

# Beyond Concepts: Transfer From Inquiry-Based Physics To Elementary Classrooms

Danielle B. Harlow and Valerie K. Otero

*249 UCB, School of Education, University of Colorado, Boulder, CO 80309*

**Abstract.** Physics education researchers have created specialized physics courses to meet the needs of elementary teachers. While there is evidence that such courses help teachers develop physics content knowledge, little is known about what teachers transfer from such courses into their teaching practices. In this study, we examine how one elementary teacher changed her questioning strategies after learning physics in a course for elementary teachers.

**Keywords:** Physics Education Research, School Science, Elementary School Science, Teacher Training.

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## INTRODUCTION

It is increasingly evident that PER does and will continue to play an important role in the education of teachers at all levels [1]. One indication of this is that PER researchers have developed multiple inquiry-based curricula with elementary teachers in mind [2,-4]. These curricula use guided inquiry activities to facilitate teachers' conceptual development of physics ideas and model desired teaching strategies. Furthermore, they align with recommendations of how to best prepare K-12 teachers which suggest that teachers should have the opportunity to learn science in the ways they will be expected to teach [5].

Evidence supports that inquiry-based curricula result in greater learning gains on tests of conceptual understanding [6] and that such courses lead teachers to be more open to the prospect of teaching by inquiry [7]. However, little has been done to understand what teachers actually transfer from such courses into their teaching practices. Understanding the usefulness of inquiry physics courses such as those developed by the PER community requires investigating what teachers actually *do* when teaching science to elementary students.

We investigate how the Physics for Elementary Teachers (PET)<sup>1</sup> curriculum impacts elementary classrooms. Participants in a professional development course adopted from PET were video taped teaching science and interviewed both before and after taking

the course. We examined the data of one teacher to identify aspects of the physics course that she may have transferred. Here, we describe how the course impacted one aspect of her teaching practices: the types of questions she asked her students.

## Questioning as a Teaching Practice

Harlen [8] categorized teachers' questions as either productive or unproductive with respect to science learning. Productive questions are those which lead to scientific activities such as observing, describing and explaining observations while unproductive questions lead students to looking for answers in books or from their teacher. In elementary classrooms, students begin to acquire ways of doing science and thinking about science. When teachers ask questions which prompt students to *do* something or to reflect on their own personal experiences, they promote a view of science as a way of knowing and as something that connects to their students' own experiences rather than as a collection of facts that are found in books. Unfortunately, the vast majority of teacher questions lead students to recall or look up science ideas in books or other secondary sources. In the analysis that follows, we present evidence that after taking a physics class, one teacher changed her questioning style to one which promoted science as a way of knowing rather than as a collection of facts.

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<sup>1</sup> Physics for Elementary Teachers has recently been renamed. This curriculum is now "Physics and Everyday Thinking."

## DATA AND ANALYSIS

The participants in this study were practicing K-5 teachers who enrolled in *Magnetism and Electricity for Elementary Teachers* (MEET), a 15-hour professional development course adapted from the *Physics for Elementary Teachers* (PET) curriculum. Five participants were videotaped for the entire course and were also videotaped teaching science in their elementary classroom both before and after taking MEET. In this paper, we focus on Ms. Doty whom we chose as the initial case study teacher because she was an excellent and enthusiastic science teacher who expressed apprehension at the prospect of teaching magnetism and electricity topics.

At the time of the study, Ms. Doty had been teaching elementary school for 12 years. During the initial interview, she claimed that she struggled with teaching science because of her lack of science knowledge, but that, despite her low levels of confidence, she enjoyed teaching science. Like many teachers in her district, she relied heavily on the district created science kits which contain materials and instructions for science activities and relevant science literature for students to read. Ms. Doty typically completed four kits a year (each kit took 2-3 weeks to complete) and was comfortable teaching with the kits she regularly used. This year, however, Ms. Doty moved to a new grade level (3<sup>rd</sup>/4<sup>th</sup> combination) and was expected to teach topics in magnetism and electricity for the first time. She claimed not to know anything about either topic and did not know where to begin figuring what to do on her own.

Data about Ms. Doty's teaching and learning were collected in three stages. First, she taught two representative science classes prior to beginning MEET. In these lessons, she used a science kit entitled "The Web of Life," in which students studied how living organisms depend upon one another. In the second stage of data collection, Ms. Doty was observed as she learned about magnetism and electricity in MEET. Finally, after taking MEET, she taught two lessons based on the topics covered in MEET. In her previous 12 years of teaching, Ms. Doty had taught neither magnetism nor electricity. She chose to teach a unit on magnetism.

All pre and post observations were analyzed to determine questioning patterns before and after MEET. First, all *teacher questions* were identified in the transcripts of the pre and post observations of her science teaching. A statement was determined to be a *teacher question* if it appeared that the student(s) interpreted her statement as one that required a verbal response. This was indicated by the student(s) actually providing a subsequent verbal response. All *teacher*

*questions* were further examined to identify the purpose of the question. Questions were first categorized as either questions about science (SCI) or questions asked for the purpose of classroom management (such as making sure that students understand directions or checking to see how far along they are). The questions about science were further differentiated by the source that the students drew on to answer the teacher's question: Secondary Sources (Sci-SS), Science Experiences (Sci-SE) or their Own Ideas (Sci-OI) as shown in Table 1. We used only the three types of *science questions* in the analysis.

**TABLE 1.** Coding Scheme – Science Questions

Code	Description	Examples
Sci-SE	<b>Science Experiences:</b> Students either do something or reflect on prior experiences to answer SE questions.	<ul style="list-style-type: none"> <li>• Does that magnet work in water?</li> <li>• Have you ever left bread out for a long time? What happened?</li> </ul>
Sci-OI	<b>Own Ideas:</b> Students use their own thoughts and creativity to answer OI questions.	<ul style="list-style-type: none"> <li>• What do you think is happening inside the magnet?</li> </ul>
Sci-SS	<b>Secondary Sources:</b> Students draw upon secondary sources such as books or the teacher to answer SS questions.	<ul style="list-style-type: none"> <li>• Does anybody remember what the word hypothesis means?</li> <li>• How many species of turtles are there?</li> </ul>

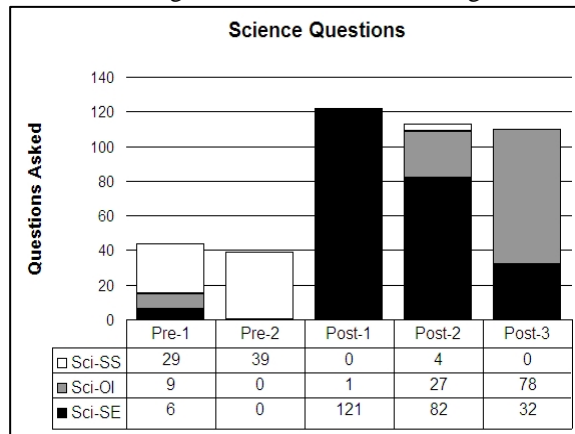
Questions were categorized by taking the context and the students' response into consideration. For example, the students in this classroom study had previously studied anoles (a lizard) and had observed a pair of living anoles in their classroom. The teacher question, "What do anoles eat?" would be a SE question if the students were expected to draw on their observations of their classroom anoles. However, this same question asked in a context in which the students are expected to look up the information on a fact sheet would be considered a SS question.

## FINDINGS

The results of coding the five observed lessons are presented in Figure 1. Pre-1 was an experiment about decomposition and Pre-2 was the cumulative activity of a life science unit. Post 1 was an experiment about magnetism and Post-2 and Post-3 were the cumulative lesson in magnetism, which spanned two class periods.

In a post interview, Ms. Doty stated that one thing she had changed about the way she taught after taking MEET is that she let the students do more of the talking. This is supported by the increase in the number of science questions she asked her students.

Figure 1 shows that Ms. Doty asked an average of 112 science questions during the post observations (Post-1, Post-2, and Post-3), more than twice as many questions as she asked during the pre observations (Pre-1 and Pre-2) which averaged 42 science questions per class meeting. This observation alone is important because it implies that Ms. Doty collected more information from her students and allowed them to talk more during science lessons after taking MEET.



**FIGURE 1.** The frequency and types of science questions asked by the teacher during each observed science lesson.

Figure 1 also provides evidence that Ms. Doty asked different types of science questions during the post observations than during the two pre observations. Ms. Doty's two pre lessons were dominated by questions that asked students to draw upon secondary sources. In contrast, during the post observations she asked students to draw on their science experiences and their own creativity almost exclusively. Following, we describe this difference in more detail.

#### *Pre-Observation Questioning Style*

In her initial interview, Ms. Doty claimed that she liked for her students to be able to figure things out on their own. However, she also expressed an understanding of science as vocabulary and as a collection of facts that are obtained by authority. When talking about why she liked to teach with district-created science kits, Ms. Doty stated, "[The kits] give you the vocabulary. And I think you have to have that entire knowledge." Furthermore, when Ms. Doty described a science lesson she created, it was heavily literature based: students used encyclopedias to gather information about the planets.

