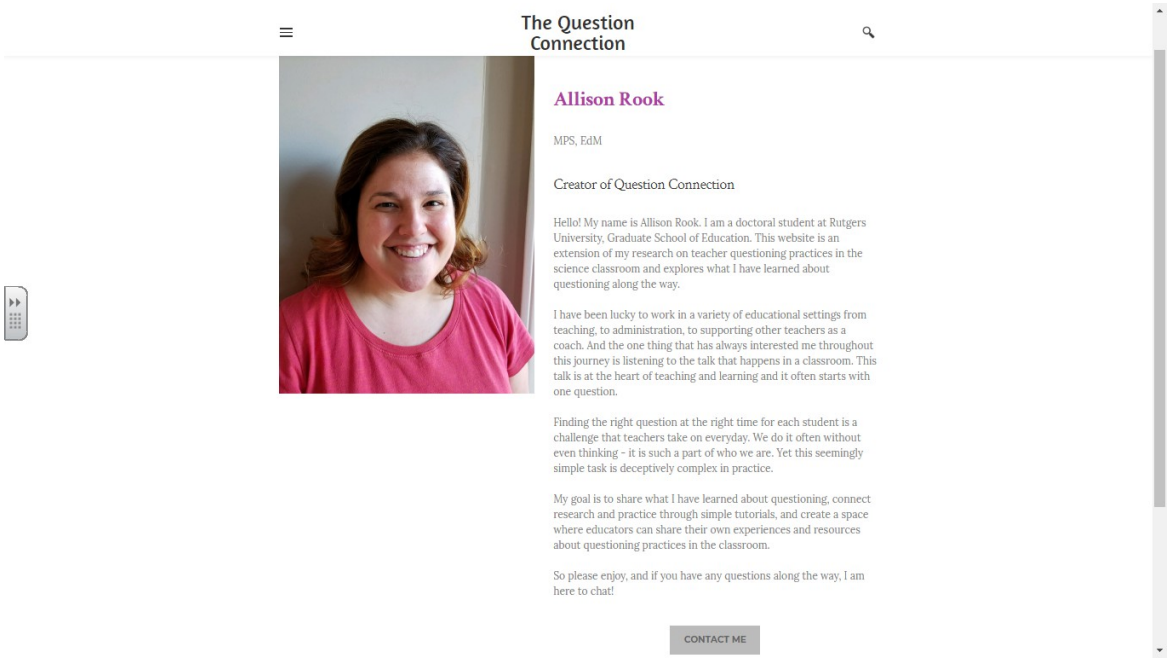

Figure 24. Final About page design

The design of the Self-Guided and Assisted pages was a direct result of learning preferences identified by survey and user-test participants. Early on, I identified that the

prototype design needed to be adaptable for a variety of teachers in a variety of settings. Thus, I created two options: one that allowed users to work independently and a second that provided assistance. Additionally, these options provide flexibility on the amount, type, and timeliness of information learned. Teachers who are motivated to work on their own will find general resources that help them make simple adjustments to improve their questioning practice. However, if teachers are interested in making more significant changes, they can connect with an instructor or "coach" for personalized, in-depth training. Also I redesigned the assisted page to include a "chat live now" feature in response to user-testing, which also affords collaborative, just-in-time learning needs. Figures 25 and 26 depict the final design for Self-Guided and Assisted pages.

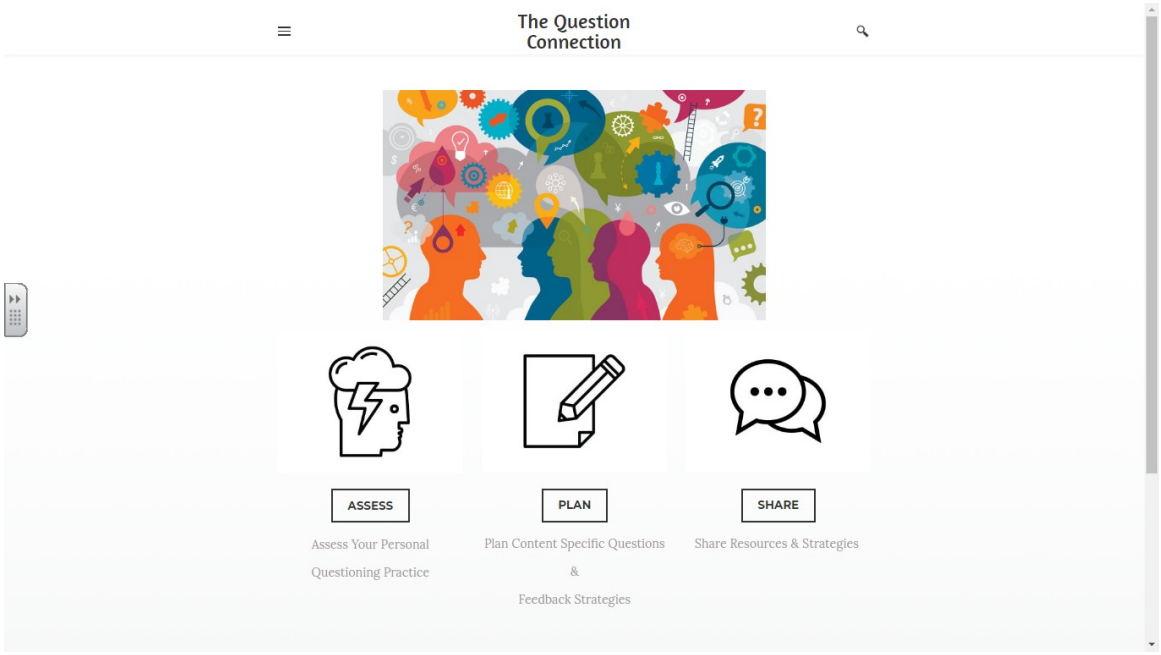

Figure 25. Final design Self-Guided page

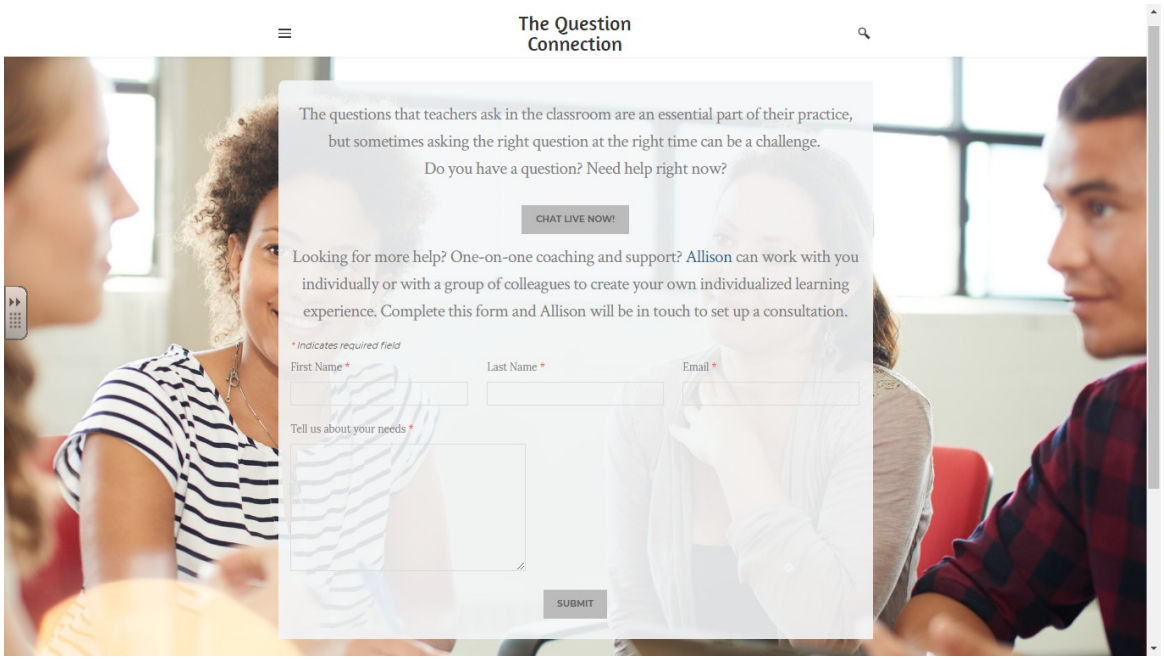

Figure 26. Final design Assisted page

Creating the content for the Assess page of this prototype was challenging. The personal nature of reflection makes it hard to identify specific information that will facilitate the reflective process for a general audience. One limitation of an informal online space is that teachers can simply avoid completing the activity. Therefore, I designed this page to create a "need to know" with the statements and questions like; "teachers ask anywhere from 300 to 400 questions each day" and "how many questions do you ask each day?" From the beginning, I decided to “chunk” information into five manageable steps: Reflect, Record, Analyze, Action Plan, and Reflect. I then created a graphic for this process to increase clarity and coherence for the user. Next, I created a narrated PowerPoint to explain the five step process. Text from the PowerPoint was made available as an Assess tool that could be downloaded and printed to work offline (Figures 27 and 28). These design decisions kept the page clean and simple to use. After user-testing I discovered that participants appreciated the simplicity, however, they wanted more contextual information. Thus, I added introductory text explaining the purpose of the video as well as links

to additional tools and resources that could facilitate just-in-time learning. Figures 29 and 30 depict the final design for the Assess page.

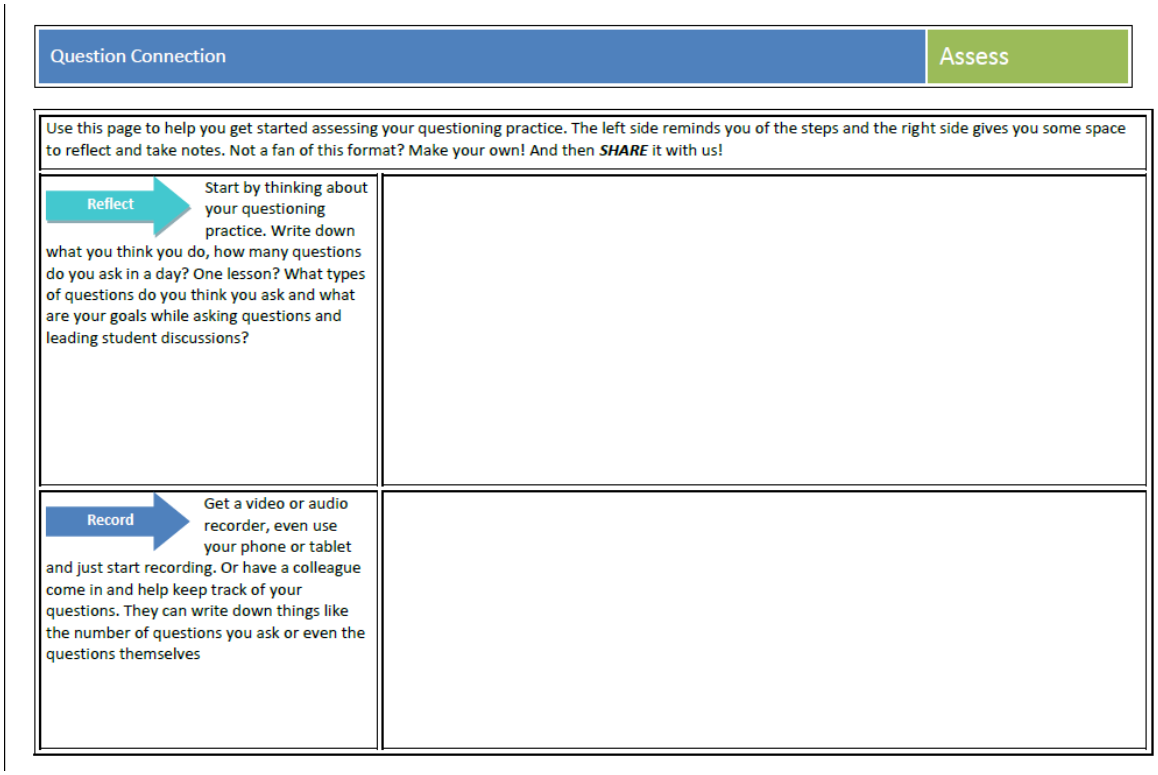

Figure 27 Assess Tool

Question Connection	Assess
Analyze Listen to your teaching or read your colleagues notes and record the results. If this is your first time analyzing your questioning, start small. Make a simple recording sheet that you can use to write down each question you asked. Then total up how many questions you asked. Even just having a simple awareness of how many questions you ask is a powerful start to making changes. If you have done this before then take it up a notch and use a tool like Bloom's Taxonomy to help you analyze your questions.	
Action Plan Now ask yourself if there are any small changes you can make to your practice right now to better meet your goals. For example, plan 2 or 3 questions for your lesson tomorrow and then use at least one.	
Reflect After the next lesson ask yourself how it went. How did the students respond? How did you respond? Did you find that you needed a follow-up question or another discourse move to keep the conversation going?	

