**A Table of Specifications for Physics Pedagogical Content Knowledge**

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ABSTRACT

 This Table of Specifications (TOS) is intended to be a tool used to create an instrument to assess the physics Pedagogical Content Knowledge (PCK) of high school teachers. This instrument will inform physics teacher candidate preparation and physics teacher professional development.  Building upon Eugenia Etkina’s five aspects of PCK and their relationships to teaching physics, the physics PCK TOS combines knowledge that a physics teacher who effectively creates an environment conducive to learning is presumed to have (2010).

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INTRODUCTION

 In a country where only 40% of physics teachers have a degree in physics or physics education and only 56% would describe themselves as physics specialists, many districts would benefit from being able to assess and improve upon their physics teachers’ pedagogical content knowledge (PCK) in physics (White & Tyler 2014, Shulman 1986). The Table of Specifications (TOS) accompanying this article will guide design of such an instrument.

Table of Specifications

 A Table of Specifications (TOS) is a two-way chart or grid which ensures a connection between content knowledge goals and pedagogical goals (Notar 2004). The column of the chart lists the objectives or "levels of skills" to be addressed; the rows list the key concepts or content the test is to measure.  A TOS helps teachers align objectives, instruction, and assessment (Fives & DiDonato-Barnes 2013). Each level of skill is the equivalent to each level of the cognitive domain of Bloom's Taxonomy (1956). Teachers can be assured that they are writing better objective tests by measuring students' content learning as well as the student’s level of skill or order thinking (Cerbin 2009). “The use of a TOS may ensure that teachers include test items that tap different levels of cognitive complexity when measuring students' achievement” (Alade & Omoruyi 2014).

Pedagogical Content Knowledge

 Imagine an English teacher who has never studied physics beyond their exposure at the high school age. This English teacher may understand how to teach, yet may struggle to teach physics due to a lack of physics content knowledge. Imagine a prominent physicist who has never studied pedagogy. The physicist might be an expert in physics, but struggle as a teacher without pedagogical knowledge.

Content knowledge is knowledge in a given field that allows students to learn maximally accurate concepts. This content knowledge is an expected quality of physicists and physics teachers alike. Pedagogical knowledge, or the knowledge of how people learn, remember, behave, and mentally develop, is an expected quality shared among teachers in every content area.

Now imagine a teacher who double majored in history education and physics. This person has a good understanding of how to teach students, and a good understanding of physics. Yet this history certified teacher may struggle to lead the students to conceptual understandings more than a person who studied physics education in particular. This history teacher is lacking physics pedagogical content knowledge (PCK), the unique knowledge specific to those who spend time thinking of ways to encourage concept construction for a given field of study (Shulman 1986).

PCK is the mixture of pedagogical knowledge and content knowledge in a specific field. The PCK required is different for every content area. Subsequently, physics PCK is professional knowledge unique to those who teach physics.

 PCK has been defined by Shulman as “the special amalgam of content and pedagogy that is uniquely the providence of teachers, their own special form of professional understanding” (1986). Such an understanding as PCK is vital to building a classroom that maximizes student learning in physics.

 Students may not efficiently acquire physics content knowledge by solely reading about the physics content and listening to lecture, but learning is effectively increased with increasing engagement (Hake 1998). Physics PCK is thought to have a similar learning efficiency function, due to overlap in physics content (Etkina 2010).

 Figure 1 is from Etkina’s “Pedagogical content knowledge and preparation of high school physics teachers” (2010). The diagram shows that the importance of the PCK is that it combines content knowledge with pedagogical knowledge. The table describes five aspects of physics PCK.



ASPECTS OF PHYSICS PCK

 The physics PCK aspects included in the TOS are modified from Etkina’s “Pedagogical content knowledge and preparation of High School Physics Teachers” (2009). The five main aspects are:

1. Orientation to science teaching,
2. Knowledge of physics curriculum,
3. Knowledge of and respect for common difficulties with key concepts and practices,
4. Knowledge of teacher strategies to scaffold student learning of key concepts and practices, and
5. Knowledge of widely accepted conceptual assessments, assessment strategies, and facilitation of metacognition.

Each aspect is applied to physics content and described below (Etkina 2009). Figure 2 organizes the five aspects of physics PCK, as well as sub-topics.



 The physics PCK TOS is included in table 1.

Orientation to science teaching is related to the teacher’s beliefs about science teaching. Throughout the physics education field, scientific investigation is regarded as an effective way to facilitate learning in the subject while simultaneously engaging the student in an activity which reveals the nature of science (MacIsaac & Falconer 2002). Also, due to the nature of science as well as the growing field of physics education, there must be at least one facet for the teacher to access up-to-date information on their field.

Knowledge of the physics curriculum is essential to guide students to an understanding in physics. The teacher must know the learning goals of the course they teach, which are usually defined by state standards. Knowing which concepts in the curriculum are essential over-arching themes that connect topics helps teachers plan to know what is most essential for students to spend time analyzing. The teacher must have a content knowledge base that extends beyond the normal range in the classroom to help students pursue answers to unexpected questions, take advantage of teachable moments, and to pursue interests of students to keep student morale high. For the same reasons, having interdisciplinary knowledge is useful. It is also useful to use to connect an abstract concept to a more “concrete” situation in which the student may bridge their understanding (Bransford 2000). Given a physics concept, a physics teacher should be able to determine what underpinnings are necessary for their students to have in order to reach the goal understanding. The teacher must also be familiar with physics pedagogical jargon to communicate with colleagues and understand professional articles.

 Knowledge of and respect for common difficulties with key concepts and practices allows students to see why there are good reasons to believe inaccurate theories until they are proven inaccurate, and accept the nature of science. Common difficulties rise from naive generalizations, or general rules extended to a situation in which that generalization does not apply. Language barriers offer a huge obstacle for many students, as was extensively addressed by Arons (1990). In addition, knowledge of the history of science may help a teacher learn about what their students may believe.

Knowledge of teaching strategies to scaffold student learning of key concepts and practices is a knowledge of techniques in teaching specific or general physics content. Widely accepted physics curricula, such as the physics tutorials, the physics of everyday thinking, and the physics modeling curriculum offer strategies and activities that may increase student learning. Poorly chosen words can ruin students’ chances of sense-making, while other carefully chosen words may clarify and facilitate rapid cognitive growth. Analogies are useful tools in bridging gaps between what students understand and a new concept. Technology may be a huge help with student understanding. For example, RealTime physics motion lab is used widespread because it graphs student motion almost instantly to help students correlate graph shape with a kinesthetic motion. Simulations and videos can raise morale and allow students to think more deeply about something abstract.

Knowledge of widely accepted conceptual assessments, assessment strategies, and facilitation of metacognition is crucial to gauge activity effectiveness and student understanding. There are many widely accepted conceptual physics assessments that students may take, such as the FCI, FMCE, TUG-K, CTSR, BEMA, CSEM, DIRECT, STEBI-B, and MCTP. In addition, physics teaching strategies can be evaluated with widely accepted teaching assessments, such as RTOP. Since teachers often create their own assessments, teachers should have a basic understanding of the difference between a mathematically involved problem solving assessment and a quality physics concept assessment. Teachers should also know how to encourage and facilitate metacognition. One way to do this is through reflective journaling.

PHYSICS PCK ASSESSMENT

 The PCK aspects outlined above are mostly knowledge-based. Yet knowledge does not create an effective teacher. The teacher must be able to use higher levels of thinking from Bloom’s Taxonomy to be able to use this knowledge to the students’ advantage (1956). Figure 3 displays several ways in whichteachers must be able to apply physics PCK to create effective lessons.



Figure 3: Bloom’s Taxonomy lists several verbs which a physics teacher should be able to do with physics PCK (1956).

Performance-based assessments are used to measure the amount of inquiry-based or constructivist methods being used in the classroom via RTOP (MacIsaac & Falconer 2002, 479). The edTPA Secondary Science assessment is also performance-based with a video component and a written task accompanying several student samples, lesson plans, and worksheets. The edTPA assesses teacher candidates in this manner to measure teacher readiness and to allow the candidates to “demonstrate their understanding of teaching and student learning” (SCALE 2015, 1).

Understanding of physics PCK should be evaluated through a performance-based assessment for the same purposes. Physics teachers should be given an opportunity to demonstrate their understanding of PCK through planning, instruction, and assessment, as well as an explanation accompanying each task, as displayed in figure 4 from the edTPA assessment handbook (SCALE 2015, 2).



Figure 4: The edTPA tasks and cycle of effective teaching (SCALE 2015, 2).

 Table 2 shows every aspect and subtopic of physics PCK, as well as resources to find quantifiable items of each subtopic.

CONCLUSION

 This table was a compilation and organization of several great minds in the physics education field. Therefore, it has a slight advantage over other tables in assisting in the creation of an assessment tool to detect physics PCK in a teacher.

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