A physics teacher candidate knowledge base

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What prospective physics teachers need to know and be able to do should be grounded in what their future students need to know and be able to do in order to live in and contribute meaningfully to life in a democratic society. National goals and standards reflect these needs, and have strongly converged in recent years on what it is that future teachers of science must know and be able to do. In response, a knowledge base has been established at Illinois State University to be used to guide the preparation of our prospective physics teachers.

It is sometimes noted that in order to teach well, teachers must possess an identifiable knowledge base. Philosophers as early as Aristotle addressed the question of what teachers need to know and be able to do in order to be effective at their chosen profession. Writing in *Nicomachean Ethics,* Aristotle saw the teacher's knowledge base as consisting of sophia ("wisdom") and phronesis ("prudence"). Sophia is the ability to think well about the nature of the world. It is used in the effort to discover phronesis, the ability to think about how and why we should act in order to accomplish a particular end.

In more recent times, the knowledge base of physics teachers has been described in the pages of this journal and elsewhere as consisting of three elements or components: content knowledge, pedagogical knowledge, and pedagogical content knowledge (Etkina, 2005). Content knowledge is knowledge of the discipline itself, and includes such things as procedural methods and possibly even dispositions. According to Etkina, content knowledge consists of "knowledge of physics concepts, relationships among them, and methods of acquiring knowledge" (2005, p. 3). Various documents define the content students should learn (e.g., *Benchmarks for Science Literacy*), and teacher preparation documents describe the role of the teacher (e.g., *National Science Education Standards*). Teachers must know what they are expected to teach their students, and probably substantially more as well.

Pedagogical knowledge, represents the "generic why and how to" of teaching. According to Etkina, pedagogical knowledge consists of "knowledge of brain development, knowledge of cognitive science, knowledge of collaborative learning, knowledge of classroom discourse, knowledge of classroom, and management and school laws" (2005, p. 3).

Pedagogical content knowledge (PCK) represents a situation-specific overlap of content knowledge and pedagogical knowledge. PCK deals with the "specific why and how to" of teaching a given discipline. According to Etkina, PCK consists of "knowledge of physics curriculum, knowledge of student difficulties, knowledge of effective instructional strategies for a particular concept, and knowledge of assessment methods" (2005, p. 3). PCK per se is hard to teach, and is often the result of many years of classroom experience (Wells et al., 1995). It can be described as "knowledge in action."

A Physics Teacher Candidate's Knowledge Base

A broader description of what a physics teacher candidate's knowledge, skills, and dispositions should be is provided in a less generic description as follows:

A. Content and Procedural Knowledge

The prospective teacher should have a broad and current understanding of the major content areas of physics. These include such areas as mechanics, electricity and magnetism, heat and thermodynamics, waves and light, optics, and modern physics. The prospective teacher's understanding will be at a level consistent with appropriate national and state standards, and includes a familiarity of the unifying principles of physics such as conservation of energy, momentum, mass, and charge. This presupposes that the prospective teacher will possess a general understanding of the closely allied fields of astronomy, chemistry, and mathematics, and will be aware of the major findings of the biological and environmental sciences.

The prospective teacher must have an accurate understanding of the processes of science, and its underlying assumptions. The prospective teacher should see scientific knowledge as emergent, and not absolute. Ideally, the prospective teacher will have learned content knowledge through methods of inquiry thereby acquiring closely associated procedural knowledge. The prospective teacher should have had an opportunity to experience the processes of scientific investigation: observing; defining a problem; hypothesizing from an evidence base; creating an experiment; identifying and controlling variables; collecting, graphically representing, and interpreting data; conducting error analyses; drawing conclusions; and communicating results. Knowledge so gained and communicated should help students understand that science is a way of knowing, and help them distinguish information that is not so derived.

B. Pedagogical Knowledge

The prospective teacher must understand what constitutes effective teaching, and be able to distinguish authentic teaching practices from practices so called such as instructing, informing,

training, and brainwashing. The prospective teacher should have a demonstrable understanding of:

- **planning and preparation** – Prospective teachers must demonstrate an ability to prepare lesson plans for a variety of lesson types, create a unit plan, and deal with the broad implications of year-long curriculum planning. The prospective teacher must know how to integrate lecture-demonstrations, laboratory work, homework, discussion, presentations, assessment, student research projects, and out-of-class activities in a way that maximizes student learning.
- **quality teaching** – Prospective teachers must understand the difference between the transmission and constructivist views of teaching. They must understand the worth and power of constructivist forms of teaching, and the limitations of transmission forms.
- **inquiry practices** – Prospective teachers must be able to use inquiry practices effectively to help students construct knowledge from evidence, be familiar with concept change and its relationship to constructivism, be able to assist students participate in the procedures whereby knowledge of nature and technology is constructed.
- **cooperative/collaborative learning** – Prospective teachers must demonstrate an ability to utilize any of a number of cooperative and collaborative learning strategies, and be able to distinguish these strategies from traditional group learning.
- **problem-based learning** – Prospective teachers must demonstrate an ability to utilize problem-based learning as a means to promote problem solving and enhance critical thinking skills, and as a way to integrate diverse elements of the physical and biological sciences.
- **multiple representations** – Prospective teachers must demonstrate the ability to use a variety of representations to help students learn and understand the content of physics.
- **preconceptions and concept change** – Prospective teachers must demonstrate an understanding of a student's need for the construction of knowledge and its relationship to preconceptions derived though casual observations of the world.
- **learning cycles** – Prospective teachers must demonstrate an understanding of the relationship between learning cycles and classroom activities, and their effects on individual lessons and the broader curriculum. The complex interrelationship of lecture-demonstrations, laboratory work, homework, discussion, presentations, assessment, and student research projects, and out-of-class activities must be understood.
- **instructional resources** – Prospective teachers must demonstrate an ability to select, use, and adapt instructional resources to the needs of students.

