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ABSTRACT

For more than a decade, there has been a call for reform in science education. This effort stresses the creation of a scientifically literate population. Required in this effort to create a more scientifically literate populace is an understanding of the Nature of Science (NOS) on the part of the average citizen. This call for reform recognizes the classroom teacher as the main vehicle through which images of the NOS and scientific inquiry are portrayed for students. In order to improve both science teachers' and students' understanding of the NOS and inquiry, the National Science Foundation has implemented the Graduate Teaching Fellows in GK-12 Education (GK-12) initiative. This initiative, which is consistent with reform efforts that call for scientist involvement in K-12 science classrooms, supports programs that place graduate level scientists (GTFs) with K-12 science teachers (PTs) to act as classroom resources. One such program focuses on sustained collaborations between GTFs and PTs with a hands-on, inquiry based planning and teaching emphasis. This naturalistic study used mixed methods of surveys, observation, interviews and artifact collection to examine how this program influenced PTs' inquiry practices and perceptions. During data analysis classroom features of inquiry emerged. These features led to the creation of five components of two types of inquiry, Technical and Substantive. These types of inquiry, the components, and their features, make-up an Inquiry Framework that represents a continuum of understandings related to inquiry and is grounded in the practice of teaching. This framework was applied to inquiry features captured from each PT involved in the study. This paper highlights the framework used to capture and articulate these PT's beliefs and practices related to inquiry. Initial attempts demonstrate the potential of this framework as a tool for improving understanding of inquiry. It also shows the capability to reduce the gap between science teachers, science educators, and educational researchers who are struggling to articulate, capture and demonstrate inquiry-based teaching practices. (Contains 27 references.) (Author)

# Development of a Framework to Measure Science Teachers' Inquiry Perceptions and Practices

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Development of a Framework to Measure Science Teachers' Inquiry Perceptions and Practices

For more than a decade, there has been a call for reform in science education. This effort stresses the creation of a scientifically literate population. Required in this effort to create a more scientifically literate populace is an understanding of the Nature of Science (NOS) on the part of the average citizen. This, in turn requires an understanding of scientific inquiry. This call for reform recognizes the classroom teacher as the main vehicle through which images of the NOS and scientific inquiry are portrayed for students. In order to improve both science teachers' and students' understanding of the NOS and inquiry, the National Science Foundation has implemented the Graduate Teaching Fellows in GK-12 Education (GK-12) initiative. This initiative, which is consistent with reform efforts that call for scientist involvement in K-12 science classrooms, supports programs that place graduate level scientists (GTFs) with K-12 science teachers (PTs) to act as classroom resources.

One such program focuses on sustained collaborations between GTFs and PTs with a hands-on, inquiry-based planning and teaching emphasis. This naturalistic study used mixed methods of surveys, observation, interviews and artifact collection to examine how this program influenced PTs' inquiry practices and perceptions.

During data analysis classroom features of inquiry emerged. These features led to the creation of five components of two types of inquiry, Technical and Substantive. These types of inquiry, the components, and their features, make-up an Inquiry Framework that represents a continuum of understandings related to inquiry and is grounded in the practice of teaching. This framework was applied to inquiry features captured from each PT involved in the study. This paper highlights the framework used to capture and articulate these PTs' beliefs and practices related to inquiry. Initial attempts demonstrate the potential of this framework as a tool for improving understanding of inquiry. It also shows the capability to reduce the gap between science teachers, science educators and educational researchers who are struggling to articulate, capture and demonstrate inquiry-based teaching practices.

## Literature

For more than a decade, there has been a call for reform in science education. This effort stresses the creation of a scientifically literate population, defined as all citizens having an understanding and ability in science in order to be fully functioning citizens in contemporary U.S. society (American Association for the Advancement of Science (AAAS), 1989; 1993; National Research Council (NRC) 1996a; 2000). The National Research Council argues that being scientifically literate implies an understanding of the Nature of Science (NOS), and understanding NOS in turn requires an understanding of scientific inquiry (1996a). These same reform documents also assert that in order to achieve scientific literacy for all, science teachers must be able to teach an understanding of scientific inquiry. Further, the reform documents call for scientists to assist the science education community in implementing the reforms that are being sought (AAAS, 1989; 1998; NRC, 1996a; 1996b). Understanding inquiry is an aspect of science teaching in which scientists can be of tremendous value (NRC, 1996b). These reform documents go on to suggest that scientists and science educators should be involved in sustained collaborations in the school context that focus on teaching inquiry as one means of improving science teachers' ability to teach inquiry (NRC 1996a; 1996b; 2000).

