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Feature Article

Dilemmas of Teaching Inquiry in Elementary Science Methods*

William J. Newman, Jr.
Department of Mathematics and Science Education, Illinois Institute of Technology, Chicago, IL 60616, U.S.A.

Sandra K. Abell
Southwestern Bell Science Education Center, University of Missouri-Columbia, Columbia, MO 65211, U.S.A.

Paula D. Hubbard
Department of Curriculum & Instruction, Purdue University, West Lafayette, IN 47907, U.S.A.

James McDonald
Department of Teacher Education and Professional Development, Central Michigan University, Mt. Pleasant, MI 48859, U.S.A.

Justine Otaala & Mariana Martini
Department of Curriculum & Instruction, Purdue University, West Lafayette, IN 47907, U.S.A.

Because various definitions of inquiry exist in the science education literature and in classroom practice, elementary science methods students and instructors face dilemmas during the study of inquiry. Using field notes, instructor anecdotal notes, student products, and course artifacts, science methods course instructors created fictional journal entries to represent the experiences of both the instructors and students during instruction on inquiry. Identified dilemmas were varying definitions of inquiry, the struggle to provide sufficient inquiry-based science-learning experiences, perceived time constraints, determining how much course time should be slated for science instruction versus pedagogy instruction, instructors' and students' lack of inquiry-based learning experiences, grade versus trust issues, and students' science phobia. Instructors' attempts at dealing with these dilemmas included using analogies, increased field-experience time, modeling, and detailed rubrics.

Introduction

Although the definition of inquiry varies among science educators, its presence is undeniable in current science education research and in reform documents,

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including U.S. national and state standards. Given its importance in reform documents and in the science education literature, addressing inquiry is essential in science teacher education programs. In our teaching of elementary science methods, we emphasize inquiry as a set of learning outcomes and as a teaching approach. However, our teaching of inquiry has created for us several teaching dilemmas stemming from our students' lack of exposure to learning science through inquiry, our own limited experiences with teaching and learning through inquiry, and the variety of meanings for inquiry that we have constructed. These teaching dilemmas include our inability to provide sufficient inquiry-based science-learning experiences given the time constraints we face, conflicts between modeling science as inquiry versus teaching inquiry as a pedagogical strategy, and student attitudes toward inquiry, including science phobia and concerns about grades. In this paper, we describe our dilemmas of teaching inquiry in the context of the elementary science methods course and provide potential solutions to these dilemmas.

Inquiry Defined?

Inquiry has played a significant role in the reform literature in defining the nature of science and important learning outcomes for students. Scientific inquiry requires the use of evidence, logic, and imagination in developing explanations about the natural world (American Association for the Advancement of Science, 1989, 1993). Science students should come to understand what inquiry is, as well as develop the requisite abilities to do inquiry (National Research Council, 1996). Inquiry is also a pedagogical approach that helps students achieve science understanding "by combining scientific knowledge with reasoning and thinking skills" (p. 2). When students are engaged in inquiry, they 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 (p. 2).

Inquiry as a pedagogical approach was further detailed by the publication of an inquiry guide as a supplement to the U.S. National Science Education Standards (National Research Council, 2000), which describes the components of inquiry-based teaching and draws a parallel between scientific and school science inquiry. According to the National Research Council (NRC), learners participating in classroom inquiry (a) are "engaged by scientifically oriented questions," (b) "give priority to evidence," (c) "formulate explanations from evidence," (d) "evaluate explanations in light of alternative explanations," and (e) "communicate and justify proposed explanations" (p. 25). Researchers and practitioners have described inquiry, conducted studies, and wrote commentaries based on these definitions of inquiry (e.g., Anderson, 2002; Andersen & Speece, 1995; Caton, Brewer, & Brown, 2000; Crawford, 2000; Lederman & Niess, 2000; Luft, 1999; Rossman, 1993).

Others have used modified definitions of inquiry. Allen (1997) described seven different learner tasks at an interactive museum exhibit as *inquiry activities*, yet each contained only one or two of the NRC (2000) essential features of inquiry. Some have equated inquiry with a learning-cycle instructional approach. For example,

Colburn (Bianchini & Colburn, 2000) described his teaching of the nature of science in a general science course for elementary education majors as inquiry-based and linked to a "three-stage process of exploration, concept introduction, and application" (p. 184). Marshall and Dorward (2000) also described using a form of the learning cycle for inquiry experiences in an introductory college physics course. In their study, students made predictions, developed conceptual models, and expressed the "behavior of the system in their own words" (p. S30). Inquiry has also been described as "giving the students experience with the development of research questions and testable hypotheses" (Stoddart, Abrams, Gasper, & Canaday, 2000, p. 1222). Edelson, Gordin, and Pea (1999) stated that inquiry "involves the pursuit of open-ended questions and is driven by questions generated by the learners" (p. 393), a description that partially reflects the science education reform literature.

Keys and Bryan (2001), while agreeing with the NRC description of inquiry, stated that "inquiry is not a specific teaching method or curriculum model" (p. 632) and that "multiple modes and patterns of inquiry-based instruction are not only inevitable but also desirable because they paint a rich picture of meaningful learning in diverse situations" (p. 632). Moreover, Keys and Kennedy (1999) stated the importance of context to inquiry-based learning, including "characteristics of the learners, the school culture, and the science topic" (p. 317). Anderson (2002) extended the context and perspective dependence of inquiry by differentiating among scientific inquiry, inquiry learning, and inquiry teaching. Given that researchers have used varied definitions of inquiry—definitions that also vary by contextual considerations—it is not surprising that science teacher educators struggle when deciding how to teach inquiry in their courses.

Taking their lead from reform documents, textbooks designed for science teacher education contain information on inquiry and provide methods instructors with a starting point. For example, Bloom (1998) expanded the 5E model described by Trowbridge and Bybee (1996) to seven stages that contain many of the essential features of inquiry. Furthermore, articles in science publications for teachers, which are included as readings in many methods courses, contain descriptions of inquiry and its implementation to facilitate prospective and in-service teachers in understanding how to teach science using inquiry (e.g., Ash & Kluger-Bell, 1999; Colburn, 2000; Kluger-Bell, 1999). Inquiry takes on many meanings in these articles, only some of which are aligned with the standards documents.

