

Running Head: METHODS OR MADNESS

Methods or Madness: Preparing the Next Generation of Elementary Science Teacher Educators

Sandra Abell (abells@missouri.edu)

Mark Gagnon

Deborah Hanuscin

Michele Lee

University of Missouri-Columbia

Meredith Park Rogers

Indiana University

Paper presented at the Association for Science Teacher Education
Clearwater Beach, Florida, January 2007

Methods or Madness: Preparing the Next Generation of Elementary Science Teacher Educators

In recent surveys of doctoral students in all fields (Fagen & Niebur, 2000; Nyquist & Woodford, 2000), respondents shared concerns that an overemphasis on research led to inadequate preparation for teaching, curricular planning, collegiality, and service. In one study (Davis & Fiske, 1999), 50% of respondents felt they received inadequate preparation as teaching assistants, and 59% felt that faculty in their programs did not emphasize the importance of teaching. A 2001 survey (Golde & Dore) indicated that most current doctoral students are primarily interested in becoming faculty members, even though most will not begin their careers in the types of institutions where they received their doctoral training. We often use such evidence to criticize our colleagues in the sciences about the inadequacies of their doctoral programs in preparing the next generation of university science instructors. However, what happens when we look inward to examine doctoral programs in science education?

Much like doctoral programs in the sciences, science education doctoral programs help students build an important disciplinary knowledge base and learn to do research in the field. However, this knowledge base lacks an explicit emphasis on learning about science teacher education. In a national survey of science education doctoral programs, Jablon (2002) found that most required coursework in research methods, nature of science, and science education curriculum, among others. However, within a list of 13 science education topics typically found in doctoral courses, the topic of science teacher education did not appear. Furthermore, according to Jablon:

Even though 100% of the doctoral program heads expected their graduates to be able to teach methods courses and supervise student teaching (96% expected proficiency at inservice workshops), only 34% required their graduates to be involved in a mentored teaching of a methods course, student teaching, or inservice workshops. Forty two percent said the students could do this as an elective and 24% said their graduates had no opportunity to be mentored in any of these skills.

Clearly our science education doctoral programs are missing a critical piece (Abell, 1997)—the explicit preparation of future science teacher educators.

In 1997 the then Association for the Education of Teachers in Science published a set of standards for “those individuals designing and implementing teacher education programs, institutes, workshops, etc.” (Lederman, et al., p. 233). These *Professional Knowledge Standards for Science Teacher Educators* include expectations that teacher educators will have a strong science knowledge base; understand science pedagogy, curriculum, instruction and assessment; and know about learning and cognition. Each of these standards focuses on science education as applied to K-12 education. A fifth standard discusses preparation for research, and a sixth standard applies to knowledge and experience in offering professional development “workshops and institutes” (p.239). However, the standards do not address a critical aspect of what science teacher educators should know: how to teach future science teachers.

The purpose of this paper is to address this missing link in science education doctoral programs. First we present a theoretical framework that can help situate our work in preparing future science teacher educators. Next we provide vignettes of our experiences as mentors or mentees in learning to become science teacher educators. We end by recommending a vision for doctoral preparation and a new set of standards to be included in the *ASTE Professional Knowledge Standards for Science Teacher Educators*.

Theoretical Framework

Shulman (1986) posited a specialized knowledge that distinguishes teachers from subject matter specialists—pedagogical content knowledge (PCK). According to the PCK framework, knowing science is a necessary but not sufficient condition for teaching. Science teachers must also have knowledge about science learners, curriculum, instructional strategies, and assessment through which they transform their science knowledge into effective teaching and learning. These types of knowledge, or PCK, are filtered through a teacher’s orientation to science teaching as they are put into action (Grossman, 1990; Magnusson, Krajcik, & Borko, 1999) (see Figure 1).