The relationship between inquiry and the nature of science is a key element of the current reform effort in science education (AAAS, 1989; NRC, 1996a). As the importance of scientific inquiry and its relationship to the NOS became increasingly prominent, education researchers began to ask about the relationship between teachers' beliefs and their practice related to the nature of science and to inquiry. Early research was unclear if there was a relationship between teachers' views of the NOS and teaching practice, and if there was a relationship, what it was (Lederman and Zeidler 1987; Duschl and Wright, 1989). Later research first hinted at, and then confirmed, the connection between teachers' beliefs and practices related to the NOS (Benson, 1989; Brickhouse, 1990; Hashew, 1996; Schwartz and Lederman, 2002).

If beliefs are important to teachers' practices, and if scientific inquiry is important to US education, this leads to the question, "How do we influence science teachers' perspectives of the nature of scientific inquiry and ultimately the NOS?" Scientist and science educator collaborations, such as those discussed above, are proposed as one means of improving understanding of the nature of scientific inquiry, and ultimately scientific literacy, among science teachers and eventually the general population.
An examination of multiple documents currently used to support reform efforts in science education demonstrates that stakeholders involved in this reform agree that inquiry is a part of the NOS (AAAS, 1989, 1990, 1993, 1998: NRC 1996a, 1996b, 2000: National Commission on Mathematics and Science Teaching [NCMST], 2000).

These endorsements lead to a series of questions related to the teaching of inquiry, the most immediate and important of which is, "What exactly is scientific inquiry?" This question has been asked in science education for a hundred years. John Dewey emphasized inquiry as a facet of not just science education, but life in general (1900). He believed children had a natural curiosity that could be built upon to develop their abilities and understandings of inquiry. Later Joseph Schwab, a philosopher of education, attempted to define the nature of scientific inquiry. Schwab stated that there are two types of scientific inquiry, which he called stable inquiry and fluid inquiry (1962).

Thomas Kuhn, a historian of science, also attempted to address the understandings and abilities that capture the ways of knowing inherent in scientific inquiry (1962). He used the concept of paradigms to explain his interpretations of the nature of scientific inquiry. More recent attempts to define the nature of scientific inquiry have been made. William F. McComas, a science educator, attempted to clarify what it means to develop an understanding of the nature of science and uncovered 14 common myths (1998). At about the same time, the National Research Council attempted to define exactly what constitutes scientific inquiry and how it should be taught (1996a; 2000).

These attempts to define scientific inquiry are important milestones in the history of science education in America. At the same time, these attempts to define scientific inquiry are far removed from actual classroom science instruction related to inquiry. The gap between policy and science and education research documents and classroom practice has made the implementation of scientific inquiry into classroom practice difficult. To bridge this gap, the National Science Foundation (NSF) has invested heavily in the concept of bringing graduate level scientists into K-12 science classrooms to work in collaboration with teachers to improve their understanding of the NOS. One of the sites supported by the NSF stresses the co-implementation and co-development by teachers and graduate level scientists of hands-on, inquiry-based activities in an attempt to improve science teachers understanding of the NOS.

This combination of a call by policy makers for more teaching of scientific inquiry, the ambiguity of existing educational research on the relationship between beliefs and practices related to inquiry, the multiple definitions of scientific inquiry, the distance between policy and research documents and practice of teaching inquiry as well as my personal experiences as a middle grades science teacher trying to teach inquiry and my involvement as a staff member with a program focused on improving teachers' understanding and ability with inquiry by providing the collaboration of graduate level scientists led me to question how working with graduate level scientists influences science teachers' conceptions of inquiry, a key aspect of their views of the NOS.