Figure 28 Assess Tool Continued

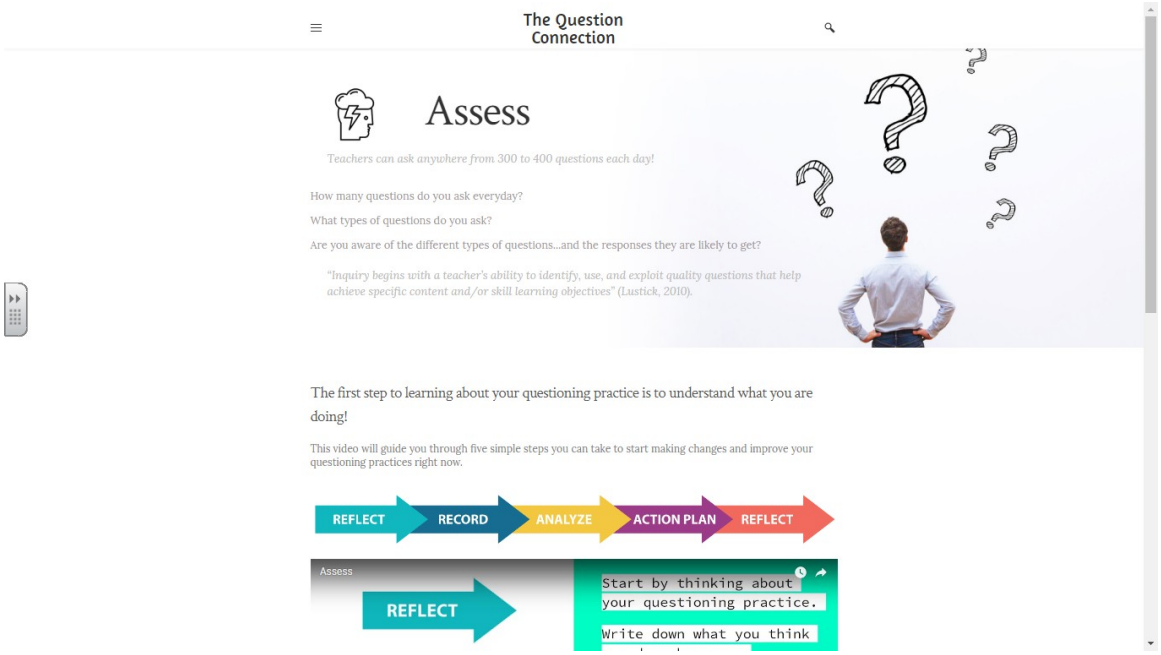

Figure 29. Final design Assess page

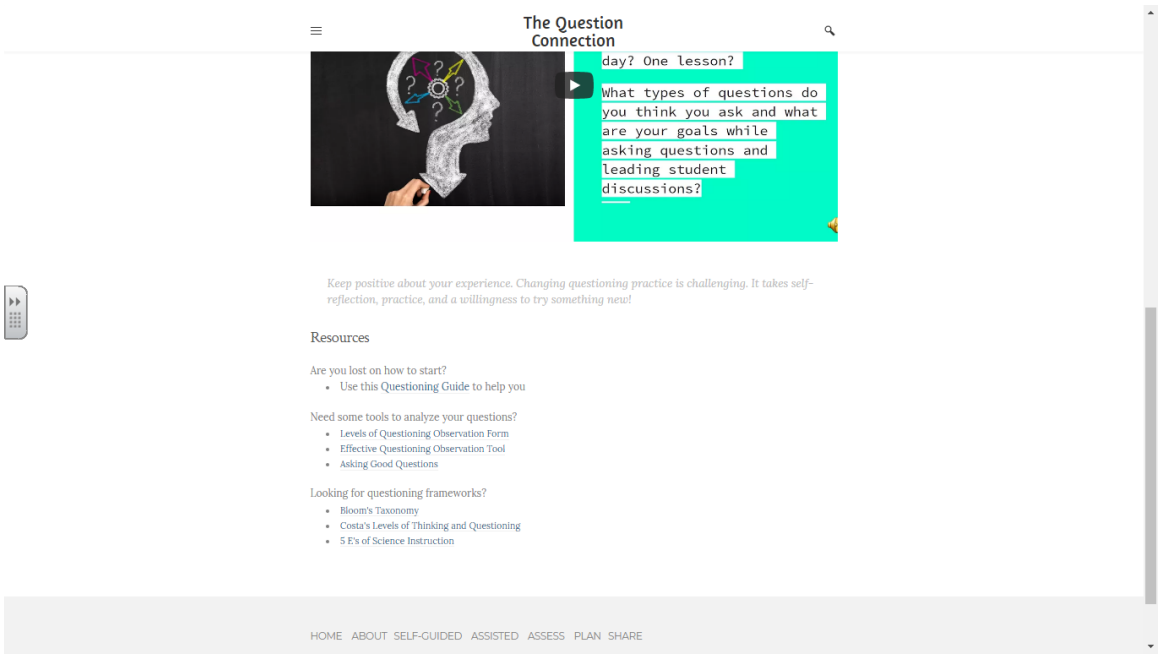

Figure 30. Final design Assess continued

The Plan page presented similar challenges because there is no right or wrong way to plan and use questions. However, to increase motivation and interest for users I added questions to the top of the page similar to the Assess page layout. Further, I also organized information into three steps to provide general advice teachers can take and customized to their practice; plan, purpose, and discourse. The narrated PowerPoint walks users through the steps and provides examples for question planning and discourse moves. The material is meant to be simple and immediately useful, thus the design was simple and straightforward without a lot of overwhelming text and resources. However, again after user-testing I added a brief video introduction and also some additional resources that could enhance the learning activity on this page. The final design is depicted in Figures 31 and 32.

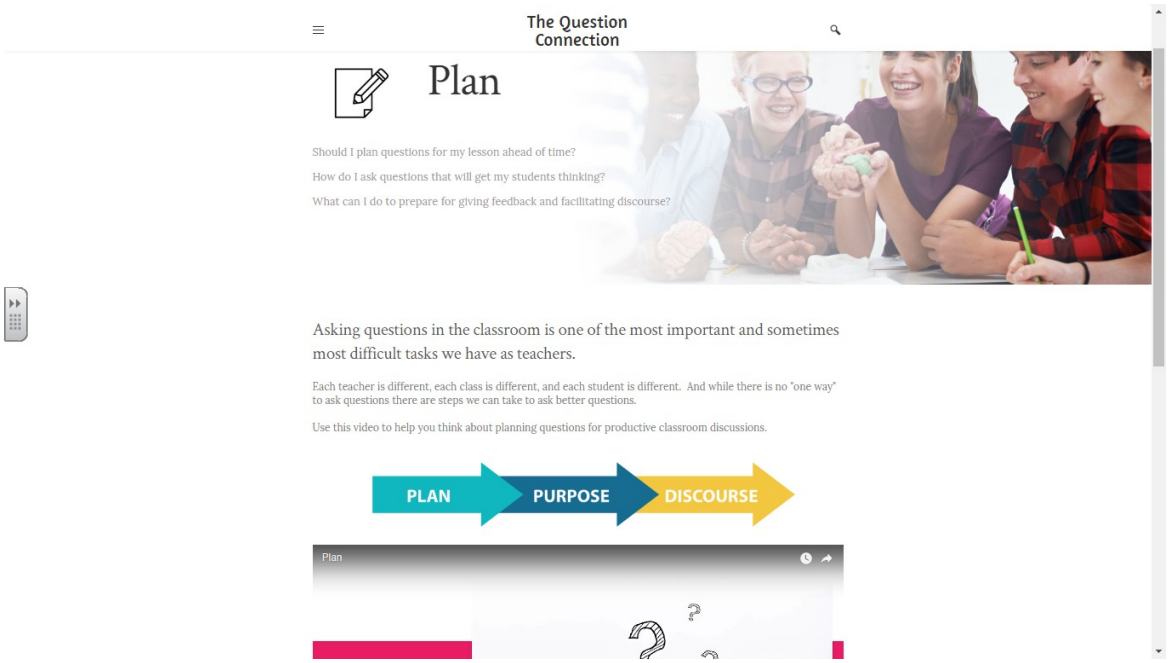

Figure 31. Final design Plan page

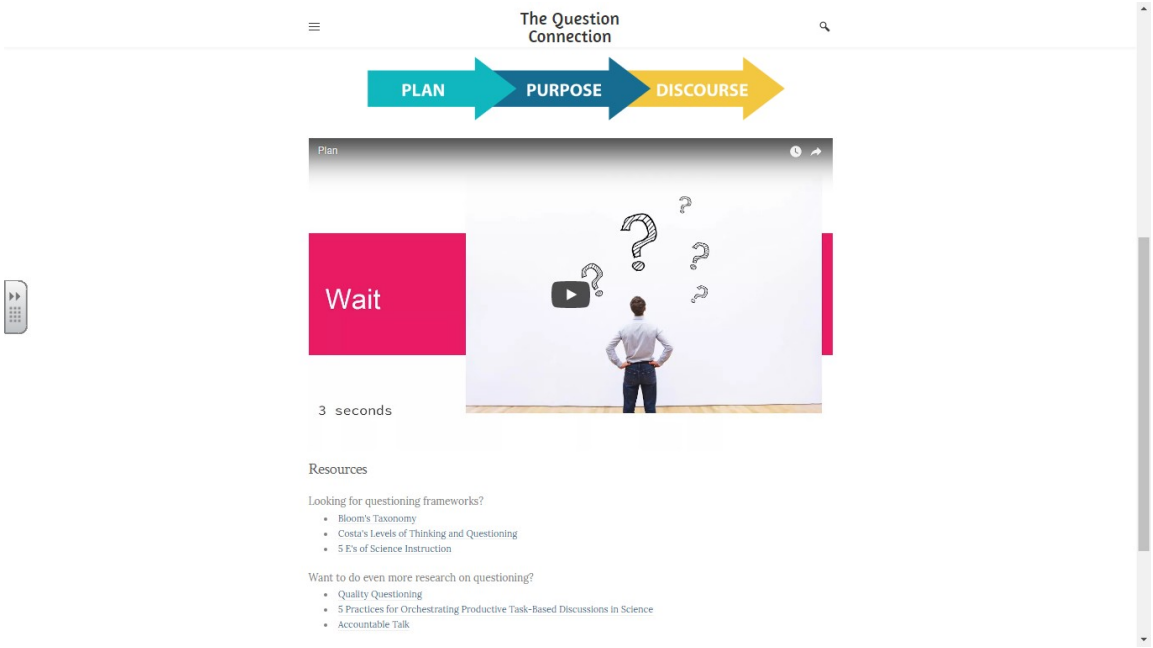

Figure 32. Final design Plan page continued

Designing a space for users to collaborate and share information and resources turned out to be the most challenging aspect of this design. I needed to decide who would share information and what information should be shared. I could curate the page, filter responses, and post only

those I feel are useful. Or it could be open for all users to post information and resources. Ultimately, I designed the page so it incorporates aspects of both these considerations. First, I organized the Share page by discipline, for example Earth Science, Biology, Chemistry, etc (Figure 33). Then, when the user selects a discipline they are taken to a page where they can select one of 3 resources; Sample Questions, Videos, and General Resources (Figure 34). The Sample Questions option takes users to another page where they can openly share questions organized by topic within the discipline. For example in Physics a user could post a question they use in the classroom about Forces (Figure 35). The final design for the Video page is currently under construction. After determining through user-testing that teachers would be unlikely and/or uncomfortable posting videos, I have decided at this point to make this a curated section (Figure 36). Meaning, I will find and narrate approved and vetted videos for teachers to learn about questioning practices. Finally, the General Resources includes all of the links from the entire website with a description of each. It is also an open forum where users can add their own resources (Figures 37 and 38).

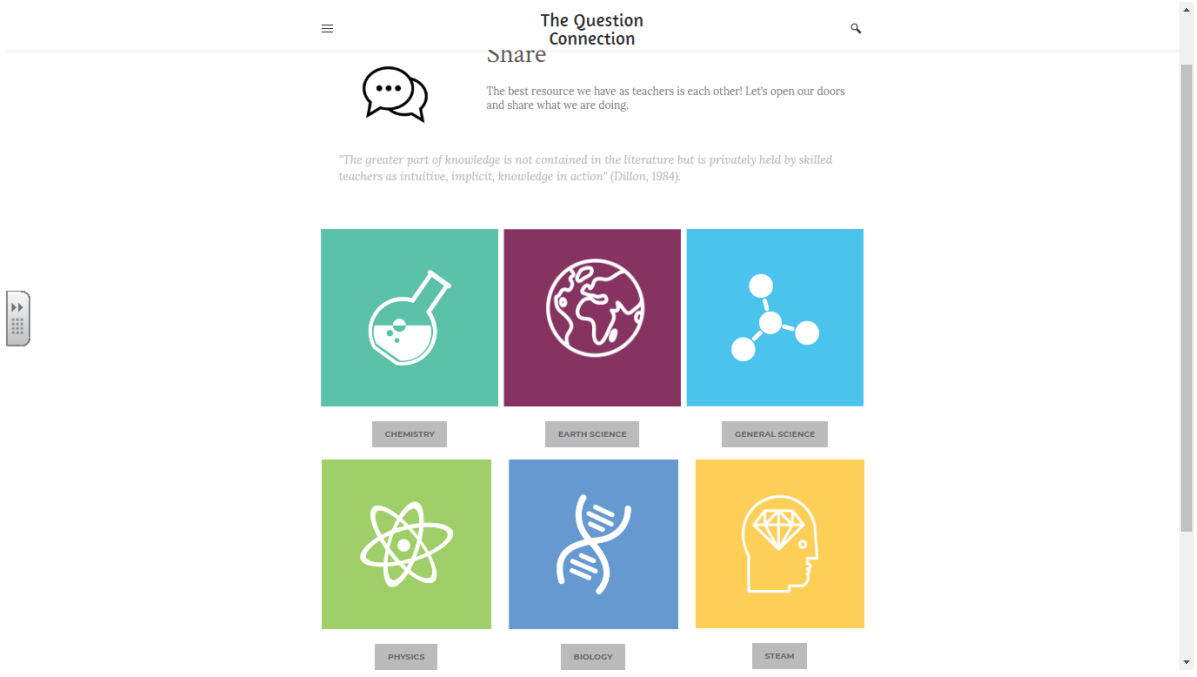

Figure 33. Final design Share page (content)

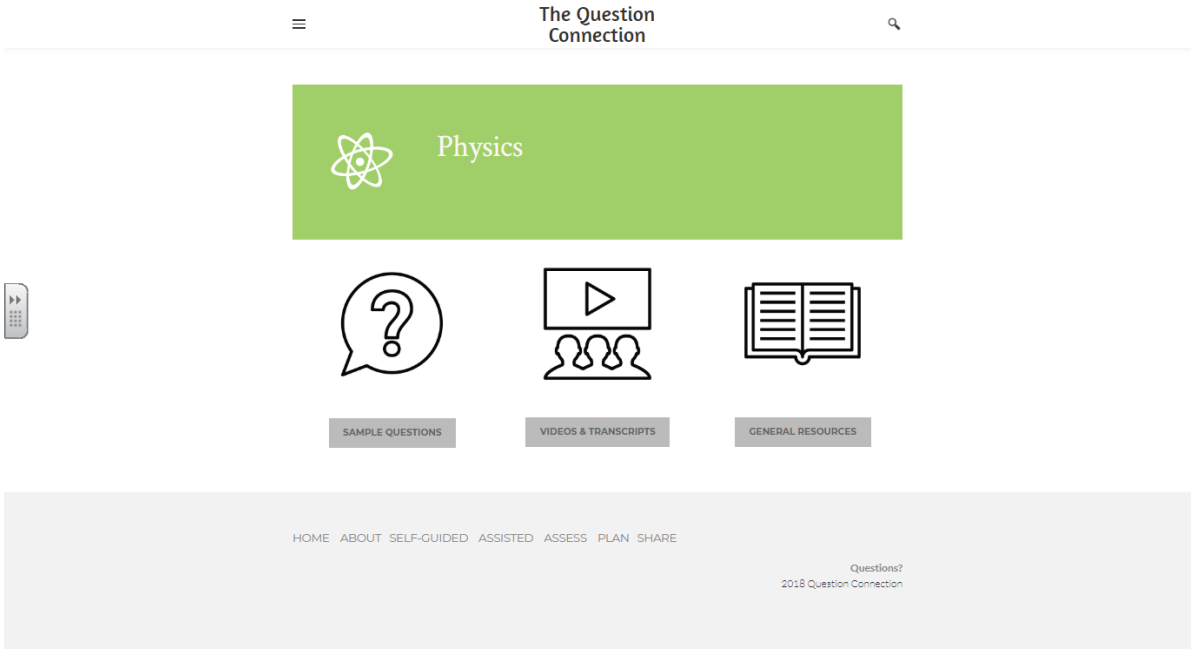

Figure 34. Final design Share page (modality)