We contend that a parallel form of PCK exists for elementary science teacher educators. In this case, the subject matter knowledge that a science teacher educator needs includes both science content and knowledge for teaching elementary science. A science teacher educator’s PCK includes his/her

knowledge about curriculum, instruction, and assessment for teaching elementary science methods courses and supervising field experiences, as well as her knowledge about preservice teachers (see Figure 2). For example, the science teacher educator should understand the points of resistance that prospective teachers might encounter when learning about science teaching. Furthermore, the science teacher educator should know strategies for helping future teachers confront their naïve conceptions of science teaching and learning (Abell, Bryan, and Anderson, 1998) and find suitable alternative views. Elementary science teacher educator PCK is filtered through their orientations to teaching science teachers (Abell & Bryan, 1997) as they design and carry out instruction.

In recent years, there has been increasing recognition that learning to teach in grades K-12 is a lifelong enterprise that comprises a professional continuum (Feiman-Nemser, 2001). This continuum originates in K-12 formal education with an apprenticeship of observation (Lortie, 1975), and proceeds through teacher preparation, induction, and recurrent professional development. Teacher learning needs change along this continuum as their PCK develops. We hypothesize that a similar professional continuum exists for science teacher educators, but has yet to be researched. Future teacher educators begin their professional development as classroom teachers, progress through their doctoral preparation, and proceed into the beginning years in the professoriate. Their development in the doctoral program is influenced by their incoming subject matter knowledge (of science and or elementary science teaching), their incoming PCK for teaching teachers, and by their opportunities and experiences in the doctoral program. We believe that explicit attention to developing PCK for teaching future science teachers is a critical component of the science education Ph.D. program. However, we acknowledge that the typical experiences of science education doctoral students may not fully address this component.

Beyond the Typical: Vignettes of Explicit Preparation to be a Science Teacher Educator

Our own experiences indicate that the opportunities for doctoral students to participate in science teacher education vary greatly. Many have no opportunity to teach or even co-teach a methods course during their graduate education, leaving them to “sink or swim” once they obtain an academic position. Some graduate students find themselves alone in the deep end of the pool when they are given a position

as instructor of record for a methods course with the full responsibilities of a faculty member, but provided little or no mentoring. At the other extreme, other doctoral students experience a highly structured “copycat” experience in which they are expected to implement a syllabus and pre-planned activities identical to those of a faculty member, rather than learning to make their own instructional decisions as teacher educators. We argue that neither the “sink or swim” or “copycat” experience provides the optimum environment for supporting development of PCK for teaching science teachers. What follows are stories that illustrate alternative structures that can provide meaningful opportunities for development of PCK for teaching science teachers.

Developing PCK of Instructional Strategies for Teaching Teachers (Mark)

My development of PCK of instructional strategies for teaching science teachers stems from three experiences during my doctoral program, involving two different mentors. All three experiences occurred during the same semester. As part of an internship course with one of my mentors, I observed an elementary science methods class she taught. Concurrently with the internship, I supervised the field experience for the same group of preservice teachers. I co-facilitated field experience seminars for this group with the same faculty mentor. Finally, I was also enrolled in a doctoral seminar course, “Research, Policy, and Practice in Science Teacher Education,” taught by my advisor. In that course, we read about and discussed the research concerning PCK of instructional strategies for preservice science teachers.

One of the goals we established for my internship was to focus on the instructional strategies the faculty member used for small and whole group discussions. Across my three experiences I was able to think about this instructional strategy through observing this strategy in action, reading and discussing research about it, and then applying the strategy in field experience seminars. At the beginning of my internship, I observed the instructor guide elementary methods students through a series of whole group discussions over a period of several weeks. She explicitly modeled how they could use this strategy in their own classrooms. As she led the whole group discussions, the preservice teachers became more adept at the roles and responsibilities of whole group discussion. I discussed these experiences with several students and they reflected on their learning. During this time I was reading and discussing research in the

doctoral seminar. The seminar group read the Cochran-Smith and Zeichner (2005) book, *Studying teacher education: The report of the AERA panel on research and teacher education*. I also read and discussed research on instructional strategies specific to science teacher education. I was able to reflect on the research and apply it to my developing knowledge of instructional strategies for teaching teachers. This reflection during the doctoral seminar and my observations during the internship observation were invaluable as I co-facilitated field experience seminars. With my faculty mentor, I developed learning goals and guiding questions to facilitate each seminar discussion. In one seminar we used a case-study instructional strategy, and I moderated the discussion in a whole group setting.

