Learning Physics by Listening To Children

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Abstract. This paper examines the role that physics subject matter knowledge plays in one aspect of elementary teaching: listening to children's science ideas. Preliminary results of this study show that prospective teachers use their conceptual understanding of physics to analyze the "physics talk" of elementary students. This is demonstrated by their restatements of the children's ideas about physics phenomena.

INTRODUCTION

Physics faculty who educate prospective elementary teachers have the difficult challenge of helping teachers attain physics knowledge in a form which is useful in tasks of teaching. This responsibility is complicated by the fact that what constitutes useful content knowledge for teaching science to elementary children is not yet fully understood [1]. However, many researchers in teacher education agree that learning to listen to and analyze elementary students' ideas about science is one skill that is both vital and difficult for teachers to acquire [2][3][4].

Researchers who have studied the influence of scientific language on the learning of science have found that specialized language in the sciences in general and physics in particular causes difficulties for science learners of all ages [5][6]. In many cases, words have scientific meanings which differ from their everyday meanings. This disconnect between everyday meanings and scientific definitions of these terms may make learning to listen to and interpret children's ideas about science difficult. Children use everyday words and everyday meanings of words to talk about science and teachers must translate between the child's words and his science ideas. For example, a teacher must use her understanding of science to discern what a child means when he makes comments such as, "the force runs out." When a child says, "the force runs out," he may be thinking of *force* as defined by physicists, or he may be talking about *motion* or *energy*, terms with different meanings in physics but similar meanings in everyday speech. How a teacher interprets this child's statement may have implications for her teaching. Based on her interpretation, she may decide that the child needs to learn more about the idea of force or she may decide he needs only to use a new word (such as *motion*) for a concept he already understands.

In the study discussed in this paper, we investigated the question: How do prospective teachers use content knowledge when analyzing video tapes of elementary children learning physics? We found that prospective teachers used content knowledge in three different ways: (1) restating children's ideas, (2) reflecting on their own learning, and (3) discussing the content involved in the elementary student videos directly. In this paper, we present detailed examples of events included in the *restating children's ideas* category which illustrate prospective teachers' use of pedagogically-relevant content knowledge, a type of knowledge used by teachers which is often referred to as pedagogical content knowledge or PCK [7] in the teacher education literature.

THE PET CURRICULUM

The participants in this study were perspective teachers enrolled in a physics course that used the NSF-funded curriculum, Physics for Elementary Teachers (PET) [8], a physics curriculum targeted toward future teachers. PET differs from traditional physics curricula in its pedagogy, its content, its focus

CP790, *2004 Physics Education Research Conference*, edited by J. Marx, P. Heron, and S. Franklin

on the nature of science and its focus on elementary students' ideas. In PET activities, prospective teachers state their initial ideas in small groups and whole class discussions and then conduct hands-on and computer-simulation activities which challenge their initial ideas. They then discuss their observations and interpretations in their small groups and present their ideas in a whole class discussion. Through this discussion, they reach a consensus of ideas which they agree satisfactorily explain the observed phenomena. The physics content objectives of PET are based on the National Science Education Standards [9] and the Benchmarks for Science Literacy [10]. The PET curriculum addresses only those standards and benchmarks that have strands in K-5 grades, but at a level appropriate for university students preparing to teach elementary children.

Special activities focusing on Elementary Students' Ideas (ESI) are integrated into the PET curriculum. ESI activities guide prospective teachers through the analysis of video clips of elementary children discussing and investigating physics phenomena. The children participate in activities similar to the activities in the PET curriculum but at a level appropriate for elementary children. Prospective teachers are asked to identify and analyze the children's ideas soon after they have covered the same content in their physics class. In many cases the children in the video clips express ideas which are nearly identical to those ideas held by the prospective teachers only a few days before. These ESI activities are designed to help prospective teachers learn to recognize and value the ideas of elementary students, value their own prior knowledge, make connections between their ideas and the children's ideas and to apply their physics knowledge in a meaningful activity in the context of their chosen profession.

