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Exploring Exemplary Elementary Teachers' Conceptions and Implementation of Inquiry Science

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Abstract This study was an exploration of the conceptions of inquiry science held by exemplary elementary teachers. The origins of these conceptions were explored in order to establish how best to improve elementary teachers' understanding and implementation of inquiry science teaching. Four focus group sessions were held as well as classroom observations. Data were also collected through surveys and interviews. The six exemplary teachers in this study held ideas about inquiry as "finding things out" and all described themselves as having been children who explored and experimented with the world around them. The teachers provided information about successful classroom environments and attitudes that they use to achieve strong inquiry science learning. The teachers had a number of recommendations for helping other teachers become inquiry science teachers and suggestions for professional development for teachers are made based on these recommendations.

Keywords Inquiry science teaching · Elementary science teaching · Teachers' conceptions about inquiry science

Introduction

Based on the current science education reforms, the National Science Education Standards (NRC 1996) and the benchmarks for science literacy (AAAS 1993), teachers are being encouraged to involve their students in authentic science investigations, or inquiry science. In inquiry science investigations, emphasis is placed on students' own questions, ideas, and understandings; inquiry science exists as a constructivist practice supporting meaningful learning (NRC 1996; Tobin and

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Tippins 1993). Carrying out inquiry investigations stemming from authentic questions allows students to construct their own understanding of real-world, relevant problems rather than verification labs where they seek one "right" answer (Roth 1995).

According to Appleton (2007), many elementary teachers may have a limited understanding of the science subject matter they are required to teach and also weak Pedagogical Content Knowledge in science. Weiss et al. (2003) have established that in many classrooms, teachers are not familiar with and do not implement inquiry science. Elementary teachers often have both low confidence and high avoidance when it comes to teaching science in their classrooms. Therefore, as teachers are requested to implement inquiry science into the teaching of science, it is informative to understand how successful teachers are implementing inquiry in their classrooms.

In order to have elementary teachers change the way they teach science and adopt a more inquiry stance of teaching and learning, it is important to change the teachers' way of thinking and understandings about science and inquiry, and the feelings they hold towards this type of teaching. Lotter et al. (2007) have suggested that the way in which teachers view science, their "core teaching conceptions", may affect the way they implement inquiry science teaching, Crawford (2007) also has stressed that teachers' conceptions about science may influence how they will teach science as inquiry. These conceptions about inquiry are based on teachers' knowledge of the nature of scientific inquiry and the recommended methods to implement inquiry in the classroom (Kang et al. 2008; Lotter et al. 2007; Windschitl 2003) and teachers' successful implementation of inquiry science in the classroom may depend on their pre-disposition to inquiry teaching (Eick and Reed 2002) as well as the clarity and strength of their conceptions about inquiry science. Exploration of exemplary teachers' conceptions of inquiry science and the roots of these conceptions as well as how these teachers implement inquiry practices in the classroom were the focus of this study.

Review of the Literature

Teachers' Conceptions About Inquiry Science

It is important to distinguish between conceptions about inquiry science and beliefs about inquiry. In this project, the focus was on teachers' "conceptions" which were defined as ideas, thoughts, and understandings as opposed to "beliefs" which hold the connotation of conviction, trust, and faith. Teachers may hold a variety of ideas about inquiry science (Demir and Abell 2010; Kang et al. 2008), and the conceptions they hold about inquiry science may affect how teachers implement inquiry (Crawford 2007; Jones and Carter 2007; Lotter et al. 2007). Teachers' prior learning orientations and past experiences may also impact their learning about inquiry (Eick and Reed 2002; Kagan 1992). Luehmann (2007) states that one of the main challenges in developing a teacher's ideas about reform is to reconcile the teacher's "personal prior beliefs about the subject matter as well as learning and

teaching developed as the result of their experiences as students in schools" (p. 823) with the recommendations made for teaching inquiry science. A study (Cronin-Jones 1991) of two middle school teachers found that their ideas about science being a body of factual knowledge and that students do not have the skills for autonomous learning impeded the efforts to implement a reform-based science curriculum. Research (Brickhouse 1990; Duschl and Wright 1989; Gallagher 1991) has found that teachers' ideas about the nature of science as an objective body of knowledge created by a rigid scientific method hindered their teaching of an accurate view of scientific inquiry. Teachers with a more accurate understanding of the nature of science are able to implement a more problem-based approach to science teaching (Brickhouse 1990). Larrivee (2008) recommends developing reflective practitioners who are able to infuse *personal* conceptions and values into a professional identity, resulting in the development of a deliberate code of conduct. These personal factors may determine whether teachers feels strongly enough to work to overcome any barriers to teaching inquiry science they may face.