As I reflect on the outcomes of my three experiences, I realize that the information I learned in the doctoral seminar gave me a unique perspective from which to view the science methods instructional strategies in my internship. Subsequently, as I reflected on my experience in observing the science methods class, I applied similar instructional strategies to field experience seminars. I developed a deeper PCK for teaching preservice teachers through the synergy of these three experiences. The opportunity to read research about best practices gave me the ability to observe in a more focused way. The opportunity to observe helped me apply strategies in my teaching. And the opportunity to try out those strategies brought life to new things I read.

Developing PCK of Curriculum for Teaching Teachers (Meredith)

My formal experience preparing to become an elementary science teacher educator during my doctoral program began in a semester-long independent readings course with my faculty advisor, who had taught elementary science methods for 15 years. The purpose of this apprenticeship relationship was to prepare me for teaching an early childhood science methods course independently the following semester. To provide some structure to the readings course, we drew up a contract outlining the goals, my responsibilities, and what would represent a summative assessment of the PCK for teaching preservice teachers that I would develop over the semester. The independent study involved one-on-one informal meetings every two to three weeks to discuss readings that pertained to the development of my PCK for teaching early childhood science methods. My responsibilities were to read the selected chapters/articles

and come to meetings prepared to discuss themes that emerged from the readings. My summative assessment would be to develop a syllabus that I would use the following semester with my own students. The syllabus would reflect my PCK for early childhood science methods curriculum.

The process of designing the independent readings course was both collaborative and practical in nature. We started by examining a reading packet that my advisor had compiled for teaching elementary science methods. We then grouped the readings around curricular themes such as: using an inquiry-based approach to teaching science (e.g., using the 5E model to plan instruction), identifying and implementing purposeful questioning techniques, and developing a community of science learners. In developing the reading list, my advisor first directed me to Wynne Harlen's book *Primary Science: Taking the Plunge* (2001). She explained that this book could act as a foundation from which to begin our conversations. We organized Harlen's chapters around our curricular themes. After reading a chapter from Harlen's book, we would outline any remaining questions I had and my advisor would suggest supplementary readings to provide me with a deeper understanding. For example, within Harlen's book Sheila Jelly describes the difference between productive and unproductive questions to teach science. Jos Elstgeest takes this idea a step further by distinguishing between five types of productive questions--attention-focusing, measuring, comparison, action, and problem-posing. While the descriptions these authors provide are clear for teaching elementary science, I questioned how to approach these kinds of questions with preservice teachers. In particular, I wanted to know what my goals would be for teaching the topic of productive questions. I also questioned where in the curriculum of the methods course this topic might be most effective, what topics should come before, and what would logically follow. My advisor directed me to read Duckworth's (1996) chapter on "Teaching as Research" to understand how to engage teachers with investigative questions and Harlen et al.'s (2003) book that uses productive question categories in actual science learning scenarios. We used these readings to sort out the answers to my curricular questions.

One outcome of this learning experience was my realization that the curricular goal of any methods course should be to develop simultaneously all four aspects of PCK—knowledge of learners, curriculum, instruction, and assessment. I thought about how the topic of productive questions could be a

springboard for thinking about each of these aspects. I also decided where in the course sequence this topic would work best. By the end of the independent readings course, my knowledge of what to include in the curriculum for an early childhood science methods course included: understanding young children and their science abilities; setting goals for science learning; designing inquiry-based instructional strategies, and developing assessment strategies that seamlessly integrate the science curriculum.