DATA

We have analyzed transcripts and video tapes of two PET classes. During these classes, prospective teachers participated in two Elementary Students' Ideas (ESI) activities. Here, we focus on only one activity, but analysis and claims are based on the entire data set. This ESI activity, *Applying Our Ideas about Friction*, follows activities in which prospective teachers develop ideas about friction forces.

ESI activity: Children discuss why things slow down

In *Applying Our Ideas about Friction* prospective teachers analyze a video of 2nd and 3rd grade children investigating the question: "Why does a toy car slow down and stop after having been given an initial push?" The video illustrates elementary children's initial, developing, and final ideas. The children's initial ideas about why a toy car slows down include that the car slows down because it does not have batteries, because of gravity, and because of little cracks in the sidewalk. The children in the movie then measure how far a toy car travels along different surfaces (different grades of sand paper) after leaving a ramp. During the experiment, the children talk about their interpretations of their observations (developing ideas) and present their final ideas. In the final ideas discussion, each child who presents his or her final ideas talks about the *surface* as playing a central role in the car's slowing motion.

Data: Prospective teachers discuss children's ideas

As homework, prospective teachers watched the video described above and responded to questions which ask them to make claims about the children's ideas and to provide evidence from the transcript and video to support their claims. During the following class meeting, prospective teachers discussed their responses with their small groups and then with the whole class. The data reported here consists of transcripts of segments of the discussion among the prospective teachers about the children's ideas.

ANALYSIS AND FINDINGS

We began analysis of prospective teachers' discussions about the video tapes with an a priori coding scheme which included four categories: 1) *talk using physics content, 2) talk using common children's ideas, 3) talk about how to use children's ideas,* and *4) talk about the nature of science.* This paper reports the analysis of data within the *talk using physics content* category. Data coded into this category included any utterance by a prospective teacher that could be directly mapped to the content learning goals of the PET curriculum and included ideas such as a *force is a push or a pull* and *a force is an interaction between two objects.*

We then further analyzed the data in the *talk using physics content* category to determine when talk about physics content occurred and how prospective teachers used content knowledge. Three patterns emerged. Prospective teachers used content knowledge when 1) restating children's ideas about science, 2) reflecting on their own learning and 3) discussing the content directly. In the remainder of this paper we present two detailed examples of prospective teachers using content knowledge when restating children's ideas. This category is of particular interest because it may represent pedagogically-relevant content knowledge.

Example 1: Kyle

After watching the second and third grade children conduct the friction experiment and analyzing the children's developing ideas, the prospective teachers talked in their small groups about what they thought the children understood about friction. Prospective teacher, Kyle, presented his group's thoughts during the whole class discussion. As illustrated in the transcript below, Kyle claimed that although the children never used the word *force*, they understood that there was an interaction between the car and the surface. He further claimed that the children attributed the car's slower motion to external factors (such as the surface) rather than an internal force or energy.

> Kyle: it's pretty surprising how much they do know. But they're not using the word force or things like that. But they clearly see that it goes fast on the ramp and that when it hits the ramp, the bumpy surface, they use the word bumps and things a lot, but they basically understand that when it hits a rougher surface, the car slows down. So although they're not understanding the fact that it is force acting on a car, they see the interaction taking place.

Kyle's evidence for the above claim was transcript excerpts from the ESI video featuring Maria and Allie talking about the car rolling down the ramp:

> Maria: I think it [the toy car] goes fast here [*pointing to smooth ramp*] but here it gets slower [*pointing to the rough sand paper*].
>
> Allie: Yeah, because there's bumpy things.

In restating two children's ideas in his own words Kyle made inferences about the children's thinking on the basis of his understanding of the physics content. In Kyle's claim above we identified two physics ideas: *friction is a force* and *force is an interaction.* Kyle used his understanding of *friction as a force* when he made the statement, "they're not using the word force…but they basically understand that when it hits a rougher surface, the car slows down." He also used his understanding that *a force is an interaction* when he stated, "they see the interaction taking place." These two physics concepts helped him to both restate the children's ideas in science terms and to make the claim that the children did understand some of the key concepts of the experiment even if they did not express the concepts in scientific language.

Example 2: Emily

Prospective teacher, Emily, discussed the conceptual development of the children over the entire sequence of video clips. Emily concentrated on one child, David, and inferred that he changed his ideas as a result of the lesson. She claimed that he initially attributed the slowing of the car to an internal mechanism (battery) during the initial ideas discussion and then changed his idea to one involving an interaction between the surface and the car when he stated his final ideas.

Emily restated David's ideas and in doing so made inferences about his thinking based on her own understanding of the content. She said, "He talks about that the cars stop because of the surface they're traveling on versus what the energy the car has…blocks or stops would be another word for pushes against." This statement was based on a comparison of David's initial ideas to his final ideas.

> David (initial): It's cause it's not like have batteries cause if it has batteries the tires move by themselves so you don't have to give them a push you just have to turn it on. But if you give it a push and it doesn't have batteries so it won't keep on going.
>
> David (final): The cars are stopping because the bumps stop the cars and it kind of blocks the cars, it blocks the cars from going really really um fast-and then it looses its speed.

Emily restated David's ideas in terms of the surface it was traveling on and the energy the car had. David, however, did not talk about an internal push or the interaction between the car and the surface. Rather, he talked about batteries and bumps. When David talked about batteries, Emily inferred that he attributed the slowing to an internal mechanism. When David talked about bumps and blocking motion, Emily inferred that he was thinking about the surface pushing against the car. To make the claim that David was no longer thinking about internal energy running out of the car, but rather about the surface slowing the car down, Emily used her understanding that *a force is a push or a pull*, and that *forces such as friction change the motion of objects* (rather than an internal push running out).

In the examples above, Kyle and Emily restated children's ideas in light of their own content understanding. That is, they used their physics knowledge to help them make sense of children's thinking. To formatively assess children's learning and determine which course of action will best facilitate students' further learning; teachers must first understand what a child is thinking. This understanding will inform teachers' pedagogical decisions. Thus, making sense of children's thinking is the first step in taking pedagogical action and therefore represents the use of pedagogically-relevant content knowledge.

DISCUSSION & IMPLICATIONS

Analyzing children's ideas requires applying physics ideas to words and thoughts not typically found in a physics course. Being able to think reasonably about what a child is saying is an important skill for elementary teachers and a meaningful application of their physics knowledge. Identifying children's ideas about physics requires more than memorized vocabulary words and phrases because children use their own informal talk to discuss their science ideas. Such analysis of children's science talk requires conceptual understanding. Thus, a necessary part of learning to teach elementary children is the acquisition of useful and relevant content knowledge.

The analysis of the prospective teachers' talk in this study provides evidence that these prospective teachers used their content knowledge to analyze the children's ideas. Specifically, the prospective teachers in this study demonstrated that they were able to use physics content knowledge to make reasonable inferences about the scientific meaning of children's informal science talk when participating in the ESI activities as part of the PET curriculum.

One implication of this study is that the integration of physics content instruction with activities which ask students to apply their developing content knowledge in activities which are relevant to teaching may facilitate the development of a form of content knowledge that is usable for teaching. Further research involving how teachers actually use their physics content knowledge in teaching situations would be useful toward substantiating this claim.

Based on the research conducted in this study, we inferred that the evaluation of children's ideas through videos can provide a meaningful context for applying conceptual physics knowledge in physics courses. This may be even more relevant to future teachers than physics application activities which are not directly related to teaching tasks. Activities that are embedded within a physics curriculum, such as the Elementary Students' Ideas (ESI) activities studied here may help prospective teachers learn to use physics knowledge in exactly the type of activity in which their content knowledge will be most useful: listening to and interpreting children's science ideas.

ACKNOWLEDGMENTS

The research in this paper is supported by grant NSF grant #ESI-0096856. We would like to thank Fred Goldberg and Benjamin Williams for their valuable assistance in the implementation of the curriculum and the collection of data used in this study.

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