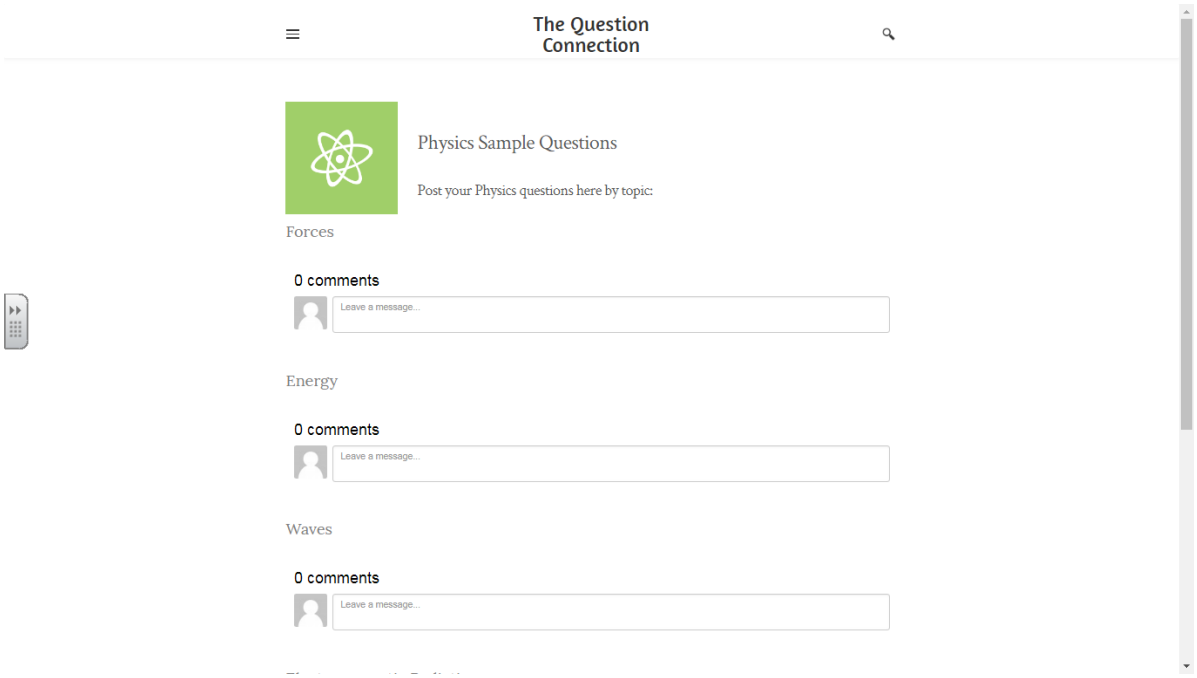

Figure 35. Physics example of final design Sample Questions

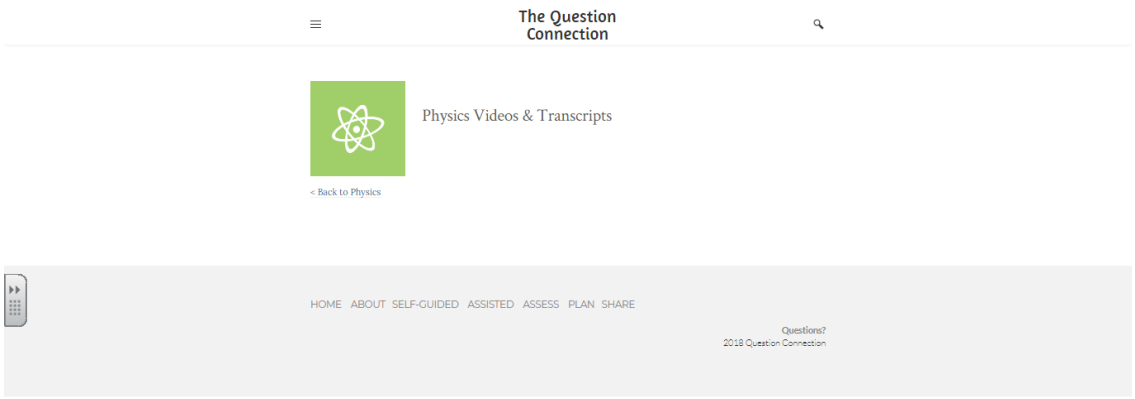

Figure 36. Video page under construction

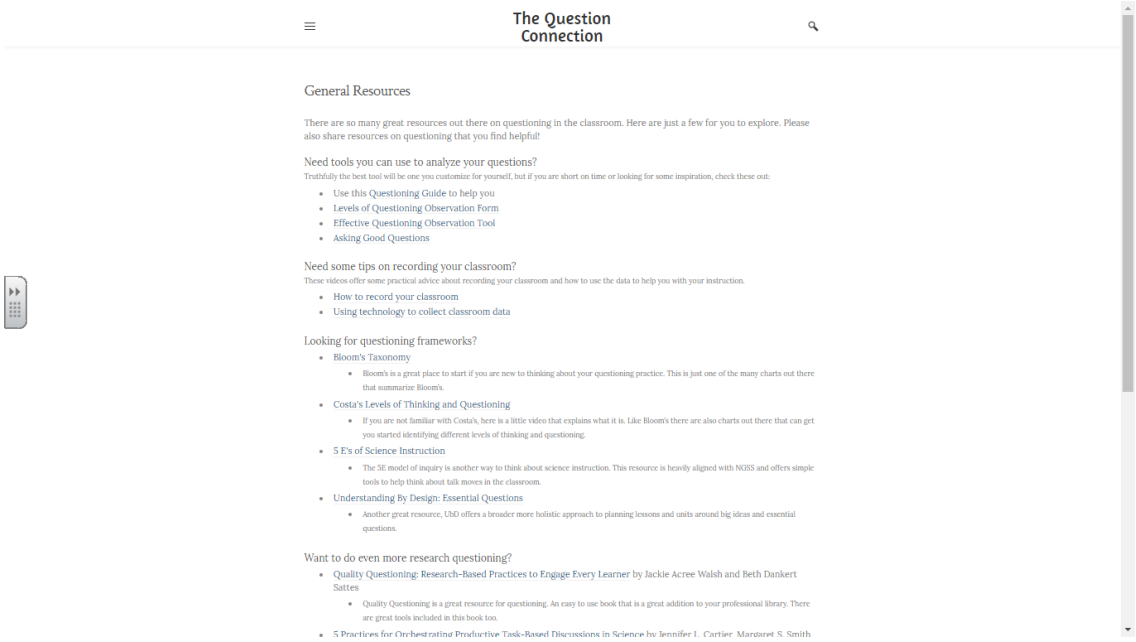

Figure 37. Final design General Resources page

Figure 38. Final design General Resources continued

Next Steps for The Question Connection

The next steps for The Question Connection include continuing the ADDIE process of implementation and further development of identified design components. As part of implementation, I will actively recruit users who will engage with the existing learning experiences and build the collaborative spaces of the Share pages. I will monitor these pages for appropriate content and discourse, generating and removing posts as needed. I will also respond to all inquiries for assistance.

Next steps will also include continued development of the prototype as more funding becomes available. First, I expect to upgrade the website platform. The current platform has limitations on certain features and functionality. For example, an upgrade would allow me to make the "chat live now" function operational. This upgrade will also allow me to select a better format for posting and sharing pages including various fields to help organize responses instead of the general comment box provided now. Additional funding would also allow me to upgrade

the content and quality of the Assess and Plan pages videos. Currently they are a narrated PowerPoints, however, having content professionally produced with a split screen to show me talking would be a better option for users as it makes the space more personable. In addition to upgrading the quality of these videos, I would also create more videos for the Assess and Plan pages, each with a different theme or topic. For example, on the Plan page there could be a video for each framework listed, one for Bloom's, one for Costa's, etc.. However, to keep the design simple, I would rotate one video on each of the Assess and Plan page and archive the rest for additional browsing. Another area of major development for the prototype would be the Videos section of the Share page. Here I would take the time to curate and/or produce quality videos of teacher practice with narration to illustrate good practices.

Finally, I would also evaluate the prototype through additional rounds of user-testing that are focused on testing the learning aspects of the design. The initial user-testing done as part of this study was focused more on usability and self-reported ideas about the potential usability for learning. It is challenging to evaluate learning in an informal learning environment because there are no set assignments or tasks. However, in the future I could evaluate the learning aspect of the prototype by recruiting participants to user-test learning content and activities of the prototype. For example, I could ask a participant to watch the Assess video and complete the Assess Tool including recording data about their questioning practice and reflecting on this data and making a plan for future practice. Separately or in conjunction with this, participants could also watch the Plan video and design sequences of questions and feedback strategies that they would implement into actual practice. Further, I could have participants review and comment on the usefulness of Sample Questions or Sample Videos in the Share section, thus requiring application of their knowledge about questioning and sharing it with others which invites the opportunity to

collaborate. I envision that there are many opportunities to test the learning of this prototype, however, the 3 listed above would be my first priorities as they focus on the 3 main learning goals; 1) reflect on and ASSESS their own questioning practice, 2) PLAN for and write quality thinking questions, and 3) SHARE with others by sharing information and/or experiences.

Implications for Further Research

This study confirms much of what is already known in the literature about professional development in teacher questioning practices. To learn better questioning practices, teachers need ongoing support that is content focused, provides time for reflection and collaboration around quality videos of good teacher practice. However, there are areas in which more research could inform future professional development designs for teacher questioning.

The first area in need of more research is how professional development design can incorporate ongoing support for teacher learning. Currently professional development often occurs in formal, one-time workshops or seminars removed from classroom practice. While this model affords an opportunity to explicitly learn about teacher questioning, it is removed from practice and does not provide ongoing support. More research focused on the efficacy of professional development models that include ongoing classroom support would inform the literature base. Further, investigating affordances and constraints of formal and informal professional development models on teacher learning would help future prototype designers.

The second area in need of more research is how to create, find, and share videos of teacher practice. The research is clear that the best way to learn about questioning practices is for teachers to watch videos of both their own and others' practice. However, there are logistical, legal, and vulnerability concerns with sharing videos of teacher practice. Technology is beginning to catch up with the logistics of recording usable video in the classroom. However, the

best way to capture all of the conversations as usable data for teachers is elusive. Currently only parts of conversations are captured and it is incredibly time consuming and challenging for teachers to record, edit, and produce videos of their own teaching. Additionally when it comes to sharing videos there are concerns about the privacy rights of the students and also the vulnerability of the teachers as they put their classrooms out there for others to view. Currently, there is not a lot of research into the solutions that would be needed to face these challenges so teachers can better utilize videos to improve their questioning practices.

Overall, this study confirms and expands upon the current research base on teacher questioning practices. This study shows that teachers need time to reflect on and assess their own questioning practices. They also need ongoing support with planning and writing quality thinking questions. And they need opportunities to collaborate with others through sharing information, resources, and experiences. Additionally, from a design perspective, this study found that teachers would like to learn about questioning and discourse in an online format that is informal, self-paced, and an individual experience with the option to collaborate with others. Finally, this study resulted in the design and development of The Question Connection (www.questionconnection.com); a prototype to help middle school science teachers who want to improve their use of questions in the classroom.

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Appendix A: Literature Review Table

Table 8. Phase 1 References for Literature Review

Author(s)	Date	Title	Publishing Information	Notes
Allen, W.C.	2006	Overview and Evolution of the ADDIE Training System	Advances in Developing Human Resources. 8 (4), 430-441	ADDIE-Analysis, Design, Develop, Implement, Evaluate. Origins of ADDIE in the military, "It is interesting to note that although the military embraced ISD for technical training, ISD was not used for creating their management training" (Allen, P. 432). " Most training sponsored by organizations, 50 years after the advent of ADDIE, still have difficulty verifying participant expertise at the conclusion of training" (Allen, P. 440).
Bell, P. Lewenstein, B, Shouse, A. W., Feder, M.A. (Eds.)	2009	Learning Science in Informal Environments	The national Academies Press: Washington DC	Informal learning is learner driven, voluntary, ongoing, contextually relevant, free from standardized assessment. Life-long, life-wide, life-deep learning (p. 28). Informal learning focused on people, places, and culture. Learners cannot be compelled, so need to "hook" them, create a cognitive dissonance.
Brookfield, S. D.	1991	Understanding and Facilitating Adult Learning	Jossey Bass: San Francisco	Strong adult education models emphasize that the learner take charge of identifying what they need (p. 37)
Brown, B.A.	2011	Isn't that just good teaching? Disaggregate instruction and the language identity dilemma.	Journal of Science Teacher Education, 22(8), 679-704.	About the role of identity in science education. Specifically discursive identity-identity enacted through language. A Vygotskian approach means that language is a primary mediator of cognition, so if language is unfamiliar or culturally conflicting, then we are limiting the learning that is happening for some students.

Burns, C., & Myhill, D.	2004	Interactive or inactive? A consideration of the nature of interaction in whole class teaching.	Cambridge journal of education,34(1), 35-49.	Definitions of interactivity vary depending on the theoretical frameworks or pedagogy represented. First up is Vygotsky-talk is essential to learning. Both a social event and a cognitive process. The dispute over interactivity is resulting in the same old same old inactivity of students. Dominated teachers talk...Term interactive is useless, classroom talk how, when, why is more important to consider.
Bybee, R. W.	1995	Science curriculum reform in the United States	National Academies of Sciences	Walks through the history of science education at the national level and how different eras and events shaped science education reform. Launch of Sputnik, Science for All Americans.
Capps, D. K., & Crawford, B. A.	2013	Inquiry-based instruction and teaching about nature of science: Are they happening?	Journal of Science Teacher Education, 24(3), 497-526.	Teacher needs from article: understanding of inquiry, own inquiry abilities, inquiry and NOS pedagogy skills, intention to teach this way (p. 498). Good teacher understanding of inquiry and NOS led to better practice. Teachers who could not describe inquiry, were unable to practice/demonstrate it in the classroom. Also many teachers who were NOT teaching with inquiry actually thought they were. Correlation between inquiry and NOS. If there is no consensus in the research about what inquiry is and what it looks like, then how can teacher expect to teach this way?? "If we expect teachers to use new instructional approaches, they will need to have well-designed, ongoing opportunities to learn and teach in this way" (p. 524).