Given the complexity of defining and teaching inquiry, researchers have documented some of the challenges of implementing inquiry-based instruction. Elementary teachers lack an understanding of inquiry and do not have the skills or experiences to effectively teach science through inquiry (Crawford, 2000; Lederman & Niess, 2000). Crawford concluded that inquiry-based teaching requires an understanding of the nature of science, as well as pedagogical content knowledge. In addition to teachers lacking the necessary skills and knowledge to teach inquiry, Keys and Kennedy (1999) discussed an elementary teacher's difficulty balancing inquiry-based instruction with district-mandated curriculum and assessment strategies. Edelson et al. (1999) posited five challenges of implementing inquiry-based learning: motivating students, accessibility of investigation techniques, student

background knowledge, student management of extended activities, and learning context constraints.

Although most studies have not directly addressed inquiry in preservice science teacher education, implications for methods course instruction are evident. The purported lack of teacher understanding and skills must be addressed in the methods course. The potential challenges that future teachers face in inquiry teaching must be an explicit part of instruction. However, because inquiry has been defined in multiple ways, facilitating preservice teachers' learning and implementation of inquiry in methods courses is complicated. We can learn more by examining how inquiry is taught in elementary science methods, how the students respond, and how improvements can be made.

Context, Questions, and Methods

At various times over the past 4 years, we have worked as members of a teaching team, planning and enacting a science methods course for future elementary teachers. Through numerous informal conversations about our teaching, we noticed that we shared concerns about the teaching of inquiry in the course. Accordingly, we undertook a more formal examination of how we teach inquiry in elementary science methods based around the following questions: How are we currently teaching inquiry? What aspects of inquiry instruction seem to be working well and what aspects are not working well? What factors influence inquiry instruction in our course? How can we address any identified problems?

The members of the team working on this project come from a variety of backgrounds. Newman is a Caucasian man born and raised in the U.S.A. who, at the time of this work, was completing his doctorate in science education. He has 10 years' high school science teaching experience, experience working with elementary teachers on curriculum development, and 2 years' experience as an elementary science methods instructor. Abell is a Caucasian woman born and raised in the U.S.A. and is a university science educator with 12 years' experience at the time of this study. She has 6 years' experience teaching elementary school and 14 years' experience teaching elementary science methods. Hubbard is a Caucasian woman born and raised in the U.S.A. who, at the time of this work, was completing her masters degree in science education. She has 3 years' experience teaching elementary and middle school science and 2 years' as an elementary science methods instructor. McDonald is a Caucasian man born and raised in the U.S.A. who, at the time of this work, was completing his doctorate in science education. He taught elementary and middle school for 10 years and worked 4 years as an elementary science methods instructor. Otaala is an African man born and raised in Uganda and was working on his doctorate in science education at the time of the study. He taught elementary school for 3 years and secondary school for 5 years in Uganda. Additionally, he has 2 years' experience as an elementary science methods instructor in the U.S.A. Martini is a South American woman born and raised in Argentina who was working on her doctorate in science education at the time of the study. She has 2 years' experience teaching elementary and secondary school science in Argentina. She

had 4 years' experience as an elementary science methods instructor in the U.S.A. at the time of the study. Thus, as a team, we bring varied teaching experiences, personal backgrounds, and areas of expertise.

The elementary science methods course under study is built on a reflection orientation (Abell & Bryan, 1997) that provides opportunities for students to build theories of science teaching and learning as they (a) observe others teach, (b) reflect on their own teaching, (c) read expert theories, and (d) examine their own science learning. We have studied this course previously to examine the development of teacher thinking about science teaching and the nature of science (Abell & Bryan, 1997; Abell, Bryan, & Anderson 1998; Abell, Martini, & George, 2001; Abell & Smith, 1994). Thus, there is a substantial database from which to work.

We each established lists of issues that related to teaching inquiry in the context of our individual science teacher preparation experiences. We then expanded and built upon the lists through the aid of field notes, instructor anecdotal notes, student products, records of team meetings, and course artifacts, such as course syllabi, lesson plans, and activity and demonstration descriptions. The student products examined included lesson plans, recorded class discussions, and course journals. Because they contained the most relevant data with regard to students' ideas and perceptions of inquiry, we used the students' course journals as the primary data source. This in turn led us to the decision to present our experiences in journal form. The students completed journals during extended inquiry projects and after each teaching experience in their field placements. Some journals were open ended and the students described their experiences and what they were learning. Other journals were created around guiding questions from the teacher, such as "What aspects of this lesson make it inquiry-based?" The codes developed for examining the data included inquiry-based science-learning experiences, limited class time, limited field-experience time, modeling inquiry, explicit instruction on inquiry as a pedagogical strategy, student attitudes toward inquiry, science phobia, and grades.

In research team meetings, we compared our individually compiled lists of issues related to teaching inquiry and then generated a common set of inquiry teaching dilemmas. In order to represent our collective thinking about teaching inquiry, we generated fictional journal entries, from both teacher and student perspectives, based on the data sources. We chose to present our ideas using summative fictional journals because using the actual journals would have required extensive space since the discussed issues were dispersed throughout the students' and instructors' work. As we created our fictional journals, we identified segments in the original coded journals that related to the topic being discussed and merged them into a concise representation. In the next section, we juxtapose these teacher and student narratives in order to exemplify our common teaching dilemmas at three points in time across the course. Finally we present some solutions to the dilemmas.

Presentation of Inquiry Dilemmas Through Journaling

In the following fictional journal entries we have attempted to illustrate the dilemmas that arise when teaching inquiry in an elementary science methods course.

The teaching dilemmas arise from a lack of inquiry-based learning experiences for our students and us, as well as from our individual constructs of inquiry. The teaching dilemmas include providing sufficient inquiry-based science-learning experiences within the limited class and field-experience time, balancing how to model inquiry with explicit instruction on inquiry as a pedagogical strategy, and confronting student attitudes toward inquiry, including science phobia and concerns about grades.

