

Uncovering the Hidden Decisions that Shape Curricula

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Abstract. Developing explanatory models is a central practice to scientific inquiry. When students create and test explanatory models for scientific phenomenon, they develop content knowledge, knowledge of the nature of science, and creative thinking skills. Unfortunately, such instruction rarely occurs in K-12 science. This is, in part, because teachers do not have the opportunity to develop sophisticated understandings of the process of modeling, but also because teaching in this way requires teachers to make real-time instructional decisions that are responsive to students' ideas. This is challenging for teachers, especially because this decision process is often invisible. In this talk, I will highlight the importance of providing opportunities for sophisticated science thinking for our youngest learners and consider how uncovering the decisions that shape physics courses for teachers may benefit their future students.

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INTRODUCTION

Now, more than ever, it is imperative that we attend to how our youngest learners are taught science. A recent longitudinal study found that self-reported interest in pursuing a career in the sciences in 8th grade is a significant predictor of whether or not that student will be working as a scientist at age 30. [1] This means that students' experiences prior to the 8th grade are critical to recruiting science, technology, engineering, and mathematics (STEM) professionals. Unfortunately the science experiences of elementary students are limited. A study of teachers in California found that only 20% of participating teachers reported spending more than one hour of class time on science per week – and 16% reported not spending any time on science at all. [2] What happens during the limited class time devoted to science may be shaped by the undergraduate science courses elementary teachers enroll in as part of their content training prior to or concurrently with a teacher education program.

Teacher Preparation

In considering what we want future elementary teachers to learn in our physics courses and the best methods of teacher content preparation, we must first consider what we want *their* future students to learn.

Prospective elementary school teachers who begin their undergraduate program in the fall of 2010 will

earn their teaching credential in the year 2015 and begin teaching children as young as 5 years old. That child will then graduate from college in the year 2032. When we prepare teachers, we are preparing them to prepare children to live, work, and vote in the 2030's and beyond.

Technology is changing at an unprecedented pace and it is difficult to predict the technology of 5 years into the future, let alone 20 years into the future. Today's elementary school students will be using technologies that do not yet exist to solve problems we have not imagined. This makes it difficult to determine what exactly children and thus their teachers will need to know.

Creative Thinking & Model-based Instruction

In an environment where information is everywhere, learners do not need to be collectors of information, but to develop the skills and habits of mind to create new knowledge, evaluate ideas, and use ideas flexibly to solve novel problems. In science courses that devote time to discussing the nature of scientific inquiry, creativity is discussed as part of the scientific process. But we may not pay enough attention to how to help children develop creative thinking, or how to help teachers help children develop these skills, or even what it is.

While there are multiple definitions of creativity, a widely accepted description is that creativity is a process that leads to ideas that are both novel and

appropriate. [3] In other words, creativity is not limited to divergent thinking or the ability to construct something unusual. Creativity also requires the ability to evaluate and select among competing ideas. Successfully developing ideas that are novel and useful within a domain requires significant domain specific knowledge and the ability to apply that knowledge flexibly. [4] [5] Unfortunately, despite the growing need for creative thinkers, scores on tests of creative thinking have been steadily dropping, especially among elementary school students. [6]

Engaging students in the scientific process of developing, testing, and revising explanatory models of scientific phenomenon is a promising instructional strategy. Through this process, students participate in the process of creating new science ideas while adding to their content knowledge, developing knowledge of the process of science and developing greater epistemological understanding. [7-9]

In the past, young children were not expected to participate in the process of scientific model building. However, we now know that young children are capable of much more sophisticated reasoning than previously thought. [10,11] Yet, model-based instruction is still rarely observed in K-12 education.

One reason for this is the current state of elementary science education. Math and literacy assessment requirements have reduced the time allotted to science instruction. [12] Other explanations relate to the content and pedagogical training of K-5 teachers. For example, many elementary school teachers have not had the opportunity to develop a sophisticated understanding of the nature of scientific inquiry. [13] It makes sense that engaging students in science instruction that aligns with scientific inquiry is difficult if the teacher does not first understand what constitutes inquiry. It is also well documented that teachers tend to teach as they were taught, [14] so it is not surprising that teachers who learned science content through traditional instructional methods tend to use these same methods when teaching. However, in the following section, I want to consider the teachers that *do* go through reformed-based physics curricula and difficulties teachers may face even after learning science in the very ways we would like them to teach.