Chen, Y. C., Hand, B., & Norton-Meier, L.	2016	Teacher Roles of Questioning in Early Elementary Science Classrooms: A Framework Promoting Student Cognitive Complexities in Argumentation.	Research in Science Education, 1-33. DOI: 10.1007/s11165-015-9506-6	"The emphasis on argumentation in science education shifts the focus of science classrooms from memorizing facts to engaging students in an authentic scientific practice in which they search for data patterns to shape evidence for the support of scientific claims and debate those claims publicly to identify the weaknesses of their arguments (Citations...)" p. 374. Study by Banilower (2013) supports the factual question at 90% rate in science classrooms. (p. 374). A shift in talk in the classroom requires a shift in roles and teachers are not always comfortable with that...students neither...Dialogic approach - Teacher ownership of ideas and activities; students ownership of ideas/teacher activities; teacher ownership of ideas/student ownership of activities; and student owns ideas and activities. "If we can gain a more nuanced understanding of the relationship between the roles of teacher questioning and students' cognitive responses as well as how teachers develop various questioning roles over time, teacher education programs including program structures and course assignments focusing on argumentation can be designed effectively and practically" (p. 379). "An increasing body of empirical evidence suggests that it takes more than 18 months before significant shifts in teachers' questioning pedagogy are observed (Citation)" p. 397

Chin, C.	2006	Classroom interaction in science: Teacher questioning and feedback to students' responses.	International Journal of Science Education,28(11), 1315-1346.	Triadic-IRE, IRF; traditional classroom low-level questioning chains. Some argue that not all IRF is bad and that the F is what is important, how are teachers following up? Traditional questioning techniques were about evaluation, but constructivist questioning techniques are about eliciting student thoughts and help them build on their conceptual knowledge (p318-319). The question as a scaffold, not evaluation...types of feedback - affirmation-direct instruction, focusing and zooming, explicit correction-direct instruction, cognitive challenge. This idea really just puts forth the notion that changing the E to an F can help change questioning based discourse in the science classroom.
Chin, C.	2004	Questioning Students in ways that encourage thinking.	Teaching Science: The Journal of the Australian Science Teachers Association, 50(4).	Question typology: Bloom, open/closed, productive, operational -students need to have enough knowledge and experience to answer the questions (p. 17). Also there is a link with teacher modeling of questions, the more they ask, the more students ask. Suggestions to foster thinking through questions: familiarize yourself with the levels of thinking associated with different types of questions; identify the cognitive skills and processes you would like for students to engage in; use wait time; provide a warm and conducive environment; pay attention to question wording and responses; look for questioning opportunities in every lesson. Analysis of questioning-number of possible/correct responses as well as level of thinking

Chin, C.	2007	Teacher questioning in science classrooms: Approaches that stimulate productive thinking.	Journal of research in Science Teaching, 44(6), 815-843.	"rhythm of discourse" alternation between presentation and exploration of ideas. Great chart on p. 819 about the differences between questions in traditional and constructivist/inquiry classrooms. Table on p. 823 with a great visual of different types of questioning strategies and the purpose. Interesting idea-using Socratic questioning as a means of direct instruction, instead of lecturing-strategies include pumping, reflective toss, and constructive challenge. questioning is an important part of inquiry-based pedagogy. And by focusing on whole class discussions, this allows for the social construction of learning to happen...
Dillon, J.T.	1985	Using questions to foil discussion.	Teaching and teacher education, 1(2), 109-121.	"Teacher questions foil discussion, whereas non-question alternatives foster discussion" (p. 109). A study of 5 classrooms in 5 big city high schools. Evidence why asking questions is so difficult. The wrong type of question or sequence, can inhibit discussion completely. It is not easy to ask questions to stimulate discussion, this article highlights the fact that it can actually stifle it. What is the point of asking questions? To stimulate discussion This article used response time as the unit of measure. As it stands now, the authors would say don't question at all...use alternatives!

Dillon, J.T.	1984	Research on questioning and discussion.	Educational Leadership, 42(3), 50-56.	"Most of what we know is either not known from research or is not publicly known"…this was the case in 1984 and not much has changed…"The greater part of knowledge is not contained in the literature but is privately held by skilled teachers as intuitive, implicit, knowledge in action"...so true, this is why I am creating this site, teachers can share this private knowledge, publicly! Discussion vs. recitation. Recitation is the typical IRE type sequence, where already known information is shared. Discussion is talking about what you don't already know. Recitation is about recall, discussion is about thinking. "Discussions are hard to conduct and they are hard to learn how to conduct. Contrary to common sense, questioning is a complex skill" (p. 53). Also, it is hard to learn from written work on questioning, it is best when video is used.
Edelson, D. C.	2001	Learning-for-Use: A framework for the design of technology-supported inquiry activities.	Journal of Research in Science Teaching, 38(3), 355-385.	Learning for Use (LfU) Design framework support the design of learning activities that achieve both content and process learning. The four principles of LfU are 1. Learning takes place through the construction and modification of knowledge structures. 2. knowledge construction is a goal-directed process that is guided by a combination of conscious and unconscious understanding goals. 3. The circumstances in which knowledge is constructed and subsequently used determine its accessibility for future use. 4. knowledge must be constructed in a form that supports use before it can be applied. Constructivism-knowledge must be incrementally built through communication and experience (p. 357). LfU is a three step process for creating useable understandings. 1. motivation-recognizing the need for new information, in this model it is NOT about the broader scope of motivation, but the idea that the learner

				is already engaged in the topic and they are motivated by a gap in knowledge/understanding. 2. Knowledge Construction-building new knowledge structures, linked to existing structures 3. knowledge refinement-organizing and connecting knowledge structures-accessibility and applicability. Table 1 on page 360 gives useful design strategies for each step (1-3). "demand must be generated by a natural use of the knowledge" (p. 375). "The construction of understanding is a continuous, iterative, often cyclical process that consists of gradual advances, sudden breakthroughs, and backward slides" (p. 377).
Edelson, D. C.	2002	Design research: What we learn when we engage in design.	The Journal of the Learning sciences, 11(1), 105-121.	"I argue for design research as a form of educational research because - design offers opportunities to learn unique lessons - design research yields practical lessons that can directly applies, and design research engages researchers in the direct improvement of educational practice". Three collections of decisions that determine design outcomes: design procedure-the process and the people that are involved in the development of the design; problem analysis-goals, needs, or opportunity that a design is intended to address and the challenges, constraints, and opportunities afforded by the context; Design solution- result of designers efforts to address the challenges, satisfy constraints, exploit opportunities, and balance the tradeoffs that were identified in the problem analysis. " A design process often begins with a perceived problem of opportunity and an idea for how to respond to it" (p. 109). Four features of design research as distinguished from just design- research driven, systematic documentation (make elements of design

				explicit for reflection), formative evaluation, generalization. "In the past, practitioners have complained that they are unable to apply the results of educational research to the problems of design and implementation" (p. 119).
Falk, J. H. & Adelman, L. M.	2003	Investigating the impact of prior knowledge and interest on aquarium visitor learning.	Journal of Research in Science Teaching, 40(2), 163-176	How educational is a free choice learning institution? If it is informal, how can it evaluate learning? And then how does motivation factor? Found that more interested individuals may actually learn less, perhaps because they think they already know, where novices actually pay more attention and perhaps learn more.
Forbes, C. T., & Davis, E. A.	2010	Beginning elementary teachers' beliefs about the use of anchoring questions in science: A longitudinal study.	Science Education, 94(2), 365-387.	Longitudinal study of 4 beginning elementary science teachers. Anchoring questions are driving questions and investigation questions. Driving questions are the big idea questions that frame the unit and are frequently referred to and returned to. The investigation questions are the more day to day questions related to the driving questions (p. 368). This paper also talks about the difference between beliefs and knowledge and that they cannot be separated. You have to believe to have the knowledge...teacher

				practice is deeply embedded in their experience. no one science curriculum or resources can be all encompassing, a resource has to be flexible so it can be adapted to a particular context.
Gall, M	1984	Synthesis of research on teachers' questioning.	Educational leadership, 42(3), 40-47.	"Questions apparently are more effective than no questions, but they are not necessarily the most effective instructional alternative" (p. 44).
Gall, M.D.	1970	The use of questions in teaching.	Review of educational research, 707-721.	It's not just the initial question that is important, but also the follow up question that really lets you know if the student is thinking. About 2/3 to 3/4 of teachers questions are direct recall questions. This has remained unchanged since 1912..Similar to what Myhill (2006) found as well...still have not changed this...Her findings in 1970- about 60% of teacher questions are recall, 20% are thinking and 20% procedural...She also included several "courses" that have been developed to help teachers develop better questioning. Really a strong call to action- we need better teacher training so they can ask better questions. Lack of change in teacher questioning over the years.

Gall, M.D. & Gillett, M.	1980	The discussion method in classroom teaching.	Theory into practice, 19(2), 98-103.	Discussion has great potential for learning. Why teachers do not use discussion: student reticence, loss of control, learning outcomes. If some students do not participate, it can be abandoned. Also allowing students to talk freely is at odds with more traditional "classroom learning", and teachers are too busy "teaching" to have time for discussion. Hinting at the fact that this is not a genuine way to learn. Discussion can have different purposes- subject matter mastery, issue oriented, problem solving, simple motivation - students who need to share knowledge may be more likely to learn. Ideal group size is 5- ways to deal with this are small groups, or use the fishbowl method. Students need training in discussion or they will not talk to each other.
Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S.	2001	What makes professional development effective? Results from a national sample of teachers.	American educational research journal, 38(4), 915-945.	What are the effects of different characteristics of professional development on teachers' learning?1,027 math and science teachers from 358 districts nationally. Survey (Spring, Summer and Fall 1998) of teachers who had attended "Eisenhower-assisted" activities (PD grants). Had a 72% response rate, responses are self-reports of teacher "experiences and behavior". "Time span and contact hours have a substantial positive influence on opportunities for active learning"; "PD is likely to be of higher quality if it is both sustained over time and involves a substantial number of hours"; "activities that give greater emphasis to content and that are better connected to teachers' other professional development experiences and other reform efforts are more likely to produce enhanced knowledge and skills" "teachers report changing practice more as a result of reform activities than traditional activities". There is a notion in this article about the distinction between "traditional" and "reform" PD. They describe the difference between the two as

				traditional is like a workshop and is removed from practice while reform is more like mentoring and is "in-situ".
Gray, B.	2004	Informal Learning in an Online Community of Practice.	Journal of Distance Education, 19(1), 20-35.	Grounded in community of practice theory (Lave & Wenger). What differentiates communities of practice: there is a shared interest, interact and learn together through shared activities and experiences, shared experiences become common knowledge that inform new experiences. Participation is varied, from central to peripheral and participation results in not only learning "how to do, but how to be" (p. 23). "...it is suggested that online communities of practice can provide a space for newcomers to become enculturated and learn elements of practice, and where all members, through sharing of stories and joint problem-solving, can learn together and continue to shape not only their own identity as practitioners, but the identity of the practice itself" (p. 23). Motivation for participation was based on their isolation from their peers (geographic). participation was equated to the break room, an informal space where you could talk about shared experiences, professionally, socially, etc. learning was not a "special activity" but rather an ongoing

				everyday practice. It did not have to be a monumental solution, but rather just people sharing their experiences, and what has worked for them , lots of small things that had worked. Utilizing a moderator in an informal LE resulted in moving the community from just "a forum for sharing information to a community of practice where knowledge was constructed through shared learning" (p. 31).
Gustafson, K. L., & Branch, R. M.	2002	What is instructional design.	Trends and issues in instructional design and technology, 16-25.	ADDIE- Analysis includes a needs assessment, identifying performance problems, and stating a goal. Design includes writing measurable objectives, classifying learning as to types, specifying learning activities, and learning media. Development includes students and instructor materials as specified during design, implementation includes delivering the instruction for the setting it was designed, and evaluation includes collecting data for both formative and summative purposes. Characteristics of ID that should be present: ID is learner centered, ID is goal oriented, ID focuses on real-world use, ID focuses on outcomes that can be measured, ID is empirical, ID is typically a team effort.

Hackling, M., Smith, P., & Murcia, K.	2011	Enhancing Classroom Discourse in Primary Science: The Puppets Project.	Teaching Science, 57(2), 18-25.	A traditional face to face model. Good with a needs analysis questionnaire as well as had videos of the teachers utilizing inquiry in their classrooms. Teacher beliefs about effective science teaching before: time, inquiry approach, science and literacy integration and after intervention: time, effective discussion, and safe environment for discussion. This reinforces the notion that explicit instruction in questioning and discourse for teachers is an effective way to get them to improve their practice.
Harris, C. J., Phillips, R. S., & Penuel, W. R. Harwell	2012	Examining teachers' instructional moves aimed at developing students' ideas and questions in learner-centered science classrooms.	Journal of Science Teacher Education,23(7), 769-788.	"Discourse among scientists is characterized by debate and argumentation based on evidence (Kuhn, 1993)" (p. 770). Case studies of using a scripted curriculum with prompts, still shows a wide range of ability to enact by teachers. One teacher was unable to get students thinking moved forward, despite the curricular guide, and another moved it great.
Hermann, R. S., & Miranda, R. J.	2010	A Template for Open Inquiry: Using Questions to Encourage and Support Inquiry in Earth and Space Science.	Science Teacher, 77(8), 26-30.	Inquiry is not a singular construct, but rather a continuum. This is a template that helps teachers ask questions that leads students to asking actual researchable questions in the laboratory, including independent and dependent variables, etc.
Hsi, S., Crowley, K., Duschl, R., Finke, C.L., King, H., & Sabelli, N.	2004	Models of learning and theories of practice for informal learning environments.	In proceedings of the 6th international conference on learning sciences (pp. 12-15). International Society of the Learning Sciences	"learning is self-directed, the administration or sponsorship of the learning activity is not always present/assumed, activity is often unsystematic and have fluid arrangements, and learners represent a diversity in groupings, age, race, and ethnicities".

Hoetker, J., & Ahlbrand Jr, W. P.	1969	The persistence of the recitation.	American educational research journal, 145-167.	"Teachers, despite differences in the sizes, ability levels, and backgrounds of their classes, acted very much like one another. They talked between two-thirds and three-quarters of the time. Their major activity was asking and reacting to questions that called for factual answers from students" (p. 148). "perhaps its very obviousness has obscured its central role in the pedagogical process" (on questioning). p. 131 Stevens report from 1912 showed the same results....it was the first major study on questioning. Recitation method grew out of progressive reform era as an effective (sampling) way to manage larger groups of students.
Ireland, J. E., Watters, J. J., Brownlee, J., & Lupton, M.	2012	Elementary teacher's conceptions of inquiry teaching: Messages for teacher development.	Journal of Science Teacher Education, 23(2), 159-175.	Theory is important for establishing consensus about inquiry instruction, however it does not usually shape teacher practice, typically it is their personal understanding and contextual constraints that are the most important factors on practice. PD need to focus on studies that document teacher thinking or implicit theories rather "fidelity". They found that there are three ways in which teachers experience teaching for inquiry in science: 1. student centered experiences 2. teacher generated problems 3. student generated questions.
Kim, M., & Chin, C.	2011	Pre-Service Teachers' Views on Practical Work with Inquiry Orientation in Textbook-Oriented Science Classrooms.	International Journal of Environmental and Science Education, 6(1), 23-37.	One problem with inquiry is the cultural expectation of content oriented curriculum and assessment, textbook focused instruction. This article is based on Korea, but it certainly happens here in the US too. Concepts Vs. understandings. You can use the textbook to create more inquiry based lessons, especially by adding good questions...making changes to textbook activities also served to increase teachers content knowledge. They had to learn what would happen when the changes were made...