C. Pedagogical Content Knowledge

Pedagogical content knowledge represents the "intersection" of content/procedural knowledge and curricular knowledge. It deals with the "specific why and how to" of teaching a given discipline – in this case physics. Physics teacher candidates should be familiar with the information contained in such books as the following: (1) *Teaching Introductory Physics* (Arons, 1997), (2) *Hands-on physics activities with real-life applications* (Cunningham & Herr, 1994), (3) *Five easy lessons: Strategies for successful physics teaching* (Knight, 2002), and (4) *Teaching introductory physics: A sourcebook* (Swartz & Miner, 1998).

The Physics Teacher Candidate Knowledge Base at ISU

Over the past 14 years, a detailed outline of a required knowledge base has been established for physics teacher education majors at Illinois State University. The current knowledge base was established on the basis of many year's experience with what high school physics teachers need to know, be able to do, and what dispositions they should possess in order to be effective. The knowledge base was established and periodically revised as part of a program accreditation review process that included addressing both the *National Science Education Standards* and the NSTA's *Teacher Preparation Standards*. The knowledge base in place today continues to guide decisions in course development and major requirements as it relates to teacher preparation. To see how these are implemented in the PTE program at ISU, readers may visit the online syllabi of six undergraduate science teaching methods courses at http://phy.ilstu.edu/pte/.

1. Knowledge of Curriculum

The prospective teacher must possess a broad understanding of the practices of physics teaching as reflected in the aims, goals, and objectives of both national and state science teaching standards. This includes a working knowledge of long-term and short-term planning required for teaching an inquiry-based program; an ability to align teaching goals, objectives, and assessment with these standards; an ability to provide needs-based rationales for inclusion of material in the curriculum grounded on student interests, community values, teacher strengths, and societal needs. The prospective teacher must be able to identify the various curricula that are available for physics teaching.

2. Understanding What "Scientifically Literate" Means

The prospective teacher must have a working definition of what it means for a person to be scientifically literate, and must be so. That is, the prospective teacher will have a well-founded "knowledge and understanding of scientific concepts and processes required for personal decision making, participating in civic and cultural affairs, and economic productivity" (*National Science Education Standards,* 1996, p. 22).

3. Understanding Students

The prospective teacher must be aware of the psychological basis for effective science teaching. The prospective teacher must also demonstrate an ability to come to know students as individuals, to assess their knowledge and background, and show a willingness

to work with parents to serve the best interests of students. This includes dealing effectively with different student learning styles, sources of interest, motivation and inspiration, and cultural and emotional differences. This also includes identifying and correcting learning difficulties where possible using personal knowledge and experiences, or through conferral and referral.

4. Classroom Management Skills

The prospective teacher must demonstrate excellent student management skills by maintaining classroom discipline using a firm, fair, friendly, and focused demeanor. The skilled classroom manager will effectively present lessons so that students will perceive time in the classroom as of significant positive value. The atmosphere so maintained should not be rigid and regimented, but should be flexible and conducive to student inquiry.

5. Communication Skills

The prospective teacher must be an excellent and effective communicator, both in conducting instruction and in receiving and responding to information. The prospective teacher will demonstrate excellence in communication by using proper vocalization (diction, grammar, enunciation, and projection). The prospective teacher will demonstrate effectiveness in communication by presenting information systematically and logically, by questioning students using appropriate means (using a variety of question types, making effective use of wait time, etc.), and by listening and responding well to students' questions, answers and comments.

6. Knowledge of the Teaching-Learning Relationship

The prospective teacher should be aware that teaching is what teachers do, that learning is what students do, and that there might be no direct relationship between teaching and learning. The prospective teacher sees the role of teacher as that of a science guide who facilitates learning, and is aware of the major principles of learning.

7. Scientific and Philosophical Dispositions

The prospective teacher should demonstrate scientific dispositions (beliefs, behaviors, attitudes, values) and should be able to engage students in activities that help clarify the need for a consistent scientific ethic. The prospective teacher should demonstrate the habits of mind closely associated with the intellectual rigor of scientific inquiry and attitudes and values conducive to science learning. The prospective teacher should understand the assumptions and limitations of scientific knowledge.