Beginning of the Methods Course

During the first class period of our methods course, we often use a short inquiry activity to get students involved, pique their interest, and decrease their anxiety about the course. After that, we introduce a month-long moon inquiry that includes keeping a moon notebook as a graded assignment for the course. During the moon inquiry, students raise questions, record observations, look for patterns, and invent explanations to fit the evidence. We have written elsewhere about this moon inquiry (Abell, George, & Martini, 2002; Abell et al., 2001; Martini & Abell, 2000) from the perspective of our students' learning about the nature of science and about science teaching. Here we use the context of the extended moon inquiry to help uncover common dilemmas we have faced in teaching inquiry in the methods course.

The Instructor's Journal. *Instructor Entry 1*. Well, I jumped right into inquiry in class today. We worked with whirlycopters and students tried to figure out which whirlycopter flew the "best." Student groups operationally defined "best," selected researchable questions (e.g., What will happen if we use different kinds of paper?), discussed and carried out a research plan, and communicated their results at the Whirlycopter Toy Company board meeting. Short, sweet, to the point. Students enjoyed it and performed confidently. Well, that is, all except that group in the back that would not get out of their chairs, even to fly the copters . . . Why are some students so afraid to "do science"? I wanted them to have some fun and relax a little about taking a course with "science" in the title. I was also aiming for students to understand fair testing and be able to make a fair test plan. I really did not care if they understood any physics principles or if they were thinking about science teaching. I have a feeling that the moon investigation won't go as smoothly as the whirlycopter activity.

Instructor Entry 2. Today I assigned the moon investigation. We constructed a KWL (Know, Want to know, Learned; Ogle, 1986) chart of what they know and want to find out about the moon, and I asked them to observe the moon over the next couple of days and bring their data to class on Thursday. When I said we'd be studying the moon for the next month or so, some students seem surprised, others nervous. If these students are like past students, I can predict that in science class they've seldom, if ever, undertaken a long-term inquiry or been asked to reason instead of memorize. Nevertheless, those old doubts about the moon investigation are again creeping into my thoughts. Why do I spend so much of class time on this activity? What are my goals for student learning? Is there a more effective way to achieve these goals in less time? After all, I was not educated this way. Okay, let's start at the top. My goals for the students: to learn something about the patterns and

explanations for phases of the moon, to feel confident asking scientific questions and using evidence to refine their explanations, to think about how they could use inquiry in their own science teaching. Well, that's a big set of expectations. Perhaps I am setting myself up for failure immediately. It looks like I have a goal for learning science content, for learning inquiry, and for learning pedagogy. And I realize there are some other goals too—like the goal of getting students to feel more confident about their abilities to think scientifically, which I think will motivate them to teach more science. Maybe that's just too much to accomplish over the coming weeks. Maybe these goals are in competition with each other. On the other hand, maybe they cannot be separated so easily.

Instructor Entry 3. The moon investigation is in full swing. We have had some very interesting discussions about the patterns we are seeing and the ways we might explain the patterns. This is where I get energy as a teacher—watching students struggle with data, ask interesting questions, and debate their ideas. But will this struggle with science ideas lead to developing their thinking about science teaching? I saw things almost backfire in class today as one frustrated group complained that they were no closer to understanding the moon than they had been 2 weeks ago. Another group chimed in: "If we can't do this, then surely fifth graders can't." Fortunately there was that group in the back that is really dedicated to their moon study, as they are about everything we have done in the course. They explained how the moon study was a great model for how they could help students build meaning in a powerful way: "I'm beginning to see how my students could learn this stuff in a fun, interactive way." This group also shared some helpful resources they had found about moon phases. The group mentioned how they could use them with a class of elementary students. Did the other groups see this as a way to use the moon journal as a teaching tool? Some of the students seem concerned about how I will grade the moon notebooks, although I thought I had been clear. The assignment sheet specifically states: "You will NOT be evaluated on the scientific accuracy of your ideas, but, rather, on the thoughtfulness of your attempts to understand." Yet their worries about getting the "right answer" seem more connected to evaluation than to caring about understanding.

Instructor Entry 4. Why was the whirlycopters lesson so much easier to carry off than the moon study has been, for both the students and me? Maybe because it only lasted one class period and had specific "steps" in the lesson sequence? My guess is that students will be more successful teaching this sort of short, structured lesson than a long-term inquiry like the moon study. But that worries me. The whirlycopter activity is a good model for fair testing. However, I think it represents inquiry only at a surface-feature level: asking questions, making a plan, collecting data, and communicating results (sounds a bit too much like THE scientific method for my liking). The moon investigation, on the other hand, represents inquiry at a deep-feature level: that questions, planning, and data collection are all in the service of building explanations of how the world works; argument and evidence are primary. Yet the pedagogy during the moon investigation is more subtle and more demanding of the teacher; I wonder if beginning teachers will be able to carry it off. Well, maybe after a few more examples, like the divers and pendulums, which

last more than a single class period but less than a month, I'll see evidence of their increasing understanding. But this sure takes a lot of time. Students also seem to be concerned about the time they spend on the assignment and their grade on the moon journal. We spent some class time going over the rubric for assessing the moon journal. I wish the methods students would trust me on the value of conducting the moon investigation. Would I be better off dropping this modeling and just telling them how to use inquiry-based teaching strategies? But that goes against the whole idea of inquiry-based learning. Argh! Very frustrating!

Student's Journal: Amy. *Amy, Entry 1*. We made and flew our whirlycopters today. I had expected a serious lecture on pressure and how an airplane actually flies and maintains balance in the air and what forces come into play, but instead we played around with paper. I've never done something like this before. It was really hard to think of a question to investigate in this activity. Defining the "best" was not as easy as I had thought. Several of us ended up doing the same thing—what kind of paper makes the best copter. We tried flying our copter, but we did not seem to get any interesting data at all. I think that was because we kept changing the height from which we let our copters go. I tried to tell my group that we needed to use the same height but . . . This kind of frustrated me and made me not enjoy the activity. I am sure elementary students would love this. However, I am wondering if this activity is appropriate for primary students since it requires being able to make the test fair. I wonder if they can?

Amy, Entry 2. Today the instructor introduced the unit on the moon. I got very excited about this unit because this is an area about which I have very little knowledge and I hope to learn more. I thought the KWL chart was cool—we had it last semester in literacy methods. The list of things we wanted to learn was three times longer than the list of what we already knew. I guess the TA will teach us this stuff over the next 4 weeks. Will it take her that long to get to all the answers? I was surprised when she explained that we were to become "moon watchers." Sounds weird to me, but I do enjoy looking at the moon!

Amy, Entry 3. Okay, I've been watching for the moon, but often I can't see it. Clouds cover the sky each time I go out to search for it. One night I went out and it was clear and I still couldn't see the moon. This is really frustrating. Anyway, my group has not seen the moon for some time either. Maybe we just don't know where to look for it. My TA suggested that we look at different times, so we are going to try that. I guess I expected the TA to teach us about the moon so that, when we go out there to teach, we have somewhere to start from, but she never does. The moon is getting smaller each night, but what does that mean? My partners say it's because the Earth is starting to cover up the moon, so the moon is moving behind the Earth. But I don't think that's it. The shadow can't be covering the moon because we did this ball thing with a yardstick and we saw that the shadow would be from the sun not shining on one side! Okay, so I guess I am figuring this out a bit. Maybe this is something I could do in my class, but I still think I would need to give some background information first. Maybe it would be good to assign questions and have kids find the answers in moon books before starting the journal.

Amy, Entry 4. I think I'm starting to figure this moon thing out. Comparing the moon models in class today really helped, and my group helped me get it. I am still worried about how I am going to teach this unit to my students, especially if they don't write yet. And we've been studying this for 4 weeks. Is it really worth that much time? I guess they could draw the moon and some of their ideas. Or I could do a class journal. Plus, the discussions really helped me, and they could do that. I do think I know more about the moon now than when I started. Maybe it is worth the time.

Student's Journal: Brenda. *Brenda, Entry 1*. I'm not exactly sure why, but we're supposed to keep this journal of how class goes this semester and how we think we're growing, and so forth. I'm pretty sick of reflecting in every ed course . . . still, it does seem to help me sort out my thoughts, and it's interesting to look back and read. I'm wondering what kind of grade or points we'll get for this thing and if we have to write in it all the time. The first day seemed pretty good. We actually did stuff today, like play with these whirlycopter things. It was fun to try and figure out how they worked. We had to write out this experiment thing and include all the directions. That was the hardest part because we realized we weren't very specific. It was so neat because our group did one that no one else did—wing length. Most people did materials. We found that the longer the wing the longer it took to fall, but it spun more slowly. It was nice to be able to get up and move around and talk . . . it makes the class go faster. I think I would like to do this whirlycopter thing with my students if I teach fourth or fifth grade. I think it can only be used with older students because I don't think that younger students could ask all the questions that we did and be able to investigate them.

Brenda, Entry 2. We've started these moon-journal things and frankly I'm journaled out. Plus, we have to draw and stuff. Oh, yeah, I forgot to mention that we started learning about the moon. I like the idea of learning a lot of facts about the moon, but I thought we were supposed to be learning how to teach. So far we just keep doing "stuff." I really am not trying to be picky, because class is fun. I just don't know what I'm learning. I'm also wondering how applicable this moon thing will be. How much time do you really need to learn this? We learned about it for maybe 3 days in fifth or sixth grade . . . It seems like our time could be better spent learning about plants or something. My table did talk about this, and one girl brought up the point that maybe the reason we all feel like we don't know anything is because we spent so little time on each topic when we were in school and were overloaded with facts. I think that if a teacher focuses on just a few facts and fun activities, then the students might remember more.

Brenda, Entry 3. This moon study is really frustrating. I never learn anything in science classes! Actually the journal's not so bad, but today in class we talked forever about the moon and why it looks how it does right now. I was frustrated because so many people were talking and the TA didn't really control the discussion. It was like anyone was right and there weren't any answers. She said that's okay right now, but I think I'm going to look up some stuff so I know the correct answers to write in my journal. We're supposed to be asking questions and figuring out answers, but

how can I do that if I don't know anything to start? It is really frustrating talking about our data and the patterns, but not figuring out much. This activity would be so frustrating to elementary students. How do you expect the children to stay out at night observing the moon? This is crazy! If I am finding this activity to be very unpleasant, how unpleasant will it be for the children?

Brenda, Entry 4. Our moon journals are over, and I still don't feel like I know a lot of stuff about the moon! We never really talked about the size of the moon or what it is made of, even though those questions were in our KWL chart. All I know about the moon now is how it moves and changes. I have no idea about teaching about the moon even after reading those articles. I think younger kids would lose interest doing a moon journal. I think that 4 weeks spent on studying the moon was a waste of time. You don't need so much time on the moon. It was very monotonous doing it every night. I wonder how my TA will grade this activity? I hope she will not expect all the right answers, since our ideas from the KWL chart barely have been tackled. The whirlycopters were much more fun. I'll for sure do them.

Interpreting the Journals. During the beginning of the methods course, we often find ourselves questioning our goals for certain activities and deciding how to best use the time available. The simple whirlycopter activity is typically a success in the eyes of instructors and students alike. Then comes the long-term moon inquiry, where we experience cycles of frustration and illumination. Part of the instructor frustration comes from our own lack of experience with learning school science by inquiry, exacerbated by how we define inquiry and select our course goals. We worry about how to balance our use of course time in service of our goals. Part of our student's frustration and apprehension comes from their lack of experience with inquiry-based science, and with their own expectations for both how science should be taught and what the methods course should be about. Another source of student frustration is their self-perceived lack of science-content knowledge, which begins to generate grade anxiety. They appreciate the active class periods, but wonder if they are learning science or teaching strategies and worry about how they will be graded. These dilemmas persist into the middle of the methods course, where new dilemmas also arise.

Middle of the Methods Course

Once the moon inquiry ends, we expect students to accelerate their transition from a student perspective on inquiry to thinking like a teacher. In a 2-day Cartesian divers inquiry, students develop and test their own investigation questions as they try to figure out how the divers work. They examine how teachers can scaffold such an experience for students. Then, in a 3-day pendulum inquiry that is based on a learning-cycle approach, students see how to put together many inquiry-based teaching strategies into a coherent learning sequence for students. By the end of this sequence, we expect students to start planning their own science lessons for elementary students in a partner school. Our fictional journals tell a typical story for this part of the course.

The Instructor's Journal. *Instructor Entry 5*. This week we used a Cartesian divers inquiry to model how teachers can scaffold student-directed inquiry in their classrooms. When students saw the diver sink as the bottle was squeezed, they asked, "Why does it do that?" Rather than provide an answer, we demonstrated a process of defining and selecting testable questions (e.g., What would happen if we used different liquids in the diver?) and required the students to write an investigation plan. Teams carried out their plan and shared the results. But what makes divers different from the whirlycopters? I think it's because, once the findings were in, we returned to the "why" question and tried to relate what we found out about the divers to what we knew about sinking and floating, and developed viable explanations for the diver behavior. Of course, this also made the divers inquiry more frustrating for the students. Their understanding of sinking and floating is pretty shaky. Feelings of science inadequacy resurfaced within several groups. So now I'm back to my old worries. Is my job to help them learn the science or just the pedagogy? Can I do the latter without the former? But do I have time to do both? During the last class period, I chose to not complete all the parts of the divers activity as I would with elementary students, opting instead for, "If you were my fifth graders, we'd now take some time to . . ." Is this a cop out, or can students fit this into their inquiry teaching–learning scheme? Making decisions about what to cut out when time runs short is a continuing dilemma for me, especially when I want to focus on pedagogy, yet they seem to need more science content.

Instructor Entry 6. With the completion of the Cartesian diver activity, we moved on to a 3-day pendulum inquiry where students try to figure out the fastest way to get Tarzan across a canyon—using a short or long vine, with or without trusted friend Cheetah. My goals for this activity are to engage students with inquiry into the pendulum phenomenon and to introduce them to the learning cycle as a model of inquiry-based instruction. Since the students are going to develop and teach their own 3-day learning-cycle unit, I want to model it for them in class. Again I face the dilemma of using so much class time for inquiry, but in this case I think it is time well spent. The amazing thing was that the talk in each group picked up while they were constructing their experimental set-ups. They were posing their own explanations and trying out various ideas. They may be finally past their fear of science; at least everyone was active! But now I wonder if my modeling will help them understand the learning cycle. Sometimes I think my goal of making sense of pendulums preempts their learning about pedagogy.

Instructor Entry 7. Today in class one group was insistent that the angle of Tarzan's vine affected the performance of the pendulum. I threw it open for discussion. All the while I worried about the time this was taking and doubted my own understanding of the concept. I reached temporary closure by agreeing to look up some information and get back to them next class. I really thought it was important to take time to analyze what we had done in terms of the learning cycle. Their inquiry lesson plan first draft is due next week, and the class had many questions about what to include in their lesson plans. I'm hoping they can translate all we have done, discussed, and read about into viable lessons.

Student's Journal: Amy. *Amy, Entry 5*. Today it was fun to do the divers with two-liter bottles. We were on our feet most of the time and talking and discussing our ideas. I was surprised that when you squeeze the bottle, the dropper inside of it plunges to the bottom of the bottle, but when you release the bottle, the dropper quickly shoots up to the surface. What's the trick? Why does this happen? We talked about why this happened and thought that it may be due to the pressure (air) or the weight and gravity? Or maybe the water inside of the dropper was lighter? Our test was to change the color of the water in the diver. We could then easily see that when we pushed the bottle, the water came out of the dropper. It was fun when all the groups got together to discuss their findings. It was like putting a puzzle together—little by little we saw this picture of the diver sinking and floating and we decided that weight (or what someone called density) was a factor. What we did was just like what we read about in the chapter about planning an investigation. The readings are starting to connect to the course and help me understand why we're doing what we're doing.

Amy, Entry 6. Today we brainstormed the factors that can affect the pendulum. I had an idea of how pendulums are applied in clocks because of the grandfather clock that I grew up watching. I think elementary students will enjoy this activity too. It was interesting making our predictions and designing and carrying out the investigation to test them. But the most difficult thing was to determine what a swing was, when to begin counting and timing, and eventually drawing graphs. One girl in our team, who took Physics 151 last semester, yelled, "Why don't you give us the instructions? How do you expect us to know what to look for in our investigation?" In Physics 151, she was my lab partner and we did a similar activity, but I remember we were given a list of instructions and a worksheet to follow and that made it pretty simple and we obtained more accurate results. I like this better, even if she doesn't. I feel like I understand so much more because I have to figure it out for myself. I'm worried about the lesson plan we are supposed to start writing. I'm having fun with these activities, and think I can use this stuff with kids, but I'm not quite sure how to organize it.

Amy, Entry 7. Today we continued working on this Tarzan problem. We really are learning about pendulums, but I think that the TA used the Tarzan story to make it more interesting. We got to use all this stuff and set it up to figure out the answers. We found out that he went a lot faster if he used the short vine. That really didn't surprise me, but the cool part was that it didn't matter whether we added a ton of weight or not! It still went the same! Not what I predicted! One group set up their experiment more like the picture or something, but they got a lot of different data. It was so funny because this guy kept arguing with the TA that the angle of the vine mattered and that's why it worked that way. I didn't get everything they were talking about, so I didn't get involved, but it was interesting to listen. The TA asked what we would do as teachers if someone got different results. At first, I thought I would just say that all the other groups got the same answer, so he must have a problem. Our TA didn't seem to do that though . . . she just let it ride. So now I am thinking I would too, but I would want the students to try to figure out why the results were different. I did figure something out today, though my TA showed us how the pendulum activity

was like the learning cycle that we read about. I get it! In our units, we can start by exploring, and then come with some kind of application. I may not understand everything about pendulums, but I do think I get this learning-cycle business.

Student's Journal: Brenda. *Brenda, Entry 5*. In this two-liter-bottle thing, if you squeeze the bottle, the dropper inside sinks, and if you let go, it floats. I have no idea why, but this guy in my group said that it's air pressure. I think the answer to everything is air pressure to him. It was fun because we got to try and figure out why it did that. My group is going to try to figure out how it works if you use three droppers with different amounts of liquid in each. Of course we have Mr. Smartie in our group, and he said all of this stuff about density and pressure. But I still don't get it. I wish we'd get it right and learn something or at least have the TA teach it to us.

Brenda, Entry 6. We spent almost the whole class again working on our investigations! I'm freaking out because we have not heard anything about this lesson we're supposed to teach in, like, 2 weeks! We don't have a rubric, and the syllabus doesn't seem to explain exactly what we're supposed to do. I understand we're supposed to be getting good ideas by doing all this stuff in class, and it is fun, but shouldn't we start learning about how to teach science? I don't think we've really done a lot of that, I mean, we talk about the articles we read, but she doesn't really make us take notes or anything (not that I care), and we don't really have examples of how to do this. They really haven't given us a set way to write a lesson plan, and I'm getting a little worried. My whole group is worried. And Tarzan! How lame! Plus everyone knows weight matters.

Brenda, Entry 7. We continued the pendulum study today, the activity part was fun. My group tested length and weight. I think it's interesting they both changed how the vine worked. I knew it! He better leave Cheetah behind! At first we got the same results for the different weights, but I knew we were wrong so we fixed it. I couldn't believe how John kept arguing with the TA, and she didn't know if he was right or not. We finally went over the next assignment. I think teaching this cycle thing will be fun. There are lots of fun activities I know about from this great teacher website. Can't wait to do some of them with the students.

Interpreting the Journals. By the middle of the course, we often notice that student's fear of doing science begins to wane. We see them becoming a bit more confident with doing inquiry, and some even recognize that they can generate viable explanations based on the evidence from their investigations. The students also begin to see the pedagogical side to teaching inquiry, but it is still frustrating for them.

Our concerns about how to best use class time are exacerbated as our priorities shift. At this point in the course, we have a primary objective of preparing students for their field-based teaching that takes place concurrently with the methods course. The pressure to help students understand inquiry-based pedagogy is great. It takes astute students to see how our modeling can be applied to their future teaching, and we always feel the need to spend more time explicitly addressing pedagogical

issues. The time issue persists throughout the entire course, right up to the time when the methods students plan and implement their 3-day science units.

End of the Methods Course

By the last third of the course, the priority becomes preparing for teaching a 3-day lesson sequence in a partner school. With input from their cooperating teacher and course instructor, teaching teams select a topic, develop learning goals, and create learning and assessment activities. In addition to curriculum design, most groups spend some time making sense of the science they are preparing to teach. In the field, they team teach and individually reflect on their teaching and student learning, with feedback from the cooperating teacher and the course instructor.

The Instructor's Journal. *Instructor Entry 8*. Today in class, groups worked on the inquiry-based lessons they will be teaching next week. Plus, it is only 2 weeks until they teach their learning-cycle lessons. Where does the time go? For the learning cycle, one team wants to plan lessons on volcanoes for their second-grade class. They think volcanoes will be "fun." I am so sick of that word! Just because a model of a volcano explodes and the elementary students think it is fun does not mean that it is inquiry-based science. Some topics are more conducive to engaging students with phenomena and allowing them to develop explanations. The state standards for the second grade require students to investigate weather, the patterns in seasons, and examine earth materials. Volcanoes are not even mentioned. Another issue came up near the end of the class period while we were going over the learning-cycle assignment. Some students feel they did not have enough opportunities to understand inquiry-based instruction this semester. They are also concerned about how that lack of experience will translate into their grade for the final science unit. I thought that by using Cartesian divers, pendulums, whirlycopters, and the moon investigation that inquiry-based teaching was being modeled. I think they were focusing too much on the science and not enough on the pedagogy. How can I fix this? What else could I do to provide a more complete picture of classroom inquiry? How can I address the concern they have about their grades?

Instructor Entry 9. I held unit-plan conferences today during class time. That one group still wants to present a unit on volcanoes using an activity they found on the Web. The cooperating teacher in their field-experience classroom has a volcano chapter in the science textbook and encouraged them to pursue the activity. The students were well prepared with a copy of the lesson plan and the book borrowed from the classroom teacher. I repeated my concern that their lesson was not inquiry based: It did not engage students with scientifically oriented questions or give the students an opportunity to give priority to evidence in developing explanations. I asked them where their unit was hands-on, minds-on, and engaged the children with phenomena. I then asked them what standards support the teaching of volcanoes in a second-grade lesson. I'm not sure how volcanoes could be taught in an inquiry-based manner, but they are definitely NOT doing it. If I don't know if I have the expertise to figure it out, how will they? After the unit-plan conference, a member of the

volcano group e-mailed me to say they were changing their unit topic to erosion and that it was all right with the cooperating teacher. I am eager to see what they come up with. I think they're mad at me but just gave in to get the grade. I hope after all is said and done, they learn something about the difference between planning lessons and planning inquiry lessons.

Instructor Entry 10. The students are teaching their inquiry lessons this week at the field-experience site. I went to the school site to observe them. The erosion group started with a KWL chart to find out what students knew; they got some really good questions from their second-grade students. Then they got the stream tables going and students explored what happened with different amounts of water. The teaching group seemed pleased with the interest level in the class and the degree to which students actually talked about their ideas. Maybe inquiry is starting to make more sense to them.

Student's Journal: Amy. *Amy, Entry 8*. Today we looked at some lessons. I was surprised planning a lesson is so demanding. Objectives need to be clearly stated and achievable; a lesson should have all the necessary concepts and activities, methods, and assessment strategies. I guess, with time, I will develop the skill. But it is tough making these lessons inquiry based. I hope this pays off.

Amy, Entry 9. We began teaching our inquiry lessons today. Children were knowledgeable about swings and were very eager to do the activity. We identified factors that affect the swing of a pendulum and children began their investigations. Children had a problem in counting the number of swings. However, because we spent a lot of time in planning, we did not finish the activities we had planned to do for the day. It was frustrating that we did not achieve our objectives for the day. The teacher said she would let the students finish tomorrow, so, when we come back, they'll be ready. We met with the instructor about our learning-cycle lessons. She really likes our magnet lessons and thinks we did a great job planning. I hope the students like it!

Amy, Entry 10. Our learning-cycle lessons on magnets went well. The kids had a lot of fun playing with the magnets the first day and figuring what sticks and what doesn't. I think they figured out that it wasn't just metal, but certain kinds of metal. I was surprised at how they figured stuff out. It was kind of cool to hear them talking to each other about why they thought stuff, but it was crazy to have them all talking at once. But the discussion helped so many of the students understand, so I would do it again. The journals we had them do didn't work very well. They ended up being too hard to manage. I think we could have done better if we just had them talk about what they thought, but then it's hard to get individual ideas. But the journals just took too much time. Yet, I know it's important for them to use these to work out and express their ideas. Maybe the problem was our limited teaching time? I bet this will work when I have my own class if I simplify the journals a little. This is the last week to write in our journals. I think that I've learned a lot this semester. I have a lot of good stuff to do with my students, like our moon journal, electricity stuff, Tarzan, magnets, and sink-and-float stuff. If I get a job teaching younger grades, I know I won't have as much time to teach science,

but at least I have some ideas about science stuff to do that isn't just textbook and vocabulary.

Student's Journal: Brenda. *Brenda, Entry 8*. Okay . . . we went over the lesson plan stuff today and are starting to design our first inquiry lesson. But why do we have to do all this? The lesson plan was like 100 pages long. Will I ever do this when I am teaching? I don't think it is necessary to have everything in the lesson. My group is okay. For our learning-cycle unit, we're supposed to teach about earth science, and I want to do some real fun activity because we are working with second grade. I'm not sure that they are able to do much, but if we find a fun activity, then they would be more focused. Again the instructor said we have to do activities that really make them think. That's why I think it is a good idea to do volcanoes and have the kids make volcanoes that blow up. We did that in school, and I still remember it.

Brenda, Entry 9. We had our meeting with the instructor today about our unit plans. Afterwards, my volcano idea was vetoed by my group. I know that we're supposed to do this "inquiry" thing with productive questions, but I'm really not sure how practical it is. My teacher at the elementary school really liked the idea of volcanoes, and I'm a little upset that my instructor can say that it won't work and then the group agrees. I still don't really get why—our lesson was fine, and we had inquiry questions. I think that the kids would do a lot of thinking about how volcanoes work, and I know they would be interested. And if they're doing science, aren't they learning it? That's all I'm going to write today.

Brenda, Entry 10. We taught our unit lessons on Earth science. We did a lesson on erosion. It was fun! The kids used big stream tables to figure out what would happen as we poured water down each one. We did the pouring, but it was fun to see the kids get so excited about having their predictions work out! Kids asked a lot of questions whose answers I didn't know. I was just not prepared. Next time I teach this, I would be better prepared to answer their questions and we wouldn't have to do so many investigations. Maybe you could do a whole unit on Earth science and erosion, earthquakes, volcanoes, and so forth. Then I could get my volcano lesson in! No more journals!

Interpreting the Journals. As students make their final transition from thinking about inquiry as students to thinking like teachers, their constructions of inquiry come to the forefront. We discover how effective or ineffective we have been at modeling inquiry and at helping students understand inquiry-based pedagogical strategies. Sometimes we are disheartened by students who change their lessons only to please us. We know once they leave our course, they will switch back to viewing activities, such as making a volcano model, as inquiry. Other students amaze us by the degree to which they have internalized what it means to learn and to teach science through inquiry. These students have the potential to change the way science is taught in elementary schools. By the end of the course, we are left with our own dilemmas of how to balance our use of class time as we balance our learning goals for both science content and science pedagogy. These dilemmas of student learning

and our own teaching push us to reconsider our teaching for the next time we offer the course.

Discussion

Through our team meeting discussions, we established seven dilemmas of teaching inquiry in the methods course and then developed the fictional journal entries to portray them. The seven dilemmas are: (a) varying definitions of inquiry, (b) our struggle to provide sufficient inquiry-based science-learning experiences, (c) perceived time constraints, (d) determining how much of our course should be slated for science instruction versus pedagogy instruction and instructors' and students' lack of inquiry-based learning experiences, (e) grade versus trust issues with our students and our students' sciencephobia. In the following section, we summarize dilemmas and discuss how we have attempted to deal with them within our elementary methods course.

Varying Definitions of Inquiry

The definition of inquiry has a "decades-long and persistent history as the central word used to characterize good science teaching and learning" (Anderson, 2002, p. 1). However, the definition of inquiry in science education is dynamic and context dependent. Moreover, if one frames inquiry within a constructivist paradigm in which reality is a socially and experientially constructed entity and its form and content depend on those who hold the construction (Lincoln & Guba, 2000; Schwandt, 1997, 2000; von Glasersfeld, 1996), then a larger dilemma looms. Each instructor and each student will construct his or her own working definition of inquiry. While certain components of inquiry appear common to the instructors, this dilemma loomed large for the students and provided them ammunition for dismissing inquiry as valid in science teaching and learning. In addition to lack of agreement in the literature, each instructor of the course teaches by using his or her own working definition of inquiry. Members of the team have held lengthy discussions about the importance of certain inquiry components, such as the need for student developed investigation questions. Ultimately, for each of us, there are components of inquiry that are non-negotiable and others that vary in importance based on the context of instruction. For example, Hubbard felt inquiry required that the students participate in the development of the question being investigated, while Newman felt that the teacher could provide the question as long as the students participated in the development of the methods used to answer the question. For him, this was especially true in classrooms where time and curriculum constraints limited the investigation. One non-negotiable component we all agreed on was that inquiry requires the students to use evidence to formulate explanations.

We have addressed this issue via multiple routes. The first solution was to provide the students multiple readings on inquiry, including sections of the standards

(Ash & Kluger-Bell, 1999; Bloom, 2000; Colburn, 2000; Kluger-Bell, 1999; National Research Council, 1996, 2000; Whitin & Whitin, 1997). These readings and ensuing class discussions allow the students to examine multiple perspectives on inquiry and often help them when planning lessons because they can determine which stance they feel most comfortable using. In addition to science talks (Gallas, 1995; Lemke, 1990), we hold pedagogy talks. These provide the students opportunities to develop an understanding of inquiry-based pedagogy in a similar social framework to the talks in which they develop and express much of their science understanding. These thought-provoking discussions are often linked to reflections that students write expressing their ideas on inquiry-based lessons. These reflections help the students construct a personal working definition of inquiry. Another route for addressing this problem is through lessons on the nature of science. Using black box activities, demonstrations, articles, and discussions, we expose the students to multiple aspects of the nature of science, including the idea that science is done through many different approaches. By helping the students realize this, we are able to utilize an analogy for inquiry-based instruction: If there is more than one way to do science, there can be more than one way to do inquiry.