King, A	1993	From sage on the stage to guide on the side.	College teaching,41(1), 30-35.	"In this view of teaching and learning (transmission), students are passive learners rather than active ones. Such a view is outdated and will not be effective for the twenty-first century, when individuals will be expected to think for themselves, pose and solve complex problems, and generally produce knowledge rather than reproduce it" (p. 30). Constructivism has connections to Mayer and information processing theory.
Kirschner, P. A., & van Merriënboer, J. J.	2013	Do learners really know best? Urban legends in education.	Educational Psychologist, 48(3), 169-183.	Learners have a hard time identifying what they do not know. Further, they often chose what they prefer to learn about but not necessarily what they need to learn about. There is also "the paradox of choice", the more choice, the harder it can be. So limited choice is better than total freedom. Perhaps a quiz of some sort will limit their choices and then have them complete ongoing assessments that will guide their instruction, so it provides a scaffold. The continuum would be very guided to self directed, on demand learning where they self assess and select learning activities.
Kirschner, P. A., Sweller, J., & Clark, R. E.	2006	Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching.	Educational psychologist, 41(2), 75-86.	I am not sure I agree that inquiry based or PBL means it is unguided or unscaffolded. This is perhaps an unfair characterization. However, I like the idea of a "worked example" from this article. The idea that viewing a highly structured example will result in better transfer is great and perhaps why watching videos is so useful to teacher practice in questioning. If you see how a good example goes, you can start to incorporate some of it to your teaching because there is less of a cognitive load on your short term memory. It is guided. Interesting, they cite that unstructured learning can actually result in a loss of knowledge based on pre/post tests. Expert/novice plays a part too. novices need more structure and experts need less. If a novice is provided no structure then they are at

				risk of losing learning and if an expert is given too much structure, then they will not learn either. So creating an environment for all learning will be interesting. Perhaps the site is broken down by ability?
Kirschner, P., Strijbos, J. W., Kreijns, K., & Beers, P. J.	2004	Designing electronic collaborative learning environments.	Educational Technology Research and Development, 52, 47-66.	Design Framework based on three prerequisites: technological, educational, and social. Outcome and process again is a theme here...Affordances and constraints. What affords technology, education, and social. Technological affordances-important to consider usability, if it is not useable, then it does not matter how good the content is. In the virtual world social affordances must be designed and encompass two relationships: reciprocal relationships between group members and aspects of the environment and 2, there must be a perception-action coupling meaning you are encouraged to respond/interact with another group member. Educational affordances-relationships between the properties of an educational environment and the learners. Design guidelines-Interaction design is focused on not just usability but also utility which encompasses the educational and social functionality of the design. Kirschner's interaction design model: determine what learners actually do, determine what can be done to support those learners, determine the constraints of the learner, learning situation and environment and the

				conventions that already exist, determine how learners perceive and experience the support provided, determine how the learner actually uses the support provided, determine what has been learned. Three standards to determine the success of any interaction design: 1. effectiveness, 2. efficiency, 3. ability to satisfy the users (p. 54).
Klahr, D., Zimmernman, C., & Jirout, J.	2011	Educational interventions to advance children's scientific thinking.	Science, 333(6045), 971-975	Inquiry can actually decrease learning in science due to the fact that students do not have a sufficient knowledge base to ask meaningful questions
Knowles, M. S., Holton, E. F., & Swanson, R. A.	1998	The adult learner: The definitive classic in adult education and human resource development (5th ed.).	Houston, Tex: Gulf Publishing Company.	Historical premise of education is based on how we teach adults the conception of the teaching/learning process developed so that "they perceive learning to be a process of mental inquiry, not passive reception of transmitted content" (p. 35). Adult learning is about fitting the curriculum around the learner. it is not about "just in case learning" but more about "just in time learning". "Adults learn best in informal, comfortable, flexible, non-threatening settings" (p. 61). Assumptions of andragogy: 1. the need to know-how does it benefit them...2. learner's self-concept-resent and resist situations where they feel others are controlling them. 3The role of the learner's experience-adults have more and more varied experiences than children, focus is on greater individualization, options for learning. 4. Readiness to learn-adults become

				ready to learn those things they need to know and be able to do in order to cope effectively with their real life situations...can be induced, ie. performance assessment. 5. Orientation to learning -adults are life centered, how will the learning help them with their lives. 6. motivation- some external motivations, but usually it is internal.
Lebak, K., & Tinsley, R.	2010	Can inquiry and reflection be contagious? Science teachers, students, and action research.	Journal of Science Teacher Education, 21(8), 953-970.	Teachers need opportunities for peer reflection and collaboration to develop as practitioners. Lots of references for action research in this article...Perhaps having both knowledge and pedagogy for science teachers is the biggest challenge. Strong knowledge may not reflect in good pedagogy. "Reflecting on practice led her to begin reflecting in practice" (p. 959). One of the main ways that instruction was changes, was surveying students...interesting, how many teachers do this?? Proof of expanding the action research process by student feedback and peer collaboration can have a profound effect on practice. NRC argues that the development of expert science teachers requires opportunities for reflection, interaction with peers, and repetition of teaching science content (p. 968). 2 key features-video and collaborative reflection.

Lieberman, A., & Pointer-Mace, D.	2009	Making practice public: Teacher learning in the 21st century.	Journal of Teacher Education.	"Teachers have long perceived professional development, though well intentioned, to be fragmented, disconnected, and irrelevant to the real problems of their classroom practice" (p. 77). From isolation to colleagueship-struggling together led to mastering new practices...seminal work in the 80's that showed that teachers who began to be less isolated actually learned more and improved their practice..."As "digital natives" (Prensky, 2001) enter the teaching ranks, insular professional learning models are poorly positioned to capitalize on these teachers' talents and interests" (p. 78). Professional Learning communities 2.0-moving teachers development online-making practice public. "we (the US) have not recognized the power of teachers to analyze their own practice as a critical centerpiece of high-quality professional development" (p. 79). Teachers in the US only have between 3-5 hours a week for lesson planning...other countries can spend up to 65% of their time on their learning...teacher learning is just as valued as student learning. Ex. Japans "lesson study" where a teacher teaches and then has others watch...Other nations who are good at PD all embrace the following-working in communities, working on improving practice, and working locally with teachers as leaders. Learning is social within communities of practice-three practices-learning, meaning and identity. Core features of online learning-content focus, active learning, coherence, duration, and collective participation (p. 80). The strength of online learning experiences depends on the robustness of the "learning objectives" around which the development initiatives are centered. (p. 81). Teachers could be scholars by (from Lee Shulman 1999)-making knowledge public-critique it-build on it-pass it on. By

				making teacher practice public we can break down the barriers and isolation and connect teachers. It is so ubiquitous in our personal lives, that it needs to cross over to our professional lives. "Educators need not struggle alone" "strong practices pass on and weak ones can't hide"
Lustick, D.	2010	The priority of the question: Focus questions for sustained reasoning in science.	Journal of Science Teacher Education, 21(5), 495-511.	Focus question-"a query that addresses a natural phenomenon requiring repeated attention by the learner over an extended period of time in order to construct deep understanding of an identified solution" (p. 495). "Some have suggested that inquiry begins with a teacher's ability to identify, use, and exploit quality questions that help achieve specific content and/or skill learning objectives" (p. 496). History of question typology research..Bloom, etc. Most of the research has been on - how teachers sue question, the types of questions teachers ask, of what questions students ask (p. 500). "What is needed is a framework that builds upon cognitive appropriateness of questions to include relevant dimensions that are pedagogically meaningful to pre-service and in-service science teachers" (p. 502). "For the scrutinizing teacher, textbooks can be a good first step in constructing an effective focus question, but most questions from textbooks are too generic to be used 'as is'" (p. 503). Good focus questions should address all of these - content,

				curriculum, context, and cognition. Step by step process of how to find/create/use focus question. "By developing and incorporating science questions that promote sustained reasoning through inquiry, classroom teachers can help learners foster deeper understanding of science content and an appreciation for the scientific enterprise" (p. 508). Also this DOES NOT require large investments in time or money!!!
Lyle, S.	2008	Dialogic teaching: Discussing theoretical contexts and reviewing evidence from classroom practice.	Language and Education, 22(3), 222-240.	Vygotsky-the power of language in learning-all learning is located in social, cultural, and historical contexts. "Weels (1992: 287) defines discourse as the interactive and constructive meaning making that occurs in purposeful linguistic interaction with others" (p. 224). P4C-emphasis on questions. Implications for initial teacher training and continuing professional development for practicing teachers is immense.

Marshall, J. C., & Horton, R. M.	2011	The Relationship of Teacher-Facilitated, Inquiry-Based Instruction to Student Higher-Order Thinking.	School Science and Mathematics, 111(3), 93-101.	"When we better understand how teachers who are successful in challenging students in higher-order thinking spend their time relative to various components of inquiry-based instruction, then we are better able to develop professional development experiences that help teachers transition to more desired instructional patterns" 21st century learners need problem solving skills, not rote memorization. inquiry theoretical frameworks--need to know (Piaget), scaffolding (Vygotsky), deep conceptual knowledge over surface. Curriculum is important, but it is the teacher quality that makes the most difference. 4 components of many inquiry models - Engage, Explore, Explain, Extend. P. 95-great chart on inquiry-levels of instruction and what they look like in classroom practice. More time for student exploration resulted in higher cognitive thinking. This is an interesting question-do students who spend more time with enduring concepts do just as good or better on standardized tests than students who just memorize? "When teachers give students an opportunity to explore concepts before an explanation they think more deeply about it, it does not matter who gives the explanation...students or teachers...
Marshall, J. C., Smart, J., & Horton, R. M.	2010	The design and validation of EQUIP: An instrument to assess inquiry-based instruction.	International Journal of Science and Mathematics Education, 8(2), 299-321.	Student achievement increases when teachers practice three learning constructs: inquiry instruction, formative assessment, and teacher reflection. This is a descriptive study of how a tool for inquiry teaching was developed around four constructs: instruction, curriculum, discourse, and assessment.
McNeill, K. L., & Krajcik, J.	2008	Scientific explanations: Characterizing and evaluating the effects of teachers' instructional practices on student	Journal of Research in Science Teaching, 45(1), 53-78.	Helping students engage in explanation and argumentation in science may help them move away from the notion that science is a static set of facts to science as a social process where knowledge is constructed (p. 54). And it will actually do a better job of having students

		learning.		learn content knowledge than traditional methods.
McNeill, K. L., & Pimentel, D. S.	2010	Scientific discourse in three urban classrooms: The role of the teacher in engaging high school students in argumentation.	Science Education, 94(2), 203-229.	The idea of teachers taking on new roles, different from more traditional classrooms, this may be difficult, but can help shift the norm by being a model for students as to how to ask questions, critique others and make arguments for their case. More open questions led to more talk, use of evidence and reasoning and interactions between students.
McGough, J. V. & Nyberg, L.M	2015	The Power of Questioning: Guiding Student Investigations	NSTA Press: Arlington, VA.	Great guide that highlights the importance of questioning, how to plan for questioning and how to put the plan into action. Part of the Powerful Practices Series. Practical small book meant to give tips and tricks..
Michaels, S., O'Connor, M. C., Williams Hall, M., Resnick, L. B.	2013	Accountable talk sourcebook: For classroom conversation that works.	Institute For Learning, University of Pittsburgh.	Accountable means that it is accountable to: "the learning community, to accurate and appropriate knowledge, and to rigorous thinking" . There is no "Best" way to accomplish a particular academic purpose (p. 15). 2 musts for accountable talk: 1. all students must have access to the learning conversation 2. the content of the talk must consistently further academic learning (p. 16). Types of classroom tasks: 1. Lecture 2. Recitation (IRE) 3. Teacher guided whole group discussion. "They must have a well-developed set of strategies and "moves" for Accountable Talk facilitation. Otherwise teachers may slip into lecturing or recitation in order to "cover the material" (p. 20). 4. Teacher-guided small group discussion 5. Teacher-student conferences 6. student led small group work and peer conferencing 7. hybrid talk formats: stop and talk, fish bowl, student presentation. Teacher moves in group discussion; marking (that's an important point..), challenging students (what do you think?), modeling

				(here's what good readers so), recapping (what have we discovered). Teacher moves that support accountability to community: keeping the channels open (did everyone hear that?), keeping everyone together (who can repeat..?), linking contributions (who wants to add on...), verifying and clarifying (so, are you saying...?). Teacher moves that support accountability to accurate knowledge; pressing for accuracy (where can we find that..), building on prior knowledge (how does that connect?), Teacher moves that support accountability to rigorous thinking (pressing for reasoning (why do you think that?), expanding reasoning (take your time, say more). Norms for equitable and respectful participation; turn taking norms, wait time.
Minstrell, J., & van Zee, E.	2003	Using questioning to assess and foster student thinking.	Everyday assessment in the science classroom, 61-73.	"Knowing how we know is at least as important as what we know" (p. 61). Elicitation questions, sort of like essential questions. Reflective discourse: actively engaging in monitoring their own and others thinking (p. 68). Types of Q that can accomplish this: questions to open inquiry and gain prior knowledge; Q to interpret and make sense of data in order to make an argument; Q that clarify or elaborate observations and inferences; Q that encourage learners to go beyond a mere statement, justify answer...explain why; Q that apply what is know; Q that help them monitor their own thinking. Questioning as a means of diagnosing student thinking and then helping them bridge between their current thinking and more scientific thinking.

Myhill, D.	2006	Talk, talk, talk: Teaching and learning in whole class discourse.	Research Papers in Education, 21(1), 19-41.	Direct instruction through whole class teaching is the most common teaching strategy around the world. Talk is not only a product, but a process for learning as well...a tool for learning. "In the context of socio-constructivist frameworks for learning, the goal of classroom talk, therefore, should be to scaffold pupils' learning sensitively so that they are supported in making meaning and understanding for themselves" (p. 22). "principled understanding"- students have a strong grasp on principals rather than facts. 2.5 year national study in UK about quality of whole class discourse. Action research model. From their study over 60% of questions were factual...Teachers have a false understanding of their questioning...they think they are varying their questions, but really they are variations on one theme...factual...(p. 28). Prioritizing of teaching...delivery and content over understanding...Again the fear of coverage and time negates student talk, teachers feel pressure to keep it moving. There are ability and gender implications for participation. Girls enjoy the teacher orchestrating the conversation, and boys prefer to be in charge. Interesting, gender roles playing out...So the understanding of what constitutes prior knowledge-prior coursework or school knowledge or prior knowledge from life, home, family, world, etc. The more teachers ask, the less students say...Part of the art, not only how to question, but when and how much...Wragg and Brown..."it may be that if we want to ask questions that get children to think, then we have to think about the questions we are going to ask them" (p. 39). Perhaps a shift in planning, from content to cognitive development.
NGSS Lead States	2013	Next Generation Science Standards	National Academy Press: Washington	Students in the United States are struggling to demonstrate basic levels of proficiency in science on

			DC	national assessments and are not competitive internationally. The NGSS are different from previous standards in three ways: performance, foundations, and coherence. The NGSS incorporates three dimensions for each performance; a core idea, a science and engineering practice, and a crosscutting concept
No Child left behind act of 2001	2008	Qualifications for Teachers and Professionals	20 U.S.C. § 6319	Highly qualified regulations and what teachers need to be able to teach
NRC	1996 2011	National Science Education Standards A Framework for K-12 Science Education: Practices, crosscutting concepts and core ideas	National Academies Press: Washington, DC.	Outlines standards before NGSS. Much of this is still current, inquiry and NOS.
Nystrand, M.	2006	Research on the role of classroom discourse as it affects reading comprehension.	Research in the Teaching of English, 392-412.	This article is arguing that we don't use enough empirical research to inform teaching. And that there is a "folk wisdom" that permeates information and teaching practice. How does teacher discourse role affect student learning? Transmission oriented teachers vs. interpretation oriented teachers. "What counts as knowledge and understanding in any given classroom is largely shaped by the questions teachers ask, how they respond to their students, and how they structure small-group and other pedagogical activities" (p. 400). Nystrand-getting discussion going is like building a fire.
Oliveira, A. W.	2010 (c)	Engaging students in guided science inquiry discussions: Elementary teachers' oral strategies.	Journal of Science Teacher Education, 21(7), 747-765.	"One of the most common student-engaging strategies used by elementary science educators is children's literature" (p. 748). Types of oral strategies discussed: parallel repetition, figures of speech, colloquial language, humorous comments and rhetorical questions (p. 750). There is a social and cognitive function to language in classroom.