Barriers to Inquiry Implementation

There may be a number of barriers to implementing inquiry science teaching in the classroom. In order for teachers to adequately engage in inquiry science with their students, they may need to engage in new roles that require mentoring, guiding, or collaborating (Crawford 2000). Roehrig and Luft (2004) found that beginning secondary teachers had five constraints that impacted their implementation of inquiry science: the teachers' (a) understanding of inquiry and the nature of science, (b) strength of content knowledge, (c) pedagogical content knowledge, (d) beliefs about teaching in general, and (e) management and student concerns. This last factor, concern about the ability or maturity of students to engage in inquiry, was also seen by Keys and Bryan (2001) as a factor in teachers' implementation of inquiry. Teachers may also have concerns about letting go of authority (Hayes 2002) and dealing with students' requests for the "right" answers (Furtak 2006).

Developing Teachers' Conceptions of Inquiry

Involvement in authentic inquiry experiences is an effective way to help teachers to strengthen their understanding of inquiry science. Britner and Finson (2005) found that preservice teachers expressed an increased understanding of inquiry-oriented science and more confidence to implement inquiry-based science methods in their own classrooms as a result of their involvement in an inquiry-oriented science methods course. In a science methods course where preservice teachers carried out an inquiry project, van Zee and Roberts (2001) found future teachers gained confidence to teach science in an inquiry manner and Hanegan et al. (2009) found that professional development using authentic inquiry resulted in teachers using more inquiry in their classrooms. How these authentic inquiry explorations may translate into reform-based practice may not be completely clear and researchers have seen a variety of results (Blanchard et al. 2009; Brown and Melear 2006; Lustik 2009) and recommend further research in this area. Therefore, it is necessary

to thoroughly explore the conceptions that exemplary teachers hold about inquiry science teaching, where these ideas have come from, and how they may impact the teacher's practice.

Description of the Project

In order to gain an insight into how the process of learning to implement inquiry science may occur in certain situations, this project involved exploring the ideas, understandings, and the recommendations for teaching inquiry science of six exemplary elementary teachers and the ways that they use inquiry science in their classrooms.

After preliminary classroom observations, these teachers were invited to join a focus group that met four times for 2 h each session throughout the first academic year of the project. During these focus group sessions, the teachers discussed their understandings of inquiry science and reflected on how they came to hold those understandings. Focus group sessions also involved reflections on how the teachers felt their views and understandings affected their teaching of science, their recommendations for teaching inquiry science, and how to best prepare teachers to become experts in this area. The participating teachers were provided a stipend to attend the focus groups and were encouraged to view these focus group sessions as a form of professional development through reflection on their own ideas and practices and through collaboration with their peers. The second year of the project involved classroom observations in the teachers' classrooms of a lesson identified by the teacher as being inquiry based. These observations were followed by interviews with the teachers about their science teaching and implementation of inquiry science teaching. The research questions driving this project were as follows:

1. What are exemplary elementary teachers' conceptions of inquiry science and how were these developed?
2. How do exemplary elementary teachers use inquiry science teaching in their classrooms?
3. What recommendations do exemplary teachers have for their peers as they implement inquiry science?

Methodology

Participants

The exemplary teachers were initially identified based on either their previous involvement in another of the researcher's projects or their past enrolment in one of the researcher's graduate courses. From the initial pool, eight exemplary teachers who were known to be attempting standards-based, authentic inquiry science teaching in their classrooms were chosen which allowed the researcher to start with teachers who had previously demonstrated some understanding of inquiry science teaching. The researcher then informally observed a lesson in the teachers'

classrooms and analyzed the level of inquiry seen based on the NRC (2000) list of essential features of an inquiry lesson (see Appendix 1). Teachers for this project were considered exemplary in terms of teaching inquiry science if the teacher was observed conducting a lesson or series of lessons where student groups were allowed to generate questions to investigate, design an investigation, collect data, and generate explanations. As described on the NRC list of essential features of inquiry, a teacher was considered exemplary if, in the lesson observed and defined as inquiry by the teacher, there was evidence of at least three of the features listed on the left of the chart: (a) learner poses a question, (b) learner determines what constitutes evidence and collects it, (c) learner formulates explanation after summarizing evidence, (d) learner independently examines other resources and forms the links to explanations, (e) learner forms reasonable and logical arguments to communicate explanation (see Appendix 1). After the observation and confirmation of inquiry-based teaching, six teachers were invited to join the project. The six participating teachers represented two different school districts; two teachers taught 4th grade and four taught 5th grade. All the teachers had been teaching for at least 5 years and had taught science for all the years they had been in the classroom.

Data Collection

The focus sessions were guided by the researcher using a preset list of questions (see Appendix 2 for a list of focus group questions) generated to solicit conversations and discussions about definitions of inquiry science and inquiry teaching, origins of understandings of inquiry, struggles with understanding and teaching inquiry science, recommendations for teaching about inquiry, factors impeding the implementation of inquiry, and other topics related to views and understanding of inquiry science During the focus group sessions, all conversations were recorded and later transcribed.

The teachers were given a survey at the end of the focus group sessions asking them to describe new ideas gained through participation in the focus group sessions, how their existing ideas may have been solidified, new strategies for teaching inquiry they may have gained, and their goals for teaching inquiry in the future (see Appendix 3 for this survey).

During the second year of the study, the teachers planned a lesson that they felt would best demonstrate their implementation of inquiry science and this lesson was observed by the researcher. During the observation the researcher took field notes and completed a first draft of a rubric based on the five essential features of an inquiry lesson (NRC 2000). The researcher finalized this rubric when writing up field notes after the lesson observation (see Appendix 1 for a sample of this rubric). Also, immediately following the observations, the teacher and the researcher met for an interview focusing on: (a) the planning that occurred for the lesson, (b) the teacher's evaluation of the lesson in terms of how it fit the NRC's (2000) five essential features of an inquiry lesson, (c) evaluations and assessment strategies the teacher employed during the lesson and why, and (d) how the lesson might be improved and why. The interviews were audio taped and then transcribed.

Data Analysis

These transcriptions of the focus group sessions were analyzed using interpretational analysis (Gall et al. 2003) and the categories developed through grounded theory. Categories developed from the focus group sessions were: (a) factors that had led to teachers' conceptions of inquiry, (b) strong ideas surrounding inquiry, (c) inaccurate views of inquiry, (d) identified barriers to and successes in teaching inquiry science, and (e) recommendations for best practices. The data were specifically analyzed for any mention of teachers' ideas, views, or opinions about inquiry teaching and for recommendations they made for helping other teachers implement inquiry. The survey responses were analyzed for evidence of any self-reported change in a teacher's conceptions about inquiry, successful strategies used for teaching inquiry, and recommendations for improving teachers' inquiry practices. The transcriptions of the post observation interviews were analyzed for any mention of specific planning the teacher did for an inquiry lesson, objectives driving the lesson, assessment practices, and analysis of the inquiry level of the lesson.

Findings

Exploring the Teachers' Conceptions of Inquiry Science

The teachers all had a very open definition of inquiry as a way of "finding things out" yet they all agreed that "school science inquiry" had to be more controlled and less open. When describing someone who could do well in inquiry-situations, the teachers used descriptions such as "risk-taker", "problem-solver", and "curious about how things work." During the first focus group session and then refined at the second group meeting, the teachers developed a list of what they all agreed was a good list of the characteristics of someone who engaged in inquiry. They decided that the following were all important characteristics: (a) risk taking, (b) perseverance, (c) confidence to throw out ideas, (d) reflection, (e) observing and questioning, (f) determination, and (g) confidence to do your own thing.

Findings from the focus group sessions show that the teachers all felt that their upbringing and childhood experiences had impacted their embracing inquiry so readily and with their defining inquiry as "finding things out". They discussed explorations in the woods and playing in water and mud when they were younger. They talked about being excited to take things apart and make messes and they all stated they had been questioning, exploring, and experimenting kids. They felt that the one description that would fit them all as children was that they were inquisitive. One teacher said, after all six had shared something about their having been a "questioning type of kid":

> I find it interesting that we're all teachers and we all have this attitude. I think that it's part of what makes us the teachers that we are. I know that I am a teacher because I love to explain things. I'm an explainer and this unique attitude drives me to find out. I'm explaining things to myself first so that I can explain them to other people later.

The teachers gave a number of personal examples of what they remembered doing as children and how they felt these experiences had impacted their understandings about inquiry. A number of the teachers said that they had been kids with a lot of determination, perseverance, and confidence. One comment was that, as a child, this teacher had always wanted to make sense of the world and this had impacted how and why inquiry was such a strong component in the classroom. Besides having opportunities to explore the world around them as children, the teachers mentioned that they had had role models that had encouraged their explorations and interactions with the world around them. One teacher talked about being someone who does not like to be fed information:

> I just don't really like someone saying here is the question and, by the way, here is the answer. Don't tell me the answer! You just wrecked the problem, the puzzle, for me. I want to find the answer and at least get engaged with the question before you tell me the answer. I would rather try it first and I think that is the natural sense of wanting to be the explorer.

When asked about the factors that had helped them to understand inquiry as a teaching practice, the teachers responded that readings that they had been assigned in science methods courses had clarified inquiry for them and helped to solidify their teaching of science using inquiry. But these teachers all said that it had been a process, they had only come to understand inquiry through years of teaching and trying different strategies. All the teachers stressed that learning to teach science using inquiry had been a long term process that occurred in the classroom:

> Even this year I changed and said, what more can I do? Give up a little more control, give them a little more freedom. I think it is working. I'm impressed with the ability of the students to think on their own and take control of the materials and do different things and create their own questions.

From the survey data, most of the teachers communicated that they had not thought about what made them inquiry teachers prior to the focus sessions. They said that from the focus group sessions: "I have gained an understanding of why I teach the way I do", "I have more confidence in myself as a problem solver", and "I had never thought about how I had become a person that inquires about things before." From the survey data collected it was clear that the focus group sessions were valuable professional development experiences for these teachers. Just having time to share their understandings, reflect on their current teaching, and plan for future teaching made these sessions significant for the teachers.

Teachers' Implementation of Inquiry in the Classroom

The teachers were all rated on the observation rubric as to the evidence of the essential features of an inquiry lesson (NRC 2000, Appendix 1). All lessons observed showed evidence of students engaging in scientific questions, designing investigations, collecting data, proposing explanations based on their evidence, and providing a clear summary of their work. This is not surprising since the teachers were aware of the rubric and had used it when discussing inquiry lessons during the

focus groups. One element of the essential features that did not consistently surface in the observed lessons was that of students conducting research to validate or justify their findings. The teachers said that this often took more time than they had and said they used peer review and teacher feedback for students to connect their findings to scientific research.

The planning for inquiry science teaching that these teachers did was characterized by a focus on students' understanding, student engagement, and allowing plenty of time for student exploration. The teachers said they often felt that their lessons were constrained by a lack of time and in some cases by the curriculum they used in the classroom. One of the teachers discussed how the science kit curriculum sometimes had designs for the K-nex cars for the students to build that did not work, and he was able to incorporate this into his planning:

> I think that planning as an inquiry teacher you've got to know that there are just some designs that won't work and have faith that the kids can work through that and redesign it and not be frustrated to the point that they quit, but frustrated to the point that they want to make some changes to their design. That's a good spot to put kids in.

When discussing the planning that they did for inquiry lessons, these teachers seemed to have trouble stating specifically any steps they went through to plan for an inquiry lesson. They seemed to view making a lesson inquiry as one big step rather than a process planning many small pieces. They said that "everything can be made into some type of inquiry" and "we just start investigating, asking questions, and testing."

During the post-observation interview, the teachers were asked about assessment. They overwhelming theme in their responses was formative assessment. The talked about how when doing inquiry, they were able to find out so much about what students understood and find many venues for assessment. One teacher talked about how she assessed students at the end of an open inquiry after the students had heard from all class groups:

> What's amazing to me is that when you do an open inquiry, different groups do different things and they share out. I call them scientific conventions in my class, but they share their evidence and their claim and it's amazing what they learn. If I assess after that point and I still have kids not understanding then you have to circle back around again; its constant assessment.

Teachers' Recommendations for Teaching Inquiry Science

The teachers addressed a number of different themes as they discussed what they would recommend to other teachers to improve their inquiry science teaching. The focus discussions often revolved around understanding inquiry and the participants made statements such as: "Teachers need to recognize a problem with the traditional way of teaching before they will change to more inquiry-based practices" and "Teachers need to have a strong understanding of what inquiry is before trying to use it."