8. Social and Technological Context

The prospective teacher must demonstrate an understanding of and an appreciation for the broad applicability of physics to real-world situations. Prospective teachers must be able to provide a rationale for including physics in the school curriculum as it relates to any area of life in general, and technology in particular. The rationale must deal with the value of scientific knowledge to their students, to society, and to the scientific professions. The prospective teacher must demonstrate an understanding of the relationship between science and technology, and the relationship between scientific values and social values.

9. Learning Environment

The prospective teacher should have an understanding of how to create among students a disposition in favor of science, and scientific ways of knowing. The learning environment should be physically and emotionally safe, and one in which questioning is valued as much as knowing, and process is valued as much as product. The prospective teacher should know how to provide stimulating learning environments that develop a community of learners who share time, space, and materials to learn science. The prospective teacher should know the meaning, differences, benefits, and consequences of competitive, cooperative, and individualistic learning atmospheres. The prospective teacher should know the effect of expectations on student achievement, and how to exert appropriate classroom control measures.

10. Active and Engaged Learning

The prospective teacher should have an understanding of how to teach in active and engaging ways that create and sustain student interest in science generally, and in physics in particular. This engagement should sustained student participation in learning activities, should include learning cycles, and involve students in cooperative group processes.

11. Student Assessment

The prospective teacher should have an understanding of the goals and procedures of both "regular" and alternative/authentic assessment. The prospective teacher should know how to use a variety of means to assess stated objectives that are fair, valid, and reliable, and consistent with the decisions they are intended to inform. The prospective teacher will see ongoing assessment of student learning as a valuable adjunct to teaching. The prospective teacher should be aware of sources, and uses for standardized tests, and be able to accurately interpret results.

12. Self-Assessment and Reflective Practice

The prospective teacher should demonstrate the habit of regular self-assessment – reflecting objectively upon personal teaching practice with an eye toward improving professional practice and increasing student learning. The prospective teacher will engage in ongoing assessment of personal teaching practice, in cooperation with formative feedback provided through clinical supervision. The prospective teacher should demonstrate the disposition of a life-long learner in all areas of professional life.

13. Technology of Teaching

The prospective teacher should have knowledge of and first-hand experience with the wide range of instructional and scientific technology to be used in the classroom. This includes demonstration and laboratory equipment, computers and their applications, microcomputer- and calculator-based laboratory equipment, and the software associated with accessing the Internet to be used by students.

14. Professional Responsibilities

The prospective teacher should abide by a code of professional ethical conduct. It is incumbent upon the teacher to improve educational practice personally, and at the level of the school and the wider academic community. The prospective teacher should perceive professional organizations and publications as instrumental in professional improvement.

15. Nature of Science

The prospective teacher must possess a broad understanding of the nature of science. The teacher candidate must be able to define the values, beliefs and assumptions inherent in the creation of scientific knowledge within the scientific community. This includes being able to: distinguish science from other ways of knowing; distinguish basic science, applied science and technology; identify the processes and conventions of science as a professional activity; and define acceptable evidence and scientific explanation.

16. Responsive Teaching

The prospective teacher must know what it means to be a culturally responsive teacher in order to ensure participation of all students independent of gender, disabilities, and cultural differences. The prospective teacher must teach in such a way as to provide for gender differences, physical and mental disabilities, and racial/ethnic differences.

17. Knowledge of Authentic Best Practices

The prospective teacher must have a thorough understanding of authentic best practices, and how they relate to how students learn science. As such, the teacher candidate will understand the importance of dealing effectively with student preconceptions, will understand how to use inquiry practices effectively, will understand the meaning and roles of student metacognition and self-regulation, and will be well versed in the use of cooperative/collaborative learning practices.

18. Knowledge of Generic Best Practices

Many teaching skills come from practical experience and are not well grounded on a research base. Much of what is handed on as "grounded in research" tends to be nothing more than idiosyncratic anecdotal experience – it constitutes the craft wisdom of teaching. Nonetheless, these best practices so-called constitute the "art of teaching" and often can provide a number of valuable alternative avenues for effective teaching.

Uses of this Knowledge Base

This knowledge base can be used in a variety of fashions, not the least important of which is as a guide for developing or reformulating physics teacher education programs. Another way that this knowledge base can be used is to help school administrators make informed hiring decisions or prospective teacher candidates to make an informed choice about the school in which to enroll. It can also be used by in-service teachers to self-assess.

It's not uncommon that school administrators such as superintendents, principals, and department chairpersons need to call upon one or more experts in making a hiring decision. Often that expert is an established physics teacher. However, when such an expert is not available as when in replacing one solitary physics teacher with another or having only a less qualified cross-over physics teacher on staff, then reference to this knowledge base can provide that administrator with the background he or she needs for making meaningful inquiries into a teacher candidates' preparation.

Students seeking the best teacher preparation program in which to enroll might also want to consult this knowledge base in an effort to determine which of the elements contained herein is, in fact, addressed or ignored in a given physics teacher education program.

Reflective practice consists of self-assessment and auto regulation. In-service teachers who wish to improve their practice will compare their performance against established standards, and the current knowledge base can serve as one such set. Professional development plans can be based on any deficiencies that have been identified in comparison with this knowledge base.

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