FROM LEARNING TO TEACHING

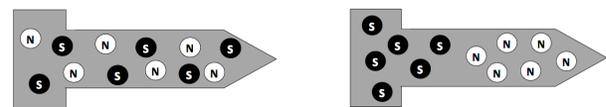
Model of Magnetism in PET

The model of magnetism series of activities in the Physics and Everyday Thinking (PET) curriculum [15] guides learners through the process of developing,

testing, and revising a model of to explain magnetism. PET is an introductory undergraduate conceptual physics course originally designed for an audience of pre-service and practicing elementary school teachers. Like many other curricula, PET development was guided by a large body of research from physics education research, science education, psychology, and cognitive science.

In PET, learners develop physics understanding through hands-on and computer-based activities and small group and whole class discussions. During the magnetism unit of PET, the learners proposed and developed models of magnetism that explained why an iron nail that had been rubbed by a magnet behaved differently than an iron nail that had not been rubbed by a magnet (a nail that has been rubbed by a magnet will act like a magnet while a nail that has not been rubbed by a magnet will act like a non-magnetized piece of ferromagnetic metal).

The learners are then asked to propose a model that accounts for their observations of the rubbed and unrubbed nail. Initially, many adult learners propose the charge separation model of magnetism [16]. The charge separation model of magnetism hypothesizes that there are entities of two types (labeled N and S in Figure 1, but many students label these + and -) that are randomly arranged in an unrubbed nail. Rubbing the nail with a magnet organizes the entities so that one type is at the tip and the other is at the head.



Unrubbed (non-magnetized) Rubbed (Magnetized)
Figure 1. The charge separation model of magnetism is a common idea proposed by undergraduates to explain observations of magnetized and non-magnetized nails.

While the charge separation model of magnetism does not align with the scientifically accepted domain model of magnetism, it is a good initial model. It accounts for all the observations thus far and provides a mechanism for the observed phenomenon. The curriculum then poses the question of what will happen when the rubbed nail is cut in half. The charge separation model predicts that cutting the nail in half will result in two monopoles, which subsequent observations challenge. When the students observe that each half of the cut nail, in fact, acts as a smaller bar magnet, learners are prompted to revise their model. By the end of the unit, they come to the consensus that there are tiny magnets in nail that are randomly arranged in an unrubbed nail. Rubbing the nail causes these tiny magnets to line up so that the north ends all point in the same direction (see Figure

2). This, in fact, is a simplified version of the scientifically accepted domain model of magnetism.



Unrubbed (non-magnetized) Rubbed (Magnetized)

Figure 2. The "tiny magnets" model of magnetism.

This series of activities is often a very powerful learning experience. Learners develop ideas about magnetism and experience the process of developing and revising models. And since the students propose the ideas that emerge during the class, they also learn that they are capable of developing sophisticated science ideas *on their own*.

The instructor does not provide direct instruction at any time. It is important to note, however, that the activity depends upon the assumption that students will initially predict the charge separation model of magnetism. Research and experience show that this is a reasonable assumption to make.

The Model of Magnetism for Elementary Students: A Tale of Two Teachers

Observations of practicing K-5 teachers who have enrolled in PET reveal that teachers often try to adapt the model of magnetism activity for their elementary school students in unanticipated ways. For example, one teacher, Ms. Shay had her 2nd grade students observe the behavior of rubbed and unrubbed nails and then asked them to draw models of how the objects differed. The 2nd graders proposed a variety of models, most of which involved the magnet "activating" something inside the nail. Ms. Shay then magnetized a nail and asked students to predict what would happen when the nail was cut in half. This test neither challenged the students' thinking, nor did it prompt them to revise their models because it was not an appropriate test of the models the children proposed.

Ms. Shay is not unusual. In fact, the cutting the nail aspect of the activity is such an important part of the activity to the teachers that many refer back to the series of activities as the "cut-the-nail activity." Looking carefully at the actions of the instructor and curriculum, it is not surprising that Ms. Shay and other teachers may not recognize that cutting the nail is *in response* to the model proposed by the learners in PET. In fact, the responsive action of the curriculum is hidden from the learners. The learners do not know that the curriculum developers *anticipated* that they would propose this particular model. When students initially propose the charge separation model of magnetism, instructors of PET may ask for students to explain their model more fully and inquire about

aspects of their model (e.g., "So you think there are positive things in the tip and negative things in the head, what do you think is between them?"), acting as if this was the first time they had seen such a model. This process has instructional value in that it helps students articulate their thinking and make their ideas visible to their peers. And yet, the question of what happens once the nail is cut in half is clearly a prepared question – it is, after all, in the printed curriculum. To the learner's perspective, it would be reasonable to conclude that predicting and testing what happened when the rubbed nail was cut in half would challenge *any* model they happened to propose.