Developing PCK of Assessment for Teaching Teachers (Michele)

As a PhD student, through a formal internship course (see Appendix) taken for graduate credit, I had the opportunity to apprentice and then partner with a professor who taught an elementary science methods course. During the apprenticeship, I focused on methods course assessment. I observed the methods course in action, took field notes, analyzed and scored student work, reflected on assessment techniques through conversations with the professor, and reflected on my own methods course assessment ideas through personal journal writing. During the internship, I also partnered with the professor to teach and assess small sections of the course. I gained a greater appreciation of what and how I needed to assess within the methods course setting. It was the collective aspect of my learning experience that enriched my PCK for assessment for teaching teachers.

At the start of the internship I observed the professor employ multiple initial pre-assessments including: the Draw-A-Scientist Test (Chambers, 1983); card sort of elementary science teaching and learning (based on Friedrichsen & Dana, 2003); and science autobiography (Koch, 1990). We reviewed and discussed student responses during weekly meetings and in informal conversations. I learned about the professor's underlying PCK for assessment and gained insight into undergraduates' learning. As part of my internship, I evaluated student work independently and then compared my evaluations with the professor's. We discussed how we aligned student products to the scoring rubric, and how we would use what we learned to plan our instruction. At the conclusion of the semester, the professor asked students to construct a portfolio as an authentic summative assessment of student growth over the semester. During the last few weeks of class, I observed the professor guiding student metacognition in preparation for the portfolio. I perused portfolios to try my hand at assessing them and then observed some final one-on-one

interviews, listening to how the professor questioned the students to elicit their understandings and abilities.

Over the semester, I learned what aspects of a preservice teacher's knowledge to assess. I recognized that it was important to assess each preservice teacher's PCK for teaching elementary science, subject matter knowledge (e.g., understanding of the nature of science, inquiry skills, conceptual understandings) and general pedagogical knowledge. I also learned various strategies to assess students formally and informally. I became more facile at using rubric criteria to evaluate levels of sophistication. In addition, as we discussed student work, I learned how the professor used information from formative assessments to inform her practice. As a result of my experience reviewing portfolios and listening to exit interviews, I realized how I could ask questions to enable future teachers to apply their understanding beyond what was written in their portfolios. I also learned how to enable a student to be metacognitive-- by asking her to revisit the initial scientist drawing and explain how her ideas about scientists changed, and to attribute that change to course experiences. My developing PCK for assessment would be helpful the following year when I would teach independently my own section of the elementary methods course.

Developing PCK of Learners for Teaching Teachers (Deborah)

Teaching an elementary science methods course for the fifteenth time, I began the semester with an awareness of common preconceptions that preservice teachers bring with them to the course. I was used to teaching "solo" and delving into student work on my own, strategizing ways to help them consider their beliefs about teaching and learning science and develop new beliefs in my course and their field experience. However, during the past year I began a mentor/mentee relationship with a doctoral student in our program who was learning to teach the elementary science methods course and would teach independently in a future semester. Our mentor/mentee relationship began with an internship in which she attended my course and met with me after each session to debrief.

My own knowledge of learners was the result of carefully planned assessments and class activities designed to elicit my students' ideas about science and science teaching. Examples include the writing of a science autobiography (Koch, 1990), various card-sort activities (e.g., Friedrichsen & Dana,

2003), and a final portfolio assignment in which students reflect on their learning throughout the course. To develop the mentee's knowledge of learners, we focused on the ideas that students expressed in these assignments, as well as during class discussions and small-group activities. Over the course of the semester, we examined samples of student work and shared our respective evaluation of students' ideas. We summarized what we learned about our students and planned the next steps in instruction. For example, one theme that emerged from students' discussions and course assignments was the belief that science was an objective endeavor, carried out by strictly adhering to the scientific method. Together, we planned explicit-and-reflective activities (e.g., Akerson, Abd-El-Khalick, & Lederman, 2000) to address their ideas about the nature of science.