Sufficient Inquiry-Based Science-Learning Experiences, Time Constraints, and Science Instruction Versus Pedagogy Instruction

These three issues are so intertwined that they require simultaneous consideration. As instructors, we feel an obligation to provide time in our course for inquiry-based science learning; yet, the focal point of the course is science pedagogy and not science instruction. Moreover, it would be impossible to provide the students multiple extensive experiences with inquiry-based learning in a one-semester methods course. Analogously, the students cannot teach multiple extensive inquiry lessons during their field-experience component. Because our students' lack of experience with inquiry and desire to learn more science, we slate several weeks of the course for modeling the teaching of inquiry-based science. Yet, we struggle with what the focal point of those weeks should be, pedagogy or science. A conundrum develops: How do we teach the pedagogy if students do not understand the science, but how do we teach the science if they do not understand the pedagogy? In other words, we cannot be successful teaching the pedagogy through modeling, because students get so wrapped in the student-based perspective of science learning that they miss the pedagogy, which is the content we desire them to learn. On the other hand, if we try to teach them science through inquiry-based methods and they do not understand the methods, they often feel they have learned no science because they have not memorized facts and taken tests.

One of the most significant changes to our course is that we have increased the amount of time devoted to field experiences without decreasing on-campus time. A separate field-experience time is scheduled as part of a block of classes, including literacy and math methods. This system allows us more class time to

conduct investigations with our students and discuss the related pedagogy. This also provides the students more time with children and more flexible teaching schedules; if their lessons do not progress as originally planned, they can make adjustments changes for the next field-experience time.

We also model inquiry at multiples levels and in stages. For example, the whirlycopter activity introduces students to the idea of planning and carrying out investigations while the Cartesian divers activity provides a more intense inquiry experience. The moon study demonstrates an extended inquiry with a strong focus on explanation and evidence. The pendulum provides an example of a lesson sequence template that can be used in their own plans for elementary students. Finally, we have made concerted efforts to be more explicit about the pedagogy while teaching all inquiry lessons.

Instructor's and Students' Lack of Inquiry-Based Learning Experiences

We, the methods instructors, did not learn school science through inquiry. This lack of experience raised the dilemma: Can teachers not taught using inquiry effectively teach using inquiry? Fortunately, the instructors have had adult experiences learning science through inquiry. Some of us have had summer experiences with companies conducting science research, some have participated in National Science Foundation teacher institutes research programs, and some have had graduate level experiences with science research. Thus, although we were not educated in schools via inquiry methods, we have adult inquiry-based learning experiences and, thus, feel somewhat comfortable teaching other adults science in a similar manner.

However, most of our students have little or no experience learning science through inquiry. This problem connects to the dilemmas of time and pedagogy versus science recounted earlier. It is obvious that we must provide inquiry-based learning opportunities as described above. However, there is another underlying problem: Our students often view inquiry lessons as weak and lacking science content because they cannot always identify what science concepts are learned from the experience. To help address this problem, we have the methods students write final reflections after some of the inquiry experiences to help them connect content learning to inquiry-based learning. The form of these reflections is a function of the instructor's desires, the students' needs, and the classroom experience with inquiry. We have effectively used the following reflection journal forms: open-ended (students' choose what to write about), teacher directed, student directed based on class discussions, and guided (students select from a list of teacher questions). We also require our students to include science-content learning objectives and a detailed explanation of their understanding of the science content in their lesson plans. This helps them to connect, from a teacher's perspective, science content with inquiry-based instruction.

Grades Versus Trust Issues and Sciencephobia

Having been taught science in the didactic orientation of "right" answers and objective testing, our students do not trust us when we ask them to write and teach inquiry-based lessons. They worry that their grades will be affected negatively by their lack of science-content knowledge. They struggle to find a balance between providing facts for their students and providing opportunities for the students to make sense of concepts through investigations. Moreover, because they have no reference frame from which to work, our students want to know "what I have to do to get an A in this course" and struggle when their own investigations do not provide what they view as the "correct answers." They get upset with instructors who do not tell or confirm the right answer. Accordingly, the assessment component of their lessons often involves participation and no assessment of content knowledge.

This problem is compounded by their sciencephobia. Many students enter the methods course with a fear of and disdain for science. When we teach using inquiry, they are further removed from their educational comfort zone and, thus, often express that they "cannot learn science this way." They want to know what facts to memorize and then take a quiz. Addressing our students' sciencephobia is difficult, but important, in a methods course.

In the syllabus, we now include grading rubrics with all major assignments. Many of us ask the students to evaluate themselves prior to turning in the assignment to help them understand our grading policies. We have also created a sample lesson plan that the students evaluate as a homework assignment early in the course. This has greatly reduced the students stress about the first major grade in our course. We have added statements regarding evaluation to the moon unit. In those statements we stress the importance of using evidence to substantiate their points and showing progress in understanding, as opposed to stressing "correct" understanding of the moon processes. Additionally, this helps alleviate some of the sciencephobia issues because they no longer need that "correct" answer to be successful. The early classroom experiences, such as the whirlycopters, can also lessen sciencephobia because the students are successful from the start.

Conclusion

Understanding what happens in a science methods course is an important step in creating a successful teacher education program. If we expect our students to teach inquiry-based science, we need to examine how we teach inquiry. The work reported here leads to research on understanding how students perceive challenges to teaching inquiry and how they make the transition from the method course to student teaching and beyond in terms of inquiry-based instruction. For example, Newman is currently conducting a research project on our former students' abilities to teach using inquiry in their own classrooms and how they relate those experiences back to their methods instruction. And most important, the opportunity for us to work as

a team to consider and reconsider our teaching of inquiry has been critical to our development as science teacher educators.

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