Through this examination I realized that the language of inquiry spoken by science educators, philosophers of science, and science education researchers was inconsistent and that none of these languages of inquiry were consistent with those used by scientists themselves or classroom teachers. As a result, I began to construct an instrument that I believe captures aspects on inquiry that are grounded in the practice of teaching and highlight the variety of ways that science teachers display inquiry to their students. This paper highlights the resulting inquiry framework that was developed to better capture and describe types and components of inquiry appropriate to emphasize at the k-12 levels.

## Methods

This study was conducted in three stages. Stage A, Determining the Cases, consisted of collecting and analyzing data to determine maximum sampling variation of a subset of four PTs to include in Stage B, Gathering Data for the Cases. In Stage A, an Inquiry Survey was administered to seven PTs and 12 GTFs to determine their initial views of inquiry. An instance interview was also conducted with a subset of the PTs to verify or refute preliminary findings about their beliefs and practices about scientific inquiry from the Inquiry Survey administered.

Stage B consisted of observations, interviews, artifact collection and data analysis with four PTs to determine their beliefs and practices related to inquiry. The data collection and analysis was also used to determine what, if any, influence collaboratively teaching hands-on, inquiry-based activities with the GTFs had on PTs' beliefs and practices related to inquiry.

Stage C, Creating the Cases, consisted of the final analysis and write up of this report. The case creation relied on a procedure of analysis in which interpretive summary statement were created and analyzed. This procedure was modeled on the system for analyzing portfolio-based teacher performances developed by the Interstate New Teacher Assessment and Support Consortium (INTASC) in science (Collins, 2000). The process of analysis led to the creation of the actual cases. When the cases had been created, a cross case analysis was conducted. It was during the case development and cross case analysis that features of inquiry began to emerge, which led to the construction of the components of inquiry that make up the two types of inquiry presented in this paper.

## Inquiry Framework

Although the nature, description and role of scientific inquiry in both science and education has been the subject of investigation by historians, philosophers, scientists and educators for years, during this study I became increasingly dissatisfied with existing definitions. There seems to be agreement that there are at least two different types of inquiry. Schwab (1962) called the two types of inquiry stable and fluid; Kuhn (1962) called them normal and revolutionary. The former type of inquiry is what is frequently captured in middle grades science textbooks as THE scientific method -- a linear series of steps that inevitably lead to an expected outcome. The latter is more abstract, creative, closer to fine art, you know it when you see it.

As the study progressed I struggled with what was really meant when the goal was to improve teachers' understanding and instruction of scientific inquiry. Using the standard recognized references on inquiry, Aikenhead and Ryan, (1992), Anderson and Rubba, (1978), Schawb (1962), Kuhn (1962), Inquiry and the National Science Education Standards (2000), Lederman and Zeidler (1987), I began to create a functional framework for describing inquiry as portrayed in the literature and as I saw it occurring in these middle school science classrooms. Data from the classroom observations and interviews were used to modify, adapt, refine, and recreate this framework. The framework labeled Features of Technical and Substantive Inquiry has five components that are shown in Tables 1 through 5 and provided the organization scheme I used for the body of the four case studies conducted as part of my dissertation. I assert that the framework is useful in organizing teachers' beliefs and practices about inquiry.

Similar to others who have struggled to define inquiry, I begin with two types. I have termed these two types of scientific inquiry Technical Inquiry and Substantive Inquiry. However, these two types are regions on a continuum, not discrete classes. For this study, I have divided the continuum into four regions, Low Technical, High Technical, Low Substantive and High Substantive. Each has its place in science education instruction and an understanding of each is required to truly understand the ways of knowing inherent in scientific inquiry. The types of inquiry are labeled across the top of the framework.

I have identified five components of inquiry. These components, although presented as discrete categories, actually overlap with the borders between them becoming blurred depending on the aspect of inquiry being discussed. These components are (1) the existence and steps of the scientific method, (2) the subjective nature of knowledge creation in science, (3) the empirical basis of scientific inquiry, (4), the tentative nature of scientific knowledge and (5) the role of creativity in inquiry. These components are in the first column of the framework. Features of each type of inquiry for each component are in the body of the framework. For example, that the "Scientific method is portrayed as series of steps that are used to investigate scientific questions in any order needed" is a feature of high technical inquiry for the existence and steps of the scientific method component of inquiry.

Within the component, the existence and steps of the scientific method (See Table 1), Technical Inquiry highlights that general methods for verifying scientific claims exist within scientific communities. Substantive Inquiry related to this component emphasizes student understanding that scientists generally don't follow a step-by-step procedure to create knowledge. Substantive Inquiry provides students with the understanding that scientists create knowledge in many ways, then they and others use the accepted forms of Technical Inquiry related to this component to verify it as knowledge.

Table 1 Components of Inquiry - Scientific Method

| | Technical | | | Substantive |
|---|---|---|---|---|
| | Low | High | Low | High |
| **The existence and steps of the scientific method** | Scientific method is portrayed as a linear, step-wise method used in the creation of knowledge. | Scientific method is portrayed as series of steps that are used to investigate scientific questions in any order needed. | Multiple methods of investigation portrayed without understanding of factors that determine method choice. | Multiple methods of investigation are portrayed with understanding of factors that determine method choice (the methods used are dependent on accepted contemporary measures, societal and cultural influences). |

An example of features related to this component occurred during a lesson led by Linda, one of the GTFs. The lesson involved students creating a written account of investigations they had conducted. During the lesson the GTF held a class discussion in which she told the students they were to write their procedures in a format similar to what would be identified as "the" scientific method. Following the same activity I talked with Linda about the scientific method being followed verbatim by scientists doing research. Linda says,

> Well I would agree and disagree with that. I think that it depends on the level, the level where the scientists is.... As a graduate student, I may not say, 'Oh, I'm using the scientific method.' It is not in our brains. But I think when it is all said and done, yes we have used it. As a graduate student, I have to, well it is technically out of order, we, you know, a problem is presented to us. Then we are encouraged to generate preliminary data. Then you kind of go back and then make your hypothesis and things like that. So I guess it is sort of out of order in a

> sense. But I think at the student level, at the student level, that we would probably be more inclined to use it or try to be more sequential than a scientist that's been practicing for eighteen years or something. They kind of do whatever works for them.

Initially, Linda seemed certain that she used these five steps in the order she had presented them on a regular basis. As she talked, however, she realized that most of her work started not with a testable question (hypothesis) but with exploring an area of interest. As she continued to talk she stated that she used the steps but not in the same order as they are stated. She then stated that this was true for all scientists, except for the most experienced scientists, who do whatever works. This discussion had an impact on Linda that was apparent in her teaching. In follow-up observations of her working in the classroom it was clear that emphasizing more than one version of the way scientists work became an explicit emphasis in her teaching.

Within the component, the subjective nature of knowledge creation in science (See Table 2), high levels of Technical Inquiry promote an understanding that scientists can reach different conclusions based on the same data. How different conclusions can be reached, however, is not made clear to students. Technical inquiry also promotes an understanding of scientific inquiry as somehow being objective. Substantive Inquiry related to this component highlights how scientist can reach different conclusions from the same data given the "objective" nature of scientific inquiry. Students learn that societal influence, cultural understanding, and background experience influence knowledge creation.

Table 2 Components of Inquiry - Subjective Nature

| | Technical | | | Substantive |
|---|---|---|---|---|
| | Low | High | Low | High |
| **Subjective nature of knowledge creation in science** | Promotes understanding that all scientists reach similar conclusions from the same investigations. | Promotes understanding that scientists can reach different conclusions from the same investigation. | Promotes understanding that scientists can reach different conclusions from the same investigation based on their own understandings and interpretations. No attention is drawn to factors that influence understandings and interpretations | Promotes understanding that scientists can reach different conclusions from the same investigation based on their own understandings and interpretations. Explicit attention is drawn to factors that influence understandings and interpretations. |

An example of features related to this component occurred when one of the PTs, Alice, had her students complete a take home investigation. As part of the assignment, students were given several experiments they could choose from to do at home. All the students that did the same experiments would present findings and stand for questions from the class. During one public presentation a student obtained results that didn't match the results of other students. During whole class questioning it was determined that this student had mistakenly altered the experiment, using sugar clumps when sugar cubes were required. Alice talks about this and how it relates to her understanding of inquiry.

> So we kept questioning to try to find out. And he said, 'Well to tell you the truth Ms. Johnson, I didn't have a sugar cube. I don't even know what a sugar cube is. But you know how the lumped sugar falls outside the bowl when you're scooping things out?' He said, 'I really used a sugar clump.'... Now to me, that's what inquiry is about. You're going to investigate with whatever you can get your

hands on. So the sugar clump man made an A+.

In this example the student did not obtain the same answer as other students when he conducted his experiment, which was the original goal of the activity. His work was, however, rewarded with an excellent grade. The positive assessment of the sugar-clump student's work rested on his ability to conduct the experiment, understand how it was altered, and explain the influence his alterations had on the experimental outcome. Alice's instruction related to this aspect of inquiry was explicit in that she related these processes to the work of scientists and then rewarded students who were able to conduct, understand and explain their investigations.

Within the component, the empirical basis of scientific inquiry (See Table 3), Technical Inquiry stresses the importance of empirical data in supporting knowledge claims. Technical Inquiry related to this component emphasizes student ability to collect data and make interpretations from existing tables and graphs. Substantive Inquiry related to this component also emphasizes that empirical data is essential to scientific inquiry and knowledge creation. What distinguishes it from Technical Inquiry, however, is an emphasis on student ability to independently formulate explanations based on evidence. Within this emphasis on formulating explanations, students build an understanding of influences and understandings related to decision-making during data collection and analysis. This includes influences and understandings regarding how the questions asked determine the type of data to collect, how the data should be displayed, and how decisions made at every step of the data collection and analysis process influence the interpretations made from the data.

Table 3 Components of Inquiry - Empirical Basis

| | Technical | | | Substantive |
|---|---|---|---|---|
| | Low | High | Low | High |
| **Empirical basis of scientific inquiry** | Inquiry abilities and understandings are learned out of context. Leads to misunderstanding of relationship between questions asked, methods used, types of data to collect, and result interpretations. | Inquiry abilities and understandings are learned within context of problem solving experiences without explicit attention being drawn to relationship between questions asked, methods used, data collected, and result interpretations. Leads to vague understanding of relationship between questions asked, methods used, types of data collected, and interpretation of results. | Inquiry abilities and understandings are learned within the context of activities that promote awareness of relationships between questions asked, data collected, and interpretations made. Leads to understanding that there is relationship between questions asked, methods used, types of data collected, and interpretation of results. | Inquiry abilities and understandings are learned within context of genuine problem solving experiences. Explicit attention is drawn to relationship between questions asked, methods used, types of data collected, and interpretation of results. |

An example of features related to this component of inquiry can be seen in the following example from one of the PTs, Kathy. Kathy taught an Introductory Physical Science (IPS) course that featured frequent lab activities. At the end of these lab periods students displayed their results on the board. While students recorded their answers Kathy would check the work. When an answer was incorrect, she would state what made it incorrect and require the students to fix it. Near the end of an activity on determining the densities of two different liquids, the students placed their results on a data table on the board. While one group recorded results, Kathy addressed them. "You need to check your math or your numbers. Something is not right." The students debated possible solutions to their dilemma when Kathy spoke to them again. "You can only have two significant digits in your density because that's as detailed as we can be in measuring volume." During this exchange Kathy stated the problem, telling the students what was wrong and how it should be fixed. This example represents low levels of technical inquiry within this component. When Kathy discussed how scientists handle anomalies in data, that this datum could be a piece of counter evidence, or ask the students if they had an argument supported by evidence to justify the answer she began to move towards higher levels of understanding related to this component.