The following semester, the doctoral student became the instructor of her own section of elementary science methods. At this point, she had more independence, but also needed support to continue developing her PCK for teaching science teachers. As colleagues, we met on a weekly basis to discuss and compare our students' ideas and their work—what surprised her, and what matched her expectations, as well as how she might address their naïve conceptions and beliefs. We were able to compare students' responses to the lessons we co-developed, and to improve these activities to better address their ideas. As a mentor during this process, I helped her develop an awareness of what students would bring to her course, and also what they were capable of learning. However, our collegial conversations were also a great support for me as well—these weekly meetings afforded me the opportunity to make reflection a regular and deliberate part of my own practice, which has helped to deepen my own PCK. Our discussions allowed me to make explicit many of the tacit ideas that guided my teaching, including my knowledge of the naïve ideas and points of resistance that future teachers encounter when learning to teach science, such as their negative feelings about science and stereotypical views of scientists. This process enabled me to more closely align my PCK and practice in teaching future teachers, and to more effectively organize my course to support students in grappling with their feelings and ideas.

Developing Orientations for Teaching Teachers (Sandra)

I had been teaching elementary science methods for a number of years when I landed my first NSF grant as PI. The goal of the grant was to develop videocases of elementary teachers using best practices in their teaching. We would then use the videocases in our teaching of the elementary science methods course. The development of the videocases went according to schedule (see Abell & Cennamo, 2004). But when the videocases were finished, we faced the challenge of inventing pedagogies for using the videocases in the methods course. I enlisted the assistance of Lynn Bryan, a doctoral student.

Lynn delved into the research literature on case-based pedagogy and reflection in teacher education. We met regularly to discuss the literature. We designed and piloted reflection tasks to accompany the videocases. At this point we faced a major challenge. To use the videocases as we intended would consume a great deal of class time. Something else in the course would have to go to make way for the videocases. That is when Lynn and I started to consider our orientations to teaching science teachers. We had to make our goals and purposes for the course explicit to ourselves in order to judge what to keep and what to omit. Through our collaborative thinking, we came to understand that several orientations to science teachers were possible, but that our orientation involved an emphasis on teacher reflection in learning from experience (Abell & Bryan, 1997).

What this experience taught me was that, in addition to apprenticeships and independent teaching of a methods course, doctoral students can develop their PCK for teaching teachers in a research and development setting. Although Lynn was not teaching the methods course at the time, her involvement in the NSF grant facilitated our collaboration in designing new pedagogies for the elementary methods course. This work led to our co-construction of PCK for teaching teachers, including our new ideas about orientations. The reflective orientation (Abell & Bryan, 1997), guided our reformulation of the methods course to include reflection via videocases. Thus the mentoring experience also led to the expansion of my PCK for teaching the elementary methods course.

The Professional Continuum of Science Teacher Educators

Based on our learning experiences in becoming science teacher educators, we posit that a continuum of professional learning exists, much like that for K-12 teacher learning. We propose the professional continuum for learning to be a science teacher educator (Figure 3) as a model of our collective experience and as a guide for planning a cohesive program for the preparation and continuing education of science teacher educators. Across the stages of career development—from the apprenticeship of observation within one’s own teacher preparation program and elementary teaching, through the doctoral program and the beginning years in the professoriate—we suggest a scaffolded sequence of learning stages for science teacher educators. As an individual moves through these career and learning stages, he/she demonstrates a trajectory of developing PCK for teaching teachers. Below we discuss the learning stages and connect them to our PCK vignettes.