Additional insight can be gained from a second teacher, Ms. Carter, who adapted the activity in such a way that her third and fourth grade students *did* have the opportunity to test and revise their models. Ms. Carter's students rubbed some nails with a magnet and observed that the rubbed nails acted like a magnet while the unrubbed did not. She then asked them to propose models to explain this behavior. When one student proposed that magnetic dust was transferred from the magnet to the nail thereby magnetizing it, Ms. Carter asked that student to predict what would happen if she rubbed the dust off of the nail with her fingers. The student predicted the nail would no longer be magnetized. When she tested this prediction, she found that the nail was still magnetized. This prompted the third grader to revise her model (for more details, see [17]).

Understanding the changes Ms. Carter made to the lesson make the decisions that go into developing curriculum visible. Figure 3 depicts the events of the PET series of activities and those of Ms. Carter's instruction at various levels of detail. Students' actions that differed from those in PET and the changes Ms. Carter made to her instruction in response are in grey boxes. That these changes were necessary to preserve the scientific processes engaged in by the students make visible the improvisational nature of teaching.

DISCUSSION

Like the process of developing new scientific knowledge, teaching is a creative process that requires flexible knowledge and adaptive expertise. While the contrast of Ms. Shay's and Ms. Carter's instruction discussed above highlights only one instructional decision, constructivist classrooms require teachers to continuously improvise and make decisions as they respond to students' ideas. [18] Unfortunately Pedagogical decisions in the curricula that model instructional methods are often not apparent to teachers. Making the decisions that inform the development of curriculum and the research that

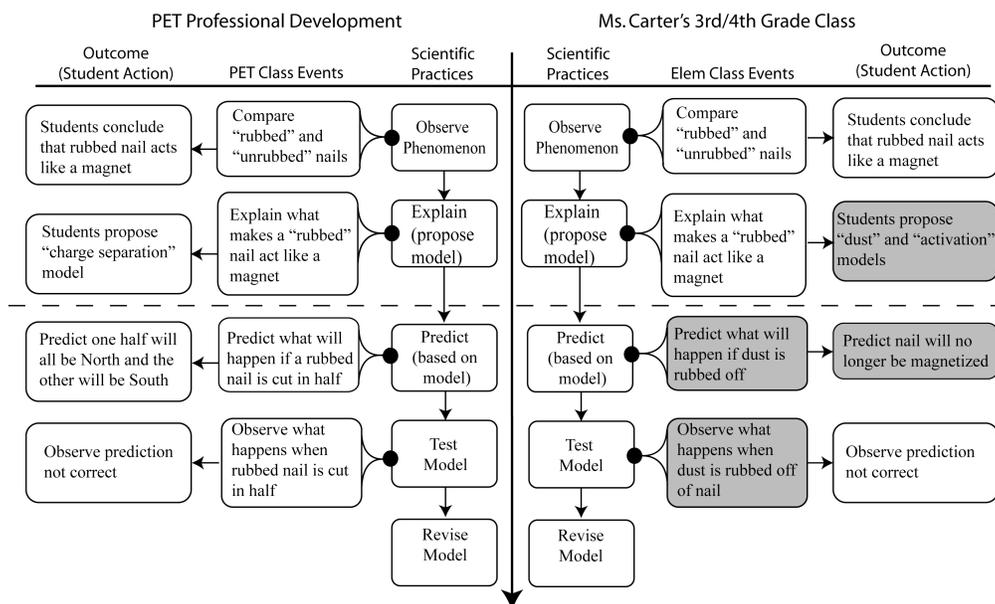


Figure 3. Event maps of the instruction during the models of magnetism series of activities in PET compared to event maps of the series of instruction in Ms. Carter's elementary school classroom. Grey boxes show events that differed between the two instructional contexts. This figure originally appeared in [17].

informs the activities that we use in our instruction is important when we instruct practicing and pre-service teachers. [19, 20] Making the curricular judgments visible may assist teachers in understanding how instruction anticipates and responds to their ideas. This may, in turn, help them provide elementary students with opportunities to create, test and revise science ideas.

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