Oliveira, A. W.	2010 (b)	Improving teacher questioning in science inquiry discussions through professional development.	Journal of Research in Science Teaching, 47(4), 422-453.	Questioning serves both cognitive and social ends and is also looked at from both cognitive and social research perspectives...Teachers social understanding of teachers as they learned about questioning-functions of teacher questioning, teachers intentions, teachers sincerity, student engagement. In this case they are evaluating their program and showing that pre vs. post institute teachers were better at asking more student-centered questions. questioning as a cognitive tool..."if employed effectively by teachers, student-centered questions (referential, confirmation checks, and clarification requests are more likely to promote higher-level thinking and encourage students to offer oral responses that are not only longer but more fully articulated and sophisticated" (p. 445). Having explicit scholarly knowledge of questioning allowed teachers to understand the social implications (authoritative, power, control, etc) of questioning and shift their practice from teacher-centered to student-centered. Essentially, PD needs not just a cognitive perspective (Q typologies) but also a social perspective of questioning...
Oliveira, A. W.	2010 (a)	Developing elementary teachers' understanding of the discourse structure of inquiry-based science classrooms.	International Journal of Science and Mathematics Education, 8(2), 247-269.	Handling students who want the "correct" answer is difficult. This research tested the idea of how academic understandings of discourse affected teachers' social understanding of discourse. The teachers struggled with the neutrality of responses, indicating that by not evaluating, there are many potential problems anyway...students may think it still is an evaluation, it becomes a guessing game, etc. Teachers need a stronger awareness of scholarly descriptions of discourse to be able to affect change in their classroom and they need to think about how the social implications of their language use affect inquiry. Emphasize that there is no one size fits all way to facilitate discourse, but rather, need to evaluate

				many ways in the context of their unique space. Really this is what makes it so hard - how do you learn something that is so subjective, it really is an art. Show teachers a variety of techniques and information and help them develop their own style.
Oliveira, A. W., Wilcox, K. C., Angelis, J., Applebee, A. N., Amodeo, V., & Snyder, M. A.	2013	Best practice in middle-school science.	Journal of Science Teacher Education, 24(2), 297-322.	Developmentally and diagnostically there is no standard operating procedure, what works for one, may not for another. There is some best practice, but it is more about process. So the first step would be to "diagnose" what is going on in your class. Then look at a "menu" of practices and decide what would work. Try them and then re-evaluate. This cycle would be "professional". Open inquiry-true inquiry. Guided inquiry-more focused with research questions-the essential question type of inquiry. New term - scientific and engineering practices (instead of inquiry). This study show that inquiry is actually good for students. Inquiry is found to be correlated with higher student and school performance (p. 314).
Parker, M., & Hurry, J.	2007	Teachers' use of questioning and modeling comprehension skills in primary classrooms.	Educational Review, 59(3), 299-314.	Teachers not aware of their modeling. They are aware of their questioning, but it is low level. However, explicit instruction in modeling could improve literacy. Need alternative pedagogy strategies…"It is sometimes the case that educational researchers identify issues and make recommendations that are difficult for teachers to implement" (p. 313).

Pasley, J. D., Weiss, I. R., Shimkus, E. S., & Smith, P. S.	2004	Looking Inside the Classroom: Science Teaching in the United States.	Science Educator, 13(1), 1-12.	Teaching for understanding is the goal of science instruction, regardless of views on the type of inquiry enacted. Further, it requires teachers to have solid content knowledge, pedagogical content knowledge, and class management skills to make it active (p. 2). In this study they determined the factors that made for a lesson which resulted in better understanding by the students-1. engage students with science content 2. create an environment conducive to learning 3. ensure access for all students 4. use questioning to monitor and promote understanding 5. help students make sense of the science content (p. 4). "Questioning was among one of the weakest elements of science instruction" (p. 8). It is not the type of instructional strategy, but rather how it is implemented...if it meets the 5 criterion above then it is a good lesson regardless of whether or not it is a lecture, demonstration, or activity...teachers need strong conceptual knowledge
Pea, C. H.	2012	Inquiry-based instruction: Does school environmental context matter.	Science Educator, 21(1), 37-43.	Research shows that three broad areas of school environment matter to inquiry instruction: 1. human 2. sociocultural 3. design. The results of the survey show that team planning is the most critical part that would help them improve inquiry practice-So what if you are alone? Student interest, or lack thereof seemed to be the biggest inhibitor of inquiry-when students are not motivated, then teachers choose not to do inquiry.

Queeney, D. S.	1995	Assessing needs in continuing education: An essential tool for quality improvement.	San Francisco: Jossey-Bass.	Educational needs (needs assessment) vs. operational needs (market research), "needs assessments determine the differences between existing and desired knowledge, skills, and performance abilities" (p. 2). educational needs amenable to education...in a needs assessment often, what people say they need, they in fact do not need, and it is the areas they do not say that is often the greatest need. It seems like it is the case of if you don't even know it is a problem, then you probably need the most help with it...so self-report is flawed, duh, and perhaps a needs assessment is a combination of perceived needs and an assessment to determine needs more objectively. "most people assume, often erroneously, that they perform their routine activities well" (p. 14). Time is the biggest deterrent to continuing education. With all the other responsibilities, there is just simply not enough time.
Reznitskaya, A., & Gregory, M.	2013	Student thought and classroom language: Examining the mechanisms of change in dialogic teaching.	Educational Psychologist, 48(2), 114-133.	Disconnect between what we know to be true (more talking by students the better) and what is happening (more talking by teachers) and how this is incredibly resistant to change. p127-128 great example of a teacher who asked a great question, but was not able to follow it up with a good discussion. She just said great and called on the next. There was no good feedback or argumentation about any one idea. So as we try to move from - an expert only has knowledge to knowledge needs to be backed up - we end up at the other extreme in that everyone has knowledge...changing beliefs without providing practical alternatives based on those theories can be frustrating. Teachers need a combination of knowledge and coaching.

Rop, C. J.	2002	The meaning of student inquiry questions: A teacher's beliefs and responses.	International Journal of Science Education, 24(7), 717-736.	Case study of a high school chemistry teacher. The focus is on what happens when students asked inquiry questions. The first finding is that the teacher assigns a value to them based on how well or not they fit in with the lesson objectives. Time and coverage are real concerns for teachers and discourse and questioning. often students have good questions, but teachers find there is not enough time to get into them. They need to stay on track with the curriculum and the lessons are carefully planned out for that. Perhaps building in time for discussion and questions is a good way to go about this...There is also a notion that the cultural expectations of the teacher as to what constitutes a good teacher and also how good teachers teach in the school (from the book) so they can be ready for the next course. Pedagogic efficiency is the priority when working as part of a system.
Roth, W. M.	1996	Teacher questioning in an open-inquiry learning environment: Interactions of context, content, and student responses.	Journal of Research in Science Teaching, 33(7), 709-736.	Interactions with students are mediated by other factors, group dynamics including gender, whole or small group, content. "Questions are not universally good, but need to be evaluated in terms of their situational adequacy" (p. 709-710). "When child-centered inquiry is combined with appropriate questioning techniques, canonical science and engineering knowledge do not have to be compromised" (p. 716). Create a culture of questioning..This is a case study of excellent questioning skills. The teacher found that girls did not like answering questions during whole class discussions, so she did not push them there, but rather engaged them during small group discussion.

Rowell, P. M., & Ebbers, M.	2004	Shaping school science: competing discourses in an inquiry-based elementary program.	International Journal of Science Education, 26(8), 915-934.	The teacher is the mediator of science. Curriculum can be dictated, however it is the teacher who decides and enacts science pedagogy in the classroom. The questioning aspect becomes a way of learning about this important pedagogical skill and how it can ultimately shape inquiry in the classroom, for better or for worse. Because if discourse is important for students to be better at inquiry, then questioning is important because it will either stifle or encourage open discourse. So it needs to be considered thoughtfully.
Ruebush, L. E., Grossman, E. L., Miller, S. A., North, S. W., Schielack, J. F., & Simanek, E. E.	2009	Scientists' Perspective on Introducing Authentic Inquiry to High School Teachers During an Intensive Three-Week Summer Professional Development Experience.	School Science and Mathematics,109(3), 162-174.	A description of an inquiry institute for teachers. Results show (not surprisingly) that teachers feel more comfortable going back to their classrooms and doing inquiry with their students as a result of being immersed in inquiry themselves. Important components of the experience included mentors, models, discussions, student presentations and feedback.
Ruiz-Primo, M. A., & Furtak, E. M.	2006	Informal formative assessment and scientific inquiry: Exploring teachers' practices and student learning.	Educational Assessment, 11(3-4), 237-263.	Formative assessment-assessment for learning and not of learning. "Assessment conversations" - different from IRE, they are about Question-Response-Acknowledge-use for learning-sounds very similar to IRF-use the final chain to actually scaffold instruction and learning. Also do not evaluate. ESRU cycles. Conclusion-teachers whose assessment conversations more consistent with ESRU cycles had students with the highest performance. They further argue that F in IRF is not as useful as the U in ESRU.

Schiller, E., & Joseph, J.	2010	A Framework for Facilitating Equitable Discourse in Science Classrooms.	Science Scope, 33(6), 56-60.	Teachers are surprised to find that their questioning habits are actually traditional, they thought they were doing inquiry...however this can be resolved with time and a plan...(again need to plan for this). A lot of useful strategies, but it felt disconnected. Perhaps having this with actual examples would be better...what does it look like?
Scott, P.	1998	Teacher talk and meaning making in science classrooms: A Vygotskian analysis and review.		"According to the Vygotskian perspective the teacher, or some other knowledgeable figure, has a key role to play in mediating and 'passing on' existing public knowledge (such as scientific knowledge) to students" (p. 47). Cued elicitation-the idea that teachers lead pupils in the discussion, but it can be guessing game for what is the "correct" answer. Authoritative vs. dialogic discourse. Authoritative is when the teacher "transmits" information. Dialogic is when the teacher asks the students for their thoughts. Talk about rhythm, a balance between authoritative and dialogic...as with anything there needs to be both there is a continuum that you need to be able to slide along as the teacher/class. Teacher responsiveness with scaffolding - monitoring, analyzing, and assisting (p. 70). Pedagogy vs. instruction (pedagogy practices are in the moment and instructional practices are planned), questioning is both pedagogical and instructional. Conceptual vs. ontological vs. epistemological shift (p. 74).

Scribner, J. P.	1999	Professional development: Untangling the influence of work context on teacher learning.	Educational Administration Quarterly, 35(2), 238-266.	1. What motivates teachers to seek professional development?; 2. What are the ways teachers experience their own professional development?; 3. How do teachers work context influence professional development? Snowball and purposeful sample of peer/administrator identified excellent high school teachers. 45 teachers and 7 administrators. One district, 3 high schools, all urban. Embedded case study (school within district). Teachers are motivated extrinsically (renumeration, licensure) and intrinsically (content knowledge needs, pedagogical skill deficit, challenges to classroom management, gaps in student centered knowledge) to learn. Less so a sense of moral obligation and content was the primary intrinsic motivator. Pedagogy was focused on practicality. "teachers mostly rely on collaboration to flesh out daily professional challenges, and collaboration is not typically built into formal professional development programs". Given the opportunity to collaborate, the focused on classroom management and pedagogical skills, preferring to do content alone and theory not at all. Work context factor affect learning-leadership, culture of school. District level-policy reform and priorities. "At the school level, professional learning must be embedded in the culture of schools". "Teachers are being asked to teach in ways that promote critical thinking and problem-solving skills and that require deeper subject matter knowledge"

Smart, J. B., & Marshall, J. C.	2013	Interactions between classroom discourse, teacher questioning, and student cognitive engagement in middle school science.	Journal of Science Teacher Education, 24(2), 249-267.	Findings: 1. better teacher Q and discourse results in better student learning (cognition). 2. Low order Q are prevalent. If teachers understood that their Q affects learning they may be more likely to change. "During a fast paced lesson, teachers may consciously struggle to increase the level of questions that they are using in instruction. However, making student questions an important aspect of lesson planning is critical to ensuring these questions take priority during instruction" (p. 265). "Professional development and online video clips could offer vicarious learning experiences for in-service teachers" (p. 266).
Smith, P. M., & Hackling, M. W.	2016	Supporting Teachers to Develop Substantive Discourse in Primary Science Classrooms.	Australian Journal of Teacher Education, 41(4).	From Mortimer and Scott (2003) 4 different types of communicative approach - 1. Interactive-Dialogic-students and teachers explore different ideas and points of view 2. Non-interactive dialogic-where the teacher considers various ideas and points of view 3. Interactive-Authoritative-where the teacher leads the students through a sequence of questions so as to reach a specific point of view and 4. non-interactive authoritative-teacher presents one specific point of view. Teachers need to know how to use these different approaches and how to transition between them during a lesson. 5E-Engage, Explore, Explain, Elaborate, and Evaluate). "The main purpose of questioning in teaching is to promote student learning" (p. 154). Table 6 on p. 167 is a possible tool to use for evaluating your own practice...Figure 2 on p. 169, good for feedback suggestions..Article strongly advocates for video usage of own and others practice. Coding scheme can be used as a tool to evaluate own practice..

Southerland, S. A., Sowell, S., & Enderle, P.	2011	Science teachers' pedagogical discontentment: Its sources and potential for change.	Journal of Science Teacher Education, 22(5), 437-457.	Learning to teach science requires conceptual change on the part of the teacher. need to make these conceptual changes before they can make changes in their practice. "a teacher's abilities and/or inclinations to learn and relearn conceptions of content, learning, and teaching present the most profound influences shaping the change of teacher practice" (p. 438). Teachers need to experience dissatisfaction with their teaching in order to seek out changes. There are two types of dissatisfaction, contextual (things like time, etc) and pedagogical-when current practices do not meet their teaching goals. Areas of discontent: teaching varying ability levels, assessment, science content knowledge, depth vs. breadth, and inquiry. research about inquiry shows that it is hard because it requires new roles for teachers and students and also requires more PCK for teachers. The key to any kind of change is to create a dissonant event-need this for conceptual change. So in the site perhaps this needs to be created by showing them their current practice, asking them questions, or having them complete an exercise like analyzing their classroom. but also need to play into their self-efficacy by having good easy examples of what they can do. If it seems to hard, they will not try. They need to feel like they can do it before they will try to do it. creating an environment where teachers reflect openly on practice opens the door to more disconnect events and then more learning. So perhaps that is how this site is useful, it is a place to reflect on practice as well and learn about how to better practice. Helping teachers with this cycle of reflection-discontent-learn. Further, focusing on pre-service or novice teachers may not be a good idea. They are too overwhelmed by contextual factors to deal with any conceptual changes.

Tienken, C. H., Goldberg, S., & Dirocco, D.	2009	Questioning the questions.	Kappa Delta Pi Record, 46(1), 39-43.	Again history here with Socrates (Socratic method) and Raphael. There is the cognitive domain of questioning, ex. Blooms taxonomy..teachers do not take full advantage of questioning's potential. Prepare, prepare, prepare…just like lawyers, teacher should be preparing questions for classes, authors suggest teachers script between 10-15 productive questions per lesson.
United States National Commission on Excellence in Education	1983	A nation at risk: The imperative for educational reform: a report to the Nation and the Secretary of Education, United States Department of Education	The Commission: Washington, DC	Context for reform
Watson, K., & Young, B.	1986	Discourse for learning in the classroom.	Language Arts, 126-133.	IRE is rampant, it is hard to get out of it. Teachers more often than not ask factual questions and then they go on to any of the interpreting, analyzing, or predicting that the students should do. They are taking on the cognitive demands of the content and letting children sit back. It seems like they do not believe that students can take on their own learning. Further, textbooks and curricular materials feed into this. Interesting, they referenced a study that concluded that teacher -led discussions where the teacher was "neutral" and more of a facilitator were more productive than small groups. Mostly because the teacher was able to help with content knowledge expertise when smaller groups of students would get stuck.

Wells, G., & Arauz, R. M.	2006	Dialogue in the classroom.	The journal of the learning sciences, 15(3), 379-428.	Learning outside of the classroom is much more participatory. And learning in the classroom happens through language and usually whole group discourse, which traditionally is IRF, so this is where we need to focus the effort. We need both monologic and idalogic communication in classrooms. Monologic serves to transmit information and collective knowledge, but the dialogic serves to allow people to digest, and perhaps improve upon existing knowledge. Often we as teachers are too focused on the monologic, but we NEED to devote time and skill to fostering the dialogic function of language in the classroom...Interesting p. 410. The idea of progressive discourse where discourse attempts to reach a new understanding that all involved agrees is better than their individual understanding. The idea that the discourse can still be triadic in nature, however, the teacher is not the primary knower, but rather it is distributed among the class. This is why traditional means of evaluating teacher talk as triadic is not necessarily capturing how discourse is changing...Further in some cases it is OK for dialogic talk to not reach a consensus, however, in some cases it needs to, like often in science, students need to reach a common accepted notion or definition of something. "They {the results} also show that the single most important action a teacher can take to shift the interaction from monologic to dialogic is to ask questions in which there are multiple possible answers and then encourage the students who wish to answer to respond to, and build upon, each other's contributions" (p. 414).

Wolf	1987	The art of questioning.	Academic Connections, Winter, 1987, 1-7.	Ask a teacher how they teach and chances are they will answer…"by asking questions" Teachers dominate questions and classroom talk; flow is usually from teacher to student, questions have power-only some are privileged to participate. "Independent of whom they teach, skilled teachers question in distinctive ways: they raise a range of questions, they sustain and build arcs of questions, their inquires are authentic, they inquire with a sense of respect flail decency" (p. 3). A range of questions: inference, interpretation, transfer, questions about hypotheses, and reflective. And it is not just the initial question and response, but also the teacher response-this is so important. Skilled teachers are good at keeping this sequence going. Why so few questions-some teachers are just not interested (not who my site is for..). Change is hard. Teachers need time and practice to build this skill and it is not valued by the institution. Students lack knowledge and ability to participate in question/discussions. Coverage, time and culture of schools. What do interested teachers want? - time to observe themselves (video), time to observe others, time to process questions before and after. Teachers want to practice inquiry themselves.
Wragg, E. C. & Brown, G.	2001	Questioning in the secondary school.	RoutledgeFalmer: London.	Teaching is about strategies that are deeply embedded. because decisions and responses have to be made quickly-under 1 second-we rely on these deeply embedded structures to guide us. So one they are in place, they are hard to change. "intelligent questioning is a valuable part of interactive teaching. Inept handling of questions, however, leads to confusion and misunderstanding" (p. 1). Types of questions cognitive (knowledge and understanding, affective (emotions), and social and procedural

Yager, R.E.	2000	The history and future of science education reform.	Clearing House, 74(1), 51-54	Historical context of reform, No Child Left Behind and the previous standards.
Yilmaz, K.	2011	The cognitive perspective on learning: its theoretical underpinnings and implications for classroom practices.	The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 84(5), 204-212.	Spectrum of learning theories-behaviorism, cognitive, constructivism…components of cognitive 1-learning is an active process and 2-the learner as an active participant in the process. Asking questions is one way of understanding what students know and how they are organizing information.
Zemke, R., & Zemke, S.	1995	Adult Learning: What Do We Know for Sure?.	Training, 32(6), 31.	Knowles' four assumptions of andragogy: adults are self-directed learners; adults learn more through experience, learning needs are determined by their life experiences, adults want to learn something they can practice/use immediately (p. 40). "Adults tend to prefer single-concept, single-theory courses that focus on applying the concept to relevant problems" (p. 43-44). "Regardless of media and learning style, most adults prefer straight-forward, how-to content "Need to have transfer strategies, "transfer strategies include pre-training and post-training activities, as well as discussions during training that focus on using the new knowledge or skills back on the job" (p. 46). Teacher behavior that is effective: create a safe and comfortable environment (physical and emotional), facilitation is more effective than lecture...good facilitation is: goals and expectations are clarified, not having to be in control, good questioning, adults are nervous about risks, variety and balance of tasks/activities, responsive to the people and their experiences, reinforcing of participants.

Appendix B: Interview Protocol

Interview protocol: Professional Development Prototype Design for Questioning in the Science Classroom

Interview Information

Participant:

Date/Time:

Method: In Person/Phone/Video Conference

Introduction

Thank you for agreeing to participate in this interview. My name is Allison Rook and I am a doctoral student at Rutgers, Graduate School of Education. I am working on a research study where I am interested in learning about what teachers would like to learn about questioning in the science classroom. Ultimately I will use what I learn and create an electronic resource with the goal of helping teachers learn more about questioning in the classroom.

I will ask you some questions about your background and education, questioning practices in the classroom, and what learning opportunities you or your teachers would like with regards to questioning.

Background and Education (All Participants):

1. What is your gender?
    a. male
    b. female

2. What is your age?
    a. 20 - 29
    b. 30 - 39
    c. 40 - 49
    d. 50 - 59
    e. 60 - 69
    f. 70+

3. What level of education have you completed?
    a. High school
    b. College degree
    c. Masters degree
    d. Doctorate

4. Tell me about your current position. Are you a (student, teacher, supervisor)?.

For teachers/pre-service teachers (Skip to below if supervisor):

5. What state(s) do you have (or will have) certification to teach science? What year did you

get it?

6. What strand(s) of science are you (or will you be) certified to teach?
    a. Biology
    b. Physics
    c. Chemistry
    d. Earth Science
    e. General Science
    f. Other

7. What grades are you (or will you be) certified to teach?
    a. 6
    b. 7
    c. 8

8. How many years have you been teaching? Teaching Science?
9. What classes do you teach?
    a. Possible prompts: how many classes?, what are the classes called?, what is covered in each class (ex. biology, chemistry?), class level (ex. honors, general, inclusion).
10. Approximately how many students do you teach in your science classes?
    a) Possible prompts: how many total?, how many per class?

For Supervisors:

11. How long have you been a supervisor? In your current position?
12. What did you do before you were a supervisor?
13. Who are you responsible for supervising?
    a. Possible prompts: How many teachers/students?
14. What does supervising entail?
    a. Possible prompts: Does it require evaluations? Observations?

Now I would like to shift gears a little bit and talk about science classroom teaching. But before we move on is there anything you would like to add to what you have already told me about your background?

Classroom Practice:

For Teachers/Pre-service teachers (Skip to below for supervisors):

15. What are your goals for teaching science?

16. If I were visiting your classroom, what would I see?

17. If I were observing you teach, what would I see?

    a. Possible Prompts: lecture, discussion, interactive, demonstrations, inquiry

    b. Follow-up Question: Why do you use this/these approach(es)?

18. What materials do you use during your classes?

a. Possible prompts: textbooks, lab kits, technology, worksheets, journals?

b. Follow-up question: How do you use these materials?

**As you know I am interested in teacher questioning so I would like to focus now on learning more about your (or the teachers you supervise) questioning practices in the science classroom.*

19. Some teachers think that questioning is very important and other teachers do not, what is your experience with questioning in the classroom?

20. Do you have a sense of how many questions you might ask each day?

21. If you had to describe the types of questions you ask, what would that look like?

    a. Possible prompt: checks for understanding/prior knowledge, open ended, closed response.

22. What are some of the social implications of teacher questions?

    a. Possible prompts: student confidence, value of student response

23. Can you please explain your understanding of the term question level?

24. How about, question complexity?

25. If we consider teacher questioning along a continuum from questions that happen spontaneously during a lesson to questions that are pre-planned, what kinds of questions do you use in your teaching?

    a. How has this practice changed over the time you have been teaching?

For Supervisors: Use *transition from above

26. How would you describe the goals of classroom science here at your school/district?

27. What does typical science classroom instruction look like amongst your teachers/students?

28. Some teachers think that questioning is very important and other teachers do not, how would you characterize the teachers that you supervise?

29. Do you have a sense of how many questions your teachers might ask each day?

30. If you had to describe the types of questions your teachers ask, what would that look like?

    a. Possible prompt: checks for understanding, check for prior knowledge, homework answers, classroom management.

31. What are some of the social implications of teacher questions?

    a. Possible prompts: student confidence, value of student response

32. How would you describe to a teacher what the term question level means?

33. How about, question complexity?

At this point I would like to learn about what you might like to learn more about with respect to questioning in the classroom.

Content and Electronic Needs (All Participants):

34. Let's start with a fill in the blank, I (teachers I supervise) find questioning to be _____ (ex. easy, difficult, second nature, natural, I don't really think about it at all)

35. How did you (of the teachers you supervise) learn to question students in the classroom? Have you (or the teachers you supervise) ever had any explicit training in teacher questioning practices? If yes, when? Pre-service? In-service? Please Describe.

36. If you were to give advice about questioning to another teacher what would it be?

37. What would you (and/or the teachers you supervise) like to know about questioning?

38. How would you describe the way you (the teachers you supervise) learn in your (their) professional practice?

    a. Possible Prompts: From peers? Personal reflection? Research? Professional development? Graduate classes?

    b. Is there someone or something in particular that influences you? Possible prompts: maybe a particular researcher or blogger, or a certain website?

As you know, I am creating a technology resource for teachers about questioning, so I would like to know...

39. ...what types of materials or activities would be useful for you (the teachers you supervise) to learn about questioning?

    a. Possible prompts: videos, blogs, tutorials?

40. ...what would be the most useful type of format?

    a. Possible prompts: website, App, other?

Thank you again for taking the time to talk with me. Are there any questions you have or anything you would like to add about anything we have talked about?

Appendix C: Participant Recruitment Flyer

Science Teacher Professional Development Design Study

Are you a middle school science teacher or supervisor?
Are you a pre-service science teacher or supervisor?

If so, you are invited to participate in a professional development research study.

My name is Allison Rook and I am a graduate student at Rutgers University, Graduate School of Education in New Brunswick, NJ. I am studying how to design an electronic professional development resource for science educators that supports effective questioning techniques in the science classroom.

I am looking for middle school science teachers and supervisors as well as pre-service science teachers and supervisors to participate in interviews, surveys, and/or user testing. The interviews and user testing will take no more than 1 hour per session and can be done in person, over the phone, or through video conferencing. The surveys will take no more than 20-30 minutes each and can be completed online.

If you are interested in participating in this study, please contact me for more information at 716-860-7864 or allison.rook@gse.rutgers.edu.

Appendix D: Survey Protocol

Question Design Survey

Start of Block: Consent

Q15 My name is Allison Rook and I am a doctoral student at Rutgers University, Graduate School of Education. I am working on a research study where I am developing an online resource for middle school science educators about teacher questioning practices. I am looking for middle school educators (teachers, student teachers, principals, supervisors, university instructors) to participate in an anonymous survey. While participation is completely anonymous, the input and feedback provided will help in making important design decisions. The survey should take no more than 25 minutes to complete.

I appreciate any help you can provide by either completing this survey yourself or passing it along to other educators who may be interested in participating. Should you have any questions or concerns about the survey or this research please contact me, Allison Rook at allison.rook@rutgers.edu or 716-860-7864 or my faculty advisor Dr. Melinda Mangin, PhD at melinda.mangin@gse.rutgers.edu or 848-932-0723. Thank you for your time and consideration, Allison Rook

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Q1 You are invited to participate in a research study that is being conducted by Allison Rook, who is a doctoral student in the Graduate School of Education at Rutgers University. The purpose of this research is to develop an online resource for middle school science educators about teacher questioning practices . This research is anonymous. Anonymous means that I will record no information about you that could identify you. There will be no linkage between your identity and your response in the research. This means that I will not record your name, address, phone number, date of birth, etc. The research team and the Institutional Review Board at Rutgers University are the only parties that will be allowed to see the data, except as may be required by law. If a report of this study is published, or the results are presented at a professional conference, only group results will be stated. All study data will be kept for 3 years after the conclusion of the study. There are no foreseeable risks to participation in this study. In addition, you may receive no direct benefit from taking part in this study. Participation in this study is voluntary. You may choose not to participate, and you may withdraw at any time during the study procedures without any penalty to you. In addition, you may choose not to answer any questions with which you are not comfortable. If you have any questions about the study or study procedures, you may contact myself at allison.rook@rutgers.edu or 716-860-7864. You can also contact my faculty advisor Dr. Melinda Mangin, PhD at

melinda.mangin@gse.rutgers.edu or 848-932-0723. If you have any questions about your rights as a research subject, please contact an IRB Administrator at the Rutgers University, Arts and Sciences IRB: Institutional Review Board
Rutgers University, the State University of New Jersey Liberty Plaza / Suite 3200 335 George Street, 3rd Floor New Brunswick, NJ 08901 Phone: 732-235-2866
Email: humansubjects@orsp.rutgers.edu Please retain a copy of this form for your records. By participating in the above stated procedures, then you agree to participation in this study. This informed consent for was approved by the Rutgers University Institutional Review Board for the Protection of Human Subjects on June 8, 2017; approval of this form expires on June 7, 2018. If you are 18 years of age or older, understand the statements above, and will consent to participate in the study, click on the I Agree button to begin the survey. If not, please click on the I Do Not Agree button which will exit this program.

- ○ I agree (1)
- ○ I do not agree (2)

Skip To: End of Survey If You are invited to participate in a research study that is being conducted by Allison Rook, who i... = I do not agree

End of Block: Consent

Start of Block: Main Survey

Q2 What is your gender?

- ○ Female (1)
- ○ Male (2)
- ○ Transgender (3)
- ○ Other (4)
- ○ Prefer not to answer (5)

Q3 What is your age?

- ○ 20-29 (1)
- ○ 30-39 (2)
- ○ 40-49 (3)
- ○ 50-59 (4)
- ○ 60-69 (5)
- ○ 70+ (6)

Q4 What level of education have you completed?

- ○ High school (1)
- ○ Associate's degree (2)
- ○ Bachelor's degree (3)
- ○ Master's degree (4)
- ○ Master’s + credits (5)
- ○ Doctorate (6)

Q5 What is your current position (check all that apply)?

- ☐ Middle School Science Student Teacher (1)
- ☐ Middle School Science Teacher (2)
- ☐ Middle School Science Supervisor/Administrator (3)
- ☐ University Professor/Instructor (4)

Q6 How would you describe your current school?