Observer

Just as undergraduate students lack the experience of how a classroom functions from a teacher’s perspective, a beginning PhD student lacks the experience of how a college/university classroom functions from an instructor’s perspective. The doctoral student has spent many years in the apprenticeship of observation (Lortie, 1975) to be a teacher educator, both during the formal teacher preparation program and as teachers themselves. However, they have viewed these experiences through the lens of a future or practicing teacher, not as a teacher educator. We propose that, early on in the science education doctoral program, the PhD student needs the opportunity to observe science teacher educators teaching methods courses. In addition to observing, the PhD student needs to reflect explicitly about how the instructor has developed and implemented PCK for teaching science teachers. Mark’s vignette demonstrates how observation can be partnered with other learning experiences to build PCK for teaching teachers.

Apprentice

To develop PCK for teaching the teachers, the science education PhD student needs to move beyond observing to being an apprentice. During the apprenticeship phase, PCK for teaching teachers

becomes an explicit focus. The apprentice learns specific knowledge and skills and has a chance to practice in ways that approximate the work of the veteran science teacher educator. Several strategies that are useful in apprenticeship learning experiences were illustrated in the vignettes. Mark learned about instructional strategies in his doctoral seminar and applied them under the tutelage of a veteran instructor. Meredith and her advisor co-developed an independent readings course to help Meredith develop her PCK for teaching early childhood science methods. Michele experienced a teaching internship where she focused on developing PCK of assessment for elementary science methods. Regardless of the strategy employed, the apprentice develops PCK for teaching teachers by actively engaging in discussion with the veteran and by practicing teacher education in small pieces (e.g., leading a discussion, writing a syllabus, scoring an assignment using a rubric).

Partner

The next learning stage in becoming a science teacher educator is the methods teaching partnership. During this stage, the veteran teacher educator and the doctoral student work as a team to design and implement a science methods course, or a section of a course. Together they consider all aspects of their PCK (knowledge of learner, assessment, curriculum, and instructional strategies) for teaching a methods course. As they co-teach, they provide each other with feedback about their instruction and about student learning. In Michele's vignette, we see her moving beyond an apprenticeship to a true partnership when she has the opportunity to teach and assess portions of the science methods course.

Independent Instructor

The student of teacher education moves from observer to apprentice to partner over several years in the science education doctoral program. At some point, he/she is ready to assume independent responsibility for teaching a methods course. The independent instructor synthesizes the PCK for teaching teachers developed in previous learning stages, and applies them to the task of designing, instructing, and assessing a methods course. The veteran can continue to play a significant role during this learning stage. Instead of working alongside the PhD student, the veteran can play a supervisory role,

periodically providing feedback on the student's teaching. Both Meredith and Michele moved on to independent instruction during their doctoral preparation. Veteran instructors provided feedback about their course design, instruction, and assessment.

Mentor

Developing PCK for teaching teachers is a career-long pursuit. Upon entering the professoriate, individuals assume the role of independent instructors, usually without the benefit of mentoring from a veteran. At some point, the new professor will be asked to mentor doctoral students to teach teachers. As the professor helps doctoral students develop PCK for teaching teachers, he/she also continues to reflect upon and enhance his/her own PCK for teaching teachers. Thus learning from mentoring is an important part of the professional continuum for learning to become a science teacher educator (see Figure 3). Deborah's and Sandra's vignettes illustrates how faculty members continue to build PCK for teaching teachers through mentoring doctoral students through the apprentice, partner, and independent instructor learning stages, in both teaching and research settings.

Policy Implications for Preparing the Next Generation of Elementary Science Teacher Educators

Implications for Science Education Doctoral Programs

Doctoral programs in science education, like those in many fields, lack explicit attention to developing future college instructors. If we are to prepare a high quality science teacher educator workforce, we need to turn this situation around. In particular, science educators need to examine the design and delivery of their doctoral programs. Our experiences as doctoral students and faculty members in science education help us to understand that doctoral programs must include a sequence of learning experiences that lead doctoral students on their trajectory of developing PCK for teaching teachers.