Table 4 Components of Inquiry - Tentative Nature

| | Technical | | | Substantive |
|---|---|---|---|---|
| | Low | High | Low | High |
| **The tentative nature of scientific knowledge** | Scientific knowledge is portrayed as being fixed and absolute. | Scientific knowledge is portrayed as being <u>less</u> fixed and absolute. | Scientific knowledge is portrayed as being tentative and subject to change as new knowledge is acquired. | Scientific knowledge is portrayed as being both fixed when it provides utility, and tentative, when its lack of utility has been exposed. |

Within the component, the tentative nature of scientific knowledge (See Table 4), Technical Inquiry portrays scientific knowledge as being more fixed and absolute. Although student understanding of the tentative nature of scientific knowledge is important, this component of Technical Inquiry provides science students with the understanding that scientific knowledge needs, at times, to be treated as a static body of knowledge. For example, when scientific knowledge related to atomic structure is applied to the building of a nuclear power plant, the designer does not treat this scientific knowledge as being less than absolute. Within this same component, Substantive Inquiry stresses student understanding that scientific knowledge is only treated as absolute to the point where it is able to predict future behavior and patterns. When the knowledge has lost its utility, its tentativeness is exposed and new understandings to be used related to Technical Inquiry must be created. Substantive Inquiry related to this component exemplifies both the tentative nature of scientific knowledge and its use as a static body of knowledge where it is appropriate to apply this understanding.

An example of features related to this component can be seen as a PT, Cindy, talks about doing inquiry with her students. She felt that student failure during inquiry was an important aspect of learning the processes of scientific inquiry. Comments made following the egg drop lab were the first indication of this. As Cindy talked about the activity she said, "But you look at them [students] and you say [to yourself], 'That one is not going to work.' But it's fun to let them, let them fall down. It is O.K., if the fall down." Intrigued by her comments I returned to failure later. I asked her, "Is falling down or failure important in inquiry?" Cindy replied,

> Like one of my genetic engineering labs, one of the things didn't work. I think it was a great opportunity to talk about scientific work in a laboratory. You can do experiments over and over again. And you don't have any idea, why in the world isn't this working? That's science. THAT'S SCIENCE. I did a thesis for three years. It never worked. Never worked.... But that's just science.

She went on to talk about how different this was from the way her students understand scientific inquiry. She felt her students expected that an experiment was done to get a predetermined answer, which would be consistent with low level features within this component. The fact that an answer might not be achievable or that the knowledge gained will remain static was not part of the way they thought about science.

Within the component, the role of creativity in inquiry (See Table 5), Technical Inquiry emphasizes that creativity plays a role in all aspects of scientific inquiry. This is similar to versions of the scientific method in which creativity is seen as being important in the development of a question and in the interpretation of results. Substantive Inquiry stresses that creativity is central to all aspects of knowledge construction in science. It highlights how creativity leads to new ideas to be examined through means that don't follow prescribed methods. It highlights how knowledge can be created in the mind, and then verified "after the fact". It also stresses how creativity is used to generate multiple interpretations from the same information. In total, Substantive Inquiry stresses student understanding of the complex relationship between creativity and scientific inquiry while Technical Inquiry stresses that creativity plays a role in only certain aspects of scientific inquiry.

Table 5 Components of Inquiry - Creativity

| | Technical | | | Substantive |
|---|---|---|---|---|
| | Low | High | Low | High |
| **Role of creativity in inquiry** | Failure to portray understanding that knowledge created during scientific inquiry is the product of human imagination, inference and creativity. | Portrayal implies that human imagination; inference and creativity are aspects of some parts of scientific inquiry. | Portrays understanding of the role human imagination, inference and creativity play during scientific inquiry | Explicit attention given to role of human imagination, inference and creativity during every stage of scientific inquiry. |

An example of feature related to this component can be seen in the work of the PT Alice. At the beginning of one lab period Alice asked Jeffrey, an at-risk student repeating the eighth grade, to stand up to be recognized as a "science star". She explained that Jeffrey was being made a science star due to his completion and sharing of an original at-home experiment. Intrigued by his results on one of the take-home experiments, Jeffrey altered the experiment so that he did an additional experiment of his own design. He then reported the altered experiment and findings to the class, for which Alice made him a science star. This included public praising, including Alice's sharing of how great she thought it was that Jeffrey did his own experiment. She also posted his name on a classroom bulletin board. During the public praising she stressed how important it was for scientists to design and create their own experiments.