- ○ Urban (located within city limits) (1)
- ○ Suburban/Town (located within 10 miles of city limits) (2)
- ○ Rural (located more than 10 miles from city limits) (3)

Q7 How would you describe your current school?

- ○ Large (500 or more students per grade) (1)
- ○ Medium (250 or more students per grade) (2)
- ○ Small (Less than 250 students per grade) (3)

Q8 How would you describe your current school?

- ○ Public (1)
- ○ Public-Charter (2)
- ○ Private-Independent (3)
- ○ Private-Religious (4)

Q9 Which of the following grades do you currently teach or supervise science (check all that apply)?

- [ ] 6 (1)
- [ ] 7 (2)
- [ ] 8 (3)

Q10 What science class(es) are you currently teaching or supervising (check all that apply)?

- [ ] Biology (1)
- [ ] Physics (2)
- [ ] Chemistry (3)
- [ ] Earth Science (4)
- [ ] General Science (5)
- [ ] Other (6)

Q11 How many content related questions would you estimate you ask students in one day of teaching?

_____

Q12 Based on the answer you just provided, how many of these questions are planned before they are asked?

- None (1)
- Less than 50% (2)
- About 50% (3)
- More than 50% (4)
- All (5)

Q13 How would you describe your knowledge of teacher questioning practices?

- Not at all knowledgeable (1)
- Slightly knowledgeable (2)
- Somewhat knowledgeable (3)
- Moderately knowledgeable (4)
- Very knowledgeable (5)

Q14 Where did you initially learn about teacher questioning practices in the classroom?

- ○ Coursework during pre-service teacher preparation program (1)
- ○ Professional development while teaching (2)
- ○ Personal Experience (3)
- ○ Colleagues (4)
- ○ Academic research (5)
- ○ Teacher websites (6)
- ○ Google (7)

Q16 When you have questions about your own teacher questioning practices which resource do you utilize the most to help you get information?

- ○ Coursework during pre-service teacher preparation program (1)
- ○ Professional development while teaching (2)
- ○ Personal Experience (3)
- ○ Colleagues (4)
- ○ Academic research (5)
- ○ Teacher websites (6)
- ○ Google (7)

Q17 Choose one word that best describes your feelings about your own questioning practices in the middle school science classroom. Complete the sentence, I find questioning to be _____

- ○ Difficult (1)
- ○ Intuitive (2)
- ○ Important (3)
- ○ Necessary (4)
- ○ Complicated (5)
- ○ Essential (6)
- ○ Easy (7)
- ○ Interesting (8)
- ○ Complex (9)

Q18 When it comes to your professional learning, learning about teacher questioning practices is:

- ○ Not a priority (1)
- ○ Low priority (2)
- ○ Moderate priority (3)
- ○ High priority (4)

Q19 How much time over the course of the year do you have available to you from your employer for professional development?

- ○ None (1)
- ○ 1-5 hours (2)
- ○ 6-10 hours (3)
- ○ 11-15 hours (4)
- ○ 15-20 hours (5)
- ○ 20+ hours (6)

Q20 How much of this time are you able to self-select your professional development?

- ○ None (1)
- ○ Less than 50% (2)
- ○ About 50% (3)
- ○ More than 50% (4)
- ○ All (5)

Q21 How many hours in the past year have you engaged in professional development specifically about teacher questioning?

- ○ 0 hours (1)
- ○ 1-5 hours (2)
- ○ 6-10 hours (3)
- ○ 11-15 hours (4)
- ○ 15-20 hours (5)
- ○ 20+ hours (6)

Q22 How many hours in the past year has professional development specifically about teacher questioning been available to you?

- ○ 0 hours (1)
- ○ 1-5 hours (2)
- ○ 6-10 hours (3)
- ○ 11-15 hours (4)
- ○ 15-20 hours (5)
- ○ 20+ hours (6)

Q23 How long would you be willing to spend learning about teacher questioning practices through a website during one online session?

- Would not spend any time (1)
- 1-15 minutes (2)
- 16-30 minutes (3)
- 31-45 minutes (4)
- 46-60 minutes (5)
- More than one hour (6)

Q24 If given the opportunity to learn about teacher questioning through a website would you prefer it to be about:

- Teacher questioning practices for general use (1)
- Teacher questioning practices for content-specific use (2)
- Teacher questioning practices for grade-specific use (3)

Q25 How would you prefer to be connected with other teachers on a website about teacher questioning practices?

- By your state (i.e. NY) (1)
- By your content area (i.e. Biology) (2)
- Both state and content (3)
- Do not want to be connected with other teachers (4)

Q26 How important is it that a website about teacher questioning practices is connected to Common Core standards?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q27 How important is it that a website about teacher questioning practices aligns with teacher evaluation models (i.e. Danielson)?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q28 How important is it that a website about teacher questioning practices provides resources for you to self-assess your own questioning practice?

- ○ Not at all important (1)
- ○ Low importance (2)
- ○ Slightly important (3)
- ○ Neutral (4)
- ○ Moderately important (5)
- ○ Very important (6)
- ○ Extremely important (7)

Q29 How important is it that a website about teacher questioning practices provide resources about planning questions for classroom discussion?

- ○ Not at all important (1)
- ○ Low importance (2)
- ○ Slightly important (3)
- ○ Neutral (4)
- ○ Moderately important (5)
- ○ Very important (6)
- ○ Extremely important (7)

Q30 How important is it that a website about teacher questioning practices provide resources on teacher responses and feedback to students?

- ○ Not at all important (1)
- ○ Low importance (2)
- ○ Slightly important (3)
- ○ Neutral (4)
- ○ Moderately important (5)
- ○ Very important (6)
- ○ Extremely important (7)

Q45 Based on your answers to the previous 5 questions, please rank in order from 1-5, with 1 being the most important and 5 being the least important, which of those resources would help you the most in immediately implementing and/or changing your questioning practices in the classroom:

_____ Connection to Common Core Standards (1)
_____ Alignment with teacher evaluation models (2)
_____ Tools to self-assess questioning practices (3)
_____ Tools to plan questions for classroom discussions (4)
_____ Resources on teacher responses and feedback (5)

Q31 How important is it that a website about teacher questioning practices provide videos of teachers modeling questioning techniques?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q32 How important is it that a website about teacher questioning practices provide informational videos on questioning techniques?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q33 How important is it that a website about teacher questioning practices provide sample questions used by teachers?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q34 How important is it that a website about teacher questioning practices provide sample lesson plans/units used by teachers?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q35 How important is it that a website about teacher questioning practices provide suggested books and articles about teacher questioning?

- ○ Not at all important (1)
- ○ Low importance (2)
- ○ Slightly important (3)
- ○ Neutral (4)
- ○ Moderately important (5)
- ○ Very important (6)
- ○ Extremely important (7)

Q46 Based on your answers to the previous 5 questions, please rank in order from 1-5, with 1 being the most important and 5 being the least important, which of those resources would help you the most in immediately implementing and/or changing your questioning practices in the classroom:

_____ Videos of teachers modeling questioning techniques (1)
_____ Informational videos on questioning techniques (2)
_____ Sample questions used by teachers (3)
_____ Sample lesson plans/units used by teachers (4)
_____ Suggested books and articles about teacher questioning (5)

Q36 If given the opportunity to learn about teacher questioning through a website would you prefer it to be:

- ○ Informal, self-paced, online, little or no instructor involvement or guidance (1)
- ○ Formal, online, with deadlines/timeframes, little or no instructor guidance (2)
- ○ Informal, self paced, online, with available instructor (3)
- ○ Formal, online with deadlines/timeframes and with available instructor (4)

Q37 If given the opportunity to learn about teacher questioning through a website would you prefer it to be:

- A mostly interactive experience with specific/known peers (1)
- A mostly interactive experience with various/random peers (2)
- A mostly individual learning experience with the option to engage with peers (3)
- A mostly individual learning experience without engaging with peers (4)

Q38 How important is it that a website about teacher questioning practices has opportunities for individuals to practice teacher questioning and receive feedback?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q39 Have you ever participated in an online learning environment where you received feedback? If so select the types of feedback you have received:

- ○ Public feedback from peers (1)
- ○ Private feedback from peers (2)
- ○ Public feedback from instructor (3)
- ○ Private feedback from instructor (4)
- ○ I have never participated (5)

Q40 If you were to receive feedback on your questioning practices through a website, what form would you like the feedback to take?

- ○ Public feedback from peers (1)
- ○ Private feedback from peers (2)
- ○ Public feedback from instructor (3)
- ○ Private feedback from instructor (4)

Q41 Have you ever shared videos or examples of your teaching for others to view on a website?

- ○ Yes (1)
- ○ No (2)

Q42 How likely would you be to post videos or examples of your own questioning practices for others to view on a website about teacher questioning practices?

- Extremely unlikely (1)
- Unlikely (2)
- Neutral (3)
- Likely (4)
- Extremely likely (5)

Q43 How important is it that a website about teacher questioning practices provides tutorials about how to record classroom discussions?

- Not at all important (1)
- Low importance (2)
- Slightly important (3)
- Neutral (4)
- Moderately important (5)
- Very important (6)
- Extremely important (7)

Q44 How important is it that a website about teacher questioning practices provides tutorials about how to upload and share videos on a website?

- ○ Not at all important (1)
- ○ Low importance (2)
- ○ Slightly important (3)
- ○ Neutral (4)
- ○ Moderately important (5)
- ○ Very important (6)
- ○ Extremely important (7)

End of Block: Main Survey

Appendix E: User-Testing Protocol

User-Testing Semi-Structured Protocol for IRB#16-041M:
Thank you again for agreeing to participate. I have your signed consent forms. Do you have any questions about these forms before we begin?

This should take about 30 to 45 minutes to complete. I would like to first ask you a little bit about yourself and your current teaching position. Then I am going to ask you some questions while you navigate the website. Do you have any questions about what we are doing? [Answer questions]

Great, let's get started!

1. Ask the following questions about demographic information:
    a. What is your gender?
    b. Male
    c. Female
    d. Transgender
    e. Other
    f. Prefer not to answer
2. What is your age?
    a. 20 - 29
    b. 30 - 39
    c. 40 - 49
    d. 50 - 59
    e. 60 - 69
    f. 70+
3. What level of education have you completed?
    a. High school
    b. Associate's degree
    c. College degree
    d. Master's degree
    e. Master's + credits
    f. Doctorate
4. What is your current position (check all that apply)?
    a. Middle School Science Student Teacher
    b. Middle School Science Teacher
    c. Middle School Science Supervisor/Administrator
    d. University Professor/Instructor
5. How would you describe your current school?
    a. Urban (located within city limits)
    b. Suburban/Town (located within 10 miles of city limits)
    c. Rural (located more than 10 miles from city limits)
6. How would you describe your current school?
    a. Large (500 or more students per grade)
    b. Medium (250 or more students per grade)

    c. Small (Less than 250 students per grade)
7. How would you describe your current school?
    a. Public
    b. Public-Charter
    c. Private-Independent
    d. Private-Religious
8. Which of the following grades do you currently teach or supervise science (check all that apply)?
    a. 6
    b. 7
    c. 8
9. What science class(es) are you currently teaching or supervising (check all that apply)?
    a. Biology
    b. Physics
    c. Chemistry
    d. Earth Science
    e. General Science
    f. Other

Close this part by saying, Is there anything else you think I should know about you or your position before we continue?

Continue with, During this section you are going to look at the website while I ask you some questions. We are going to do a concurrent think aloud. All this means is that I would like for you to verbalize your thinking while you are navigating the site. Do you have any questions before we begin? [Answer questions]

Scenario 1: This scenario will focus on the purpose and delivery of the website and how well that is communicated through the 2 different home page options. I will ask participants about their own professional online learning experiences and expectations. Examples of possible questions include:

Ask before they see the website:

1. How many times in the past 6 months have you visited a website focused on teachers? (examples of websites like edutopia and teachthought). Follow up questions may include: Why did you go there? What made you select that site? How well did the information found answer your question/help you out? What made this website helpful (or not)?
2. Based on the name of the website The Question Connection, what would you expect to learn about? Possible follow up questions: What content? Grade level?
3. Based on the name of the website The Question Connection, how would you expect the learning to happen? Possible Follow-up questions: Formal vs. informal? Mostly written information? Collaborative or individual?
4. What would you expect this website to look like?

Now have them open the website (www.questionconnection.com) and ask questions like:

1. How does the website measure up to your expectations? What seems out of place? What is missing?

2. What is the first thing you would want to explore? Why?
3. If you were looking for information about [insert content] where would you click? Content options could include: tools to plan questions, resources on questioning, contacting other teachers, contacting the website.
4. Repeat these Qs with other options as time allows.

Scenario 2: This scenario will explore the different use options (Self-Guided & Assisted) of the website and usability of the Home Page.

1. Starting at the home page select an area that you would like to explore. Before you select it, what do you expect to see when you click on it?
2. Now (after clicking) how does your expectation match what is here?
3. Which of the options would you likely use? Why? Are both of these options necessary? Why or why not?

Scenario 3: This scenario will focus on tutorials and sample activities. Is the purpose of these clear? What types of tutorials/sample activities do they expect to find? Examples of questions I may ask in this scenario include:

1. What types of tutorials/sample activities would you expect to find on this site?
2. Find the tutorial/sample activity on [insert tutorial/sample activities here]. Examples may include, recording classroom discourse, uploading videos to the website, self-assess questioning practice, plan questions for discourse.
3. Before you select it, what would you expect to find? What would the information include? How would you expect to get the information? (from a video? From text?)
4. Now select a tutorial/sample activity. How does your expectation match what you find?
5. What makes the tutorial easy to follow?
6. What is confusing or distracting about the tutorial?
7. Repeat with other options as time allows.

Scenario 4: In this scenario I am focusing on sharing information and finding useful information. Would you share information? What information would you share? Of the information provided, what is the most useful? Why? Examples of questions include:

1. What type of information would you expect to be shared on this website?
2. How would you expect it to be shared? (i.e. video, text, comments, threads, posts?)
3. What type of information would you share? (i.e. sample questions, videos of practice)
4. Navigate to the home page. Going anywhere you want, find one piece of useful information that you could implement in your practice tomorrow. Why is this useful? What makes it easy to implement?
5. Repeat with other options as time allows.

Scenario 5: This scenario will focus on the openness of the website and organization of examples. Do users prefer to have selected examples or do they want to see what everyone is doing? And where would they expect to find the information? Examples of questions I may ask in this scenario include:

1. Navigate to the area where you would expect to find [insert example]. Examples may include, sample questions or videos of practice.
2. Is this where you expected to find examples? Should the examples be embedded in this page or should they have their own page? What makes the most sense to you?
3. How many examples would you expect to find?

4. Who would you expect to post examples? Would you expect to see examples posted by...other teachers?...the website administrators? Would you prefer that examples be curated by website administrators or open to all participants? Why?
5. Repeat with other options as time allows

Closing Questions: To wrap up the user test I would ask questions like:

1. How would you describe the website using your own words?
2. Who do you know that would like to use this website? What are they like?

Conclude the user test, Thank you for your time and participation. Is there anything else you would like to share about your experience with the website? Do you have any questions for me about the website or your participation? [record comments and answer questions].