All the teachers stressed that encouraging and training students to be problem solvers was important, they said that they all started out the school year with small problem solving exercises and worked with their students to become better and stronger problem solvers by the end of the school year. The teachers stressed again and again that in order for a teacher to be successful at implementing inquiry science into his/her classroom, the teacher will need to provide students with opportunities to be explorers and independent thinkers; they must get away from the idea that the teacher is always in control and responsible for the learning. "You need to get away from a fear of failure in the classroom", and "You cannot have a tightly controlled classroom, you have to let go" were characteristic quotes made by the teachers about how more traditional teachers need to be less focused on classroom control. One of the teachers said that it important to get away from just following the science kit curriculum:

> I guess in a nutshell, are you trying to get a right answer by going through your kit or are you trying to get kids to practice science? Practicing science means you've got to fail at it; practicing science means you've got to redesign.

The participants of the focus group mentioned that in addition to understanding how important inquiry is and recognizing that there is a need for change, being able to observe inquiry science in a model classroom is essential in order to change. "Teachers will need to see it working in other classrooms and hear how beneficial it is for kids in order to be motivated to try it themselves" and "It is so important to see inquiry in action in order to understand it."

The teachers mentioned in both the focus group sessions and in the interviews that teacher content understanding of the science the students are doing inquiry in is crucial. One teacher said in the post observation interview:

> I think content knowledge is huge. If you don't have the content knowledge to understand surface area and how that applies to wind resistance, you can't do inquiry on air resistance if you don't understand how surface area and mass works together. So without the content knowledge as a starting point for teachers, I think inquiry is really hard and I think that is why some teachers are reluctant to do inquiry.

Conclusions

The exemplary teachers in this focus group all held similar ideas about inquiry and all described similar childhood experiences that they felt had been influential in the development of their inquiry characteristics. These characteristics were those that the teachers felt were crucial to encourage in their own students and their classrooms were environments for exploration, problem solving, and independent thinking. Because of who they are, these teachers do not see that inquiry science teaching is a mandate from their administration or from the science reform movement. They clearly see teaching science through inquiry as a way of interacting with the world, a way of finding things out; and finding things out is important to all of them.

As Crawford (2007) and Lotter et al. (2007) found, teachers' conceptions of inquiry may impact how inquiry is implemented in the classroom and the focus group teachers were seen to implement inquiry in their classrooms supported by their conceptions about an inquiry learner as someone who is curious about the world, has a problem solving attitude, and exhibits persistence when finding solutions. It is important to note that these characteristics are some of the characteristics or "habits of mind" that are recommended for students in documents such as 21st Century Skills (Partnership for 21st Century Skills 2009). These skills are clearly important to cultivate in students for their success in future careers but also in teachers in order to develop and strengthen their implementation of inquiry teaching.

As the teachers in this focus group project discussed their own childhood experiences and how these had led to them being a person who enjoyed figuring things out and being a problem solver, it was evident that they had not previously thought about themselves in this way in the same conversation as teaching inquiry science. These reflections led them to state on their surveys that they felt more comfortable using inquiry and had learned new strategies from others in the group. They also said that they left the focus groups with a stronger desire to work with their teaching partners and others in their schools to improve inquiry teaching. As in other studies focused on identifying teachers' conceptions of inquiry (Kang et al. 2008; Kazempour 2009), the focus group sessions were valuable professional development experiences for these teachers, providing them a venue where their conceptions about inquiry were made more salient to them and time for them to reflect on the factors that established those conceptions (Larrivee 2008). This type of professional development focusing on the personal dimension of teaching science (Schibeci and Hickey 2000 as cited in Loughran 2007) is a way for teachers to connect to science in a personal manner and to reflect on how they understand science themselves.

From the interviews and observations conducted, as well as from discussions in the focus groups, it became clear that the teachers did not view inquiry as overwhelming to implement or something that took a lot of planning. It is possible that their conceptions of inquiry as a whole concept, rather than discrete pieces, allowed them to plan an inquiry lesson as a package rather than as separate events for their students. It is also possible that these teachers were not able to clearly differentiate or describe the various components of an investigation.