## Discussion

### Implications

The work done for this study, and the subsequent analysis conducted, led me to the realization that these PTs' views of inquiry were far removed from the abstract notions of inquiry portrayed in literature related to inquiry. From my own emerging understanding I was able to develop an Inquiry Framework, grounded in the practice of teaching, that I believe accurately portrays features of scientific inquiry that are both practical and suitable for emphasis at the K-12 classroom level. This framework provides science teachers with a vehicle to improve their understanding of inquiry, the nature of science and ultimately their level of scientific literacy. This, in turn, will allow science teachers to raise the level of scientific literacy among their students, through a more grounded approach to the teaching of scientific inquiry.

From my work in this study, I developed an Inquiry Framework I believe captures the concept of inquiry, but is grounded in teaching practice. This framework displays the potential to influence science teaching on a number of levels. For practicing science teachers, this framework provides them with a clearer model of what practices associated with inquiry-based teaching look like. It also gives them a less abstract way to measure their teaching of inquiry against an accepted standard that is ground in practice. Finally, when addressing scientific inquiry with their students, this framework provides a more practical, concrete set of features that are applicable to K-12 science instruction.

For science educators this framework can be used as a learning tool. When introducing the concept of inquiry, this framework provides concrete features of inquiry-based practices for those closest to the practical level of teaching. In practicum courses, this framework would allow prospective science teachers to observe experienced science teachers' inquiry-based teaching practices through a "clearer lens". When prospective science teachers develop lesson plans, this framework could be applied to their lessons to help them focus on inquiry-based teaching practices.

For educational researchers, this framework continues a long line of attempts to define and describe inquiry. As this framework is grounded in practice, it provides the starting point for researchers interested in capturing inquiry-based teaching practices. It also provides features to look for when constructing instruments to measure and/or capture inquiry-based teaching.

Finally, this framework provides a common language and way of portraying features of inquiry for all three groups, science teachers, science educators, and educational researchers, to use. By providing common language and ways of portraying features of inquiry, a more consistent picture of inquiry can be displayed across all three communities. Although this point may seem trivial, my work to this point leads me to believe that a large part of the "inquiry struggle" has been the result of different languages and ways of portraying inquiry among these three groups.

## Future Research

The findings from this study and development of this framework leave me with several areas of interest for future research. First, research that attempts to conduct similar studies should be done. By conducting similar research and finding similar results, this study's generalizability would be increased. Conversely, a similar study with results that conflict with these would be an indication that the interpretations made in this paper are not generalizable at all.

Another question stems from both this work and similar research done by Renee Schwartz and Norman Lederman (2002). The work by Schwartz and Lederman, indicates that by focusing on beliefs, teachers become more aware of their beliefs, and that by highlighting how these beliefs translate into practice, their practice can change. This leads me to ask, "What influence would explicit instruction related to these types of inquiry have on science teachers' beliefs and practices related to inquiry?" An initial study on the influence of participation in the Graduate Teaching Fellows on the GTFs has been completed (Thompson, et al, 2003). A future parallel study on the influence of explicit, inquiry-related instruction could influence the design of future scientist-teacher collaborations.

Finally, the framework used in this study needs to be examined on a number of levels. As this is a new instrument, attempts to refine it should be the first order of business. Part of this process could include collecting data related to the acceptance and use of this framework by scientists, science teachers, science educators, and educational researchers. During this process of refinement, questions related to the use of this framework could be addressed. This may lead to better understanding of grade level appropriateness, of both the applications of this framework and of certain features and/or types of inquiry.

Each of the questions raised in this study is of great importance to the science education community. Inquiry, what it is and how to teach it, has been the source of debate within the science education community for over a century. The findings from this research led to the creation of an Inquiry Framework grounded in teaching practice. This attempt to capture and describe inquiry, as it is viewed by those most in need of a clear vision of inquiry, illustrates common misconceptions related to this important aspect of science teaching. I believe this Inquiry Framework will help those closest to the struggle of improving scientific literacy gain an upper hand in the battle to improve scientific literacy.

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