Her two lessons prior to MEET reflect this conflict between wanting to let students figure things out and needing for students to know science vocabulary and facts. During Pre-1, Ms. Doty's students buried dead

crickets in wet and dry soil to compare which crickets decomposed first. Despite the experimental nature of the activity, 66% of the science questions Ms. Doty asked her students represented science as a collection of facts and terms. She began the lesson by stating that the main topic of the day was decomposition and asked if anybody knew what the word meant. After her students suggested answers, Ms. Doty concluded, stating, "We've been working on using our dictionaries and I wanted you to see that teachers use dictionaries as well." She then read the dictionary definition. A similar pattern of discussion occurred throughout this lesson.

Furthermore, although the students spent two weeks observing live organisms in their classroom, the cumulative activity (Pre-2) for the unit emphasized science as a collection of facts. The students used books and fact sheets to create posters which summarized interesting facts about lizards, crocodiles, snakes and turtles. Ms. Doty moved between groups asking about what they had learned. At one group she asked, "What type of food do snakes eat?" The students offered many answers including "wild boars," "eggs," "anything with meat in them," and "dead snakes." After the students answered her question, Ms. Doty responded, "Sara, do you want to read – it's right here, guys {points to fact sheet} -meat eating strategies- what do they eat? Lizards, birds, what's that one right there – that should be in your garden what's that i-word right there?" to which Sara responded "insects." Ms. Doty wanted her students to read the answer from the fact sheet and her question successfully motivated this activity.

#### *Post-Observation Questioning Style*

After the post observations, Ms. Doty claimed that, during the magnetism lessons (Post 1-3), she tried, for the first time, to teach without telling her students everything because, "I just think you learn so much better when you do figure it out for yourself. That really made sense to me. [Before MEET] I was against that idea so that's kind of funny. It was like 'oh no they have to- I have to give them all the information in the end. They have to know.' Well they're not going to remember if I do give it to them."

The data collected during post observations support the claim that Ms. Doty was letting her students figure things out because the majority of her questions were about her students' ideas and experiences rather than about ideas they learned from secondary sources. During lesson Post-1, the students in Ms. Doty's class conducted experiments at stations and Ms. Doty circulated around the room asking students what they were discovering and asking them questions to prompt further investigation. Ms. Doty asked 122 science

questions during this lesson, more than any other observed lesson and 121 (99%) of these were coded as Sci-SE, indicating that Ms. Doty was encouraging her students to use their own science experiences to answer questions. She appeared to value their contributions, saying things like, “I’m curious about something you said there” and asking them to elaborate on their own ideas.

The second lesson was the final activity of the magnetism unit and spanned two class periods, (Post-2 and Post-3). The students magnetized a nail and observed that the magnetized nail attracted paperclips. They then drew, described, and refined models of what they thought made the magnetized nail different than an ordinary nail. Ms. Doty asked students to share their thinking and suggested ways they might test the alternative models presented.

Of the 223 questions that Ms. Doty asked of her students over these two class periods, only four (2%) were coded as Sci-SS, and 219 (98%) were coded as either Sci-SE or Sci-OI. Unlike the final activity of the Web of Life unit, this lesson asked students to draw upon and develop their own ideas to answer the vast majority of their teacher’s questions.

## DISCUSSION

The evidence presented here points to a substantial change in Ms. Doty’s questioning strategy. Initially her science questions asked her students to draw largely on secondary sources. After MEET, Ms. Doty asked questions which prompted students to *do* science or reflect on their experiences and own ideas to answer her questions. The primary goal of MEET was for teachers to develop a conceptual understanding of magnetism and of current electricity. The *teaching* of magnetism was not explicitly addressed in MEET. Yet there is reason to believe that Ms. Doty transferred aspects of the course pedagogy into her teaching of elementary school science.

In MEET, Ms. Doty and her classmates collected and interpreted evidence through laboratory and computer activities and developed a simplified domain model of magnetism. Throughout the course, ideas were expected to be supported with evidence collected during experiments rather than by outside sources. As a learner, Ms. Doty initially found it frustrating to not be given the correct answer; however, her experience in the course led her to attempt this same method in her own teaching. In her final interview she stated that without having had the experience of developing a model of magnetism on her own she would not have risked asking her students to do the same. Furthermore she stated that she learned in MEET that teaching

science “is about letting the kids do the work, letting the kids do the experiments, letting the kids figure things out and you just figuring out ways – how are you going to guide this particular class.” This idea is reflected in her change in questioning style.

## CONCLUSIONS

Understanding what teachers actually do in the context of teaching science in their elementary classroom is vital to understanding what teachers take away from our courses and how they use it in their teaching. The teacher described here transferred an important aspect of the course pedagogy: asking students to draw upon science experiences to make sense of the world rather than looking to other sources of authority.

## ACKNOWLEDGMENTS

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