It was interesting that the teachers in this study all stressed formative assessment when asked to describe their assessment practices when teaching inquiry. It is possible that they saw students actively engaging in the practices of science as actions that needed to be assessed through a formative or performance assessment. They did not seem to focus on assessing students' growth in content knowledge although they did mention improvement in science understanding as a positive aspect of inquiry science. Further research on how teachers' views of inquiry may affect their assessment practices would add to the understandings of teacher use of inquiry science. When teachers implement more student centered lessons with a strong focus on students actively conducting investigations, are the teachers more likely to use formative assessment practices?

The teachers in this project seemed to have moved past some of the barriers to teaching inquiry science discussed in prior research. Similar to Crawford (2007), these teachers talked about the need to be mentors and guide students as they engage in their own investigations. These teachers voiced the need for more student responsibility and less classroom control, barriers to teaching inquiry seen in the research (Hayes 2002; Keys and Bryan 2001; Roehrig and Luft 2004). Similar to research demonstrating that authentic inquiry experiences may strengthen teachers' use of inquiry (Britner and Finson 2005; Hanegan et al. 2009; van Zee and Roberts 2003), the teachers in this project, through having "authentic" experiences in their past, were successful at implementing inquiry science. These teachers knew the thrill of "finding things out" on their own and wanted to provide opportunities where their students could experience this thrill. Possibly understanding this thrill and having had experiences with this thrill as a learner in the past is one of the components necessary to implementing inquiry learning in the classroom as a teacher; research has shown that teachers who are unable to conceive of their students being able to do inquiry may not undertake to implement inquiry (Cronin-Jones 1991; Keys and Bryan 2001). Therefore, engaging in explorations and authentic inquiry investigations, either as a child or an adult learner, may be one of the factors in successful implementation in the classroom and the clarity of the teachers' understanding about inquiry may be one key to their success at implementation.

There were certain limitations to this research. One limitation was that the participating teachers had all been prior students of the researcher or involved in prior professional development experiences provided by the researcher which meant that the teachers all entered the project with prior knowledge of what the researcher defined as inquiry teaching. Another limitation was that there was only one lesson observed and discussed with each of the teachers and only six teachers in the focus group. With additional teachers, and the inclusion of teachers unknown to the researcher, the findings of the study may have resulted in fewer teachers able to trace their conceptions of inquiry as successfully as the six in this project did.

Implications

Coming to an understanding of how teachers understand inquiry science and how their ideas have been generated will allow science teacher educators to better instruct both preservice and in-service teachers about teaching science through inquiry. But as has been strongly recommended by prior research (Anderson 2002) these understandings about inquiry should not be addressed "in isolation from a practical context" (p. 9). Learners need to be given opportunities to experience authentic inquiry or problem-solving as they mature. This applies to younger students and is supported by recommendations from many sources (National Science Education Standards, NRC 1996; Partnership for 21st Century Skills 2009) but it also is necessary for older students in science methods courses as they are learning to become teachers (Britner and Finson 2005; Hanegan et al. 2009; van Zee and Roberts 2003) or for adult learners such as teachers involved in professional

development. As Hanegan et al. (2009) and Kazempour (2009) found, teachers need to be immersed in authentic inquiry experiences as adult learners in order to change their ideas and practices surrounding inquiry. Therefore, professional development designers should strive to provide experiences for teachers where they are able to generate questions, design investigations, collect and analyze data, propose explanations, validate those explanations, and communicate their complete process in the hope that experiencing this process as a learner will provide support for teachers as they implement inquiry in their own classrooms (Blanchard et al. 2009; Luft 2001). It will also be necessary for more research to be conducted on the association between a teachers' personal experiences with inquiry learning and their teaching of inquiry in their classroom. This exploratory study demonstrates that the group of teachers participating did rely on their past experiences in inquiry learning to become better teachers of inquiry. It would be interesting to explore how the type of inquiry experience or when the experience occurred (as a child, as a high school student, as a preservice teacher, or as a veteran teacher) may impact a teacher's use of inquiry teaching.

As science teacher educators plan how to improve their preservice and in-service teachers' understandings of inquiry and make decisions regarding the experiences for these teachers, it is important to keep in mind how teachers understand inquiry and the experiences they have had that have helped them develop their understandings and practices. It is also important for teachers to be asked to spend time reflecting on their own personal experiences with "finding things out" and as recommended by Blanchard et al. (2009) and Larrivee (2008), develop their inquiry skills through reflection on practice. This reflection on the process of inquiry as teachers are involved in inquiry experiences as preservice or in-service teachers may be a strong factor in later classroom use. As seen in this study, teachers were not easily able to describe their planning for inquiry and may not previously have done much, if any, reflecting on the inquiry process. This is another area where more exploration would benefit the field; research on how teachers make sense of the inquiry process and relate it to other endeavors or use it when planning for inquiry would strengthen our understanding of inquiry teaching.

If teachers new to inquiry teaching can be given the chance to identify their own questions through curiosity, struggle with problems, and experience the satisfaction of figuring things out on their own, then their chances of creating those same experiences for their students will be greater. The teachers in this group all recommended that when encouraging other teachers to implement inquiry, they need to first recognize its importance, and certainly this will take involving teachers in authentic inquiry experiences as learners so that they will be able to begin to view themselves, as these focus group teachers did, as problem-solvers and experimenters. By listening to what these exemplary teachers had to say about preparing new teachers to teach in an inquiry manner, it became clear that they valued an understanding of what inquiry really is as well as an understanding of the nature of science. For teachers to be able to successfully implement inquiry, they will need to understand its characteristics and the characteristics of science, as Crawford (2007) and Lotter et al. (2007) have stressed, conceptions of inquiry may impact teachers' practice.

Appendix 1

Classroom Observation Rubric (adapted from NRC 2000)

Essential Features of Classroom Inquiry and Their Variations

Teacher Name_____ Date_____ Observer Name_____

Essential Feature *These are the key features of inquiry*	**Variations** *The variations are different ways that the essential features might be expressed in student investigations. The observer will bold-face the variation that was most prevalent in the lesson*				**Comments**
Learner engages in scientifically oriented questions	Learner poses a question	Learner selects among questions, poses new questions	Learner sharpens or clarifies question provided by teacher, materials, or other source	Learner engages in question provided by teacher, material, or other source	
Learner gives priority to evidence in responding to questions	Learner determines what constitutes evidence and collects it	Learner directed to collect certain data	Learner given data and asked to analyze	Learner given data and told how to analyze	
Learner formulates explanations from evidence	Learner formulates explanation after summarizing evidence	Learner guided in process of formulating explanations from evidence	Learner given possible ways to use evidence to formulate explanation	Learner provided with evidence	
Learner connects explanations to scientific knowledge	Learner independently examines other resources and forms the links to explanations	Learner directed toward areas and sources of scientific knowledge	Learner given possible connections		
Learner communicates and justifies explanations	Learner forms reasonable and logical argument to communicate explanations	Learner coached in development of communication	Learner provided broad guidelines to sharpen communication	Learner given steps and procedures for communication	
	More ← *Amount of Learner Self-Direction* → **Less** **Less** ← *Amount of Direction from Teacher or Material* → **More**				

The variations differ in the amount of teacher guidance that is provided

Appendix 2

Focus Group Questions

Session 1

1. How do you personally define inquiry?
2. What is NOT inquiry science?
3. How have you come to these understandings/definitions?

4. What are the characteristics of an inquiry learner?
5. Where do the characteristics of an inquiry learner come from? How do they develop?

Session 2

1. Is there anything to add to the list of characteristics of an inquiry learner?
2. When did you first hear the term "inquiry" as it is associated with teaching science?
3. Has your understanding of that term changed?
4. How would you describe a teacher who uses inquiry science in the classroom?
5. What might you see happening in that classroom?

Session 3

1. What do you think has to occur for a teacher to become an "inquiry" science teacher?
2. What would you recommend that I do in my science methods courses to help preservice teachers understand inquiry science teaching?
3. What were the most significant experiences that you had that led to you being an inquiry teacher?

Session 4

1. What are the barriers that exist that prevent inquiry science from occurring in more classrooms?
2. How might these be mitigated?
3. What needs to happen in your school for more inquiry to take place?
4. How might you talk to the teachers in your school about inquiry?
5. How might you talk to the administrators in your school about inquiry?

Appendix 3

Post Focus Group Survey

Are there any new ideas or concepts that you have gained through our discussions in this group?

Were any of your existing ideas reinforced or solidified through discussions at our meetings?

Have you gained any teaching ideas or strategies that may be useful in your classroom?

Have you set any goals or objectives for your teaching as a result of these focus group discussions?

Do you have any ideas/opinions/feelings/thoughts about inquiry science and or teaching using inquiry that did not come out in the discussions that you are willing to share?

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