Recently at our university, we created an explicit policy for guiding our doctoral program in the area of science teacher education in the form of a set of guidelines for internships in science teacher education (see Appendix). These guidelines acknowledge that learning to teach science teachers is a process that moves individuals from observer to apprentice to partner to independent instructor during the

course of their doctoral programs. The guidelines provide structure to the process, by suggesting roles and responsibilities for the doctoral student and for the faculty mentor. We believe that these guidelines will enhance the learning experience for all individuals who desire to become science teacher educators, and could be adapted for use in other science education doctoral programs.

Implications for ASTE Policy

Learning to teach teachers in science teacher preparation programs should be an explicit goal of doctoral programs in science education. ASTE, as the only organization in the world strictly dedicated to the promotion of science teacher education research and practice, has a responsibility to develop policy that can guide programs that

Standard 7: Knowledge for Teaching Preservice Teachers. *The beginning science teacher educator possesses knowledge for teaching science teachers in preservice settings, including knowledge of preservice teacher learning, knowledge of methods course curriculum, knowledge of instructional strategies for teacher education, and knowledge of assessment for methods courses.*

prepare science teacher educators. We recommend that ASTE reconsider its Professional Knowledge Standards for Science Teacher Educators. Specially, we offer a new standard, Standard 7, that focuses on the development of knowledge about teaching future teachers (see box).

In Summary

Although our context was the development of elementary science teacher educators, we believe that our model of the professional continuum for learning to be a science teacher educator has a parallel form for the development of future middle and secondary science teacher educators. Furthermore, in our doctoral program, we recently implemented a college science teaching track. We believe that the professional continuum model could be extended to apply to those individuals who plan to work with science faculty and future faculty in teacher education settings. We believe that designing the infrastructure of learning sequences and strategies that make the development of PCK a regular and deliberate part of doctoral programs is essential to preparing the next generation of science teacher educators.

References

- Abell, S. K. (1997). The professional development of science teacher educators: Is there a missing piece? *Electronic Journal of Science Education*, 1(4). Retrieved 11/30/06 from <http://unr.edu/homepage/jcannon/ejse/ejse.html>
- Abell, S. K., & Bryan, L. A. (1997). Reconceptualizing the elementary science methods course using a reflection orientation. *Journal of Science Teacher Education*, 8, 153-166.
- Abell, S. K., Bryan, L. A., & Anderson, M. A. (1998). Investigating preservice elementary science teacher reflective thinking using integrated media case-based instruction in elementary science teacher preparation. *Science Education*, 82, 491-510.
- Abell, S. K., & Cennamo, K. S. (2004). Videocases in elementary science teacher preparation. In J. Brophy (Ed.), *Using video in teacher education* (Advances in Research on Teaching, Vol. 10) (pp. 103-129). New York: Elsevier Science.
- Akerson, V. L., Abd-El-Khalick, F., & Lederman, N. G. (2000). Influence of a reflective explicit activity-based approach on elementary teachers' conceptions of nature of science. *Journal of Research in Science Teaching*, 37, 295-317.
- Chambers, D. W. (1983). Stereotypic images of scientists: The Draw-A-Scientist test. *Science Education*, 67(2), 255-265.
- Cochran-Smith, M., & Zeichner, K. M. (2005). *Studying teacher education: The report of the AERA panel on research and teacher education*. Mahwah, NJ: Lawrence Erlbaum Associates.
- Davis, G., & Fiske, P. S. (1999). *The national doctoral program survey*. National Association of Graduate-Professional Students. Available: <http://survey.nagps.org/phdssurvey.html>
- Duckworth, E. (1987). *The having of wonderful ideas and other essays on teaching and learning* (2nd ed.). New York: Teachers College Press.
- Elstgeest, J. (2001). In W. Harlen (Ed.), *Primary science...taking the plunge: How to teach science more effectively for ages 5 to 12* (2nd ed.) (pp. 25-35). Portsmouth, NH: Heinemann.
- Fagen, A. P., & Niebur, S. M. (2000, