DEVELOPING, VALIDATING, AND MEASURING *CONTENT KNOWLEDGE FOR TEACHING:* AN EXAMPLE FROM PHYSICS

Stamatis Vokos
Physics Department
Seattle Pacific University
Seattle, WA
USA

Drew Gitomer
Graduate School of Education
Rutgers University
New Brunswick, NJ
USA

Candice Dias
Graduate School of Education
Rutgers University
New Brunswick, NJ
USA

Eugenia Etkina
Graduate School of Education
Rutgers University
New Brunswick, NJ
USA

Jim Minstrell
Facet Innovations, LLC
Seattle, WA
USA

Lane Seeley
Physics Department
Seattle Pacific University
Seattle, WA
USA

In carrying out tasks of teaching, teachers enact specialized knowledge that content experts who are not teachers do not use (and most likely do not have). How do we operationalize such a construct, validate it, and measure it in distinct ways (in teacher assessments, classroom observations, and teaching artifact analysis)? What is the relationship between these measures and student learning?

In this talk, a multi-institutional, ongoing effort (supported in part by National Science Foundation grant 1222732) to pursue these questions will be described, the project framework will be shared, sample assessments items will be illustrated, and preliminary results from a pilot study involving 222 high school physics teachers will be discussed. Implications for teacher education programs will be highlighted.

The concept of content knowledge for teaching (CKT) originated with the work of Shulman (1986) and was more fully developed by Ball and colleagues (Ball, Thames, & Phelps, 2008). CKT is premised on the idea that teachers need to understand subject matter content in ways that are specific to teaching, such as understanding challenges that specific content might present to students and how students may represent their understanding in non-standard forms, knowing how to ask questions or provide explanations that can move understanding forward, etc. (Ball & Bass, 2003).

The majority of work has been in mathematics, though related work has been done in English language arts (ELA) and science. Validation efforts have followed the strong tradition of the measurement of abilities, which assumes that individuals have traits that are stable over some range of contexts (Carroll, 1993). Therefore, the common research question has been whether relatively broad measures of CKT (e.g., elementary mathematics) are related to general measures of practice (samples of classroom observation) and student learning (annual achievement tests) (e.g., Hill et al., 2008).

This presentation brings the perspective of a multi-institutional research effort that explores CKT in a single science domain, energy in the mechanics part of the first high school physics course (CKT-E). This approach allows us to understand with precision teachers' content knowledge of energy and CKT-E of a single domain, how they enact instruction in that domain, and what their students learn in that domain. This approach allows us to explore the fundamental and relatively unexplored question that underlies CKT—what does a teacher know about the teaching of a particular content area, and how is that knowledge related to instruction and student learning in that same content area?

The talk will present the conceptual framework, measures, and initial findings from a four-year project that has now completed the first year of a two-year data collection. In particular, I will describe the construction and refinement of assessment items that probe the specialized content knowledge that teachers employ to support students' productive scientific engagement with the

domain of mechanical energy. In designing CKT-E assessment items, the project focused on the tasks of teaching and energy targets of our domain framework.

The project assumes that scientific understanding includes both knowledge about content and practices of science, consistent with the Next Generation Science Standards (National Academy of Sciences, 2012). We argue that teachers face complex, content-specific challenges that are unique to teaching. Therefore, we are striving to assess knowledge that is relevant for the following tasks that a teacher faces to support student learning of specific energy targets, all described in the project's domain framework:

- anticipating student thinking around science ideas;
- designing, selecting, and sequencing learning experiences and activities;
- monitoring, interpreting, and acting on student thinking;
- scaffolding meaningful engagement in a science learning community;
- explaining and using examples, models, representations, and arguments to support students' scientific understanding; and
- using experiments to construct, test, and apply concepts.

We designed 20 assessment tasks, including selected-response and constructed-response formats, to address authentic challenges to teaching energy. Each item contains a rationale detailing the item design and justification for both the keyed answer and the distractors. The intensive development process has included work with a small development team of teachers, a pilot study of ~200 teachers, scoring of the pilot, item revision and full field-testing with ~300 teachers. This process has helped us address the following research questions:

- To what extent do written assessments capture different aspects of the CKT-E framework?
- What aspects of the domain framework are most appropriately addressed through constructed-response formats?
- Can constructed-response items be coded reliably and provide insight that selected-response items cannot?
- What is the evidence with respect to the dimensionality of a CKT-E assessment?

Below is a sample item, which will be described in the presentation.

Ms. Patel knows from her previous experience that students often have difficulties with energy conversions. Several students in her class have expressed the idea that whenever potential energy decreases, kinetic energy increases by the same amount. She wants to present a series of scenarios for her students to consider that will start with their current ideas and then progressively challenge their ideas in a constructive way.

Determine a sequence for presenting the following four scenarios that would build Ms. Patel's students' understanding of energy conversions in a logical progression that is practical in the classroom, starting with their current ideas.

Describe your reasoning for each choice in the sequence.

A.   A block slides across the floor to a stop.

B.   A metal ball speeds up as it rolls down a smooth track.

C.   A tennis ball that has been submerged and is then released so it is rising in water.

D.   A hockey puck sliding on ice hits a horizontal spring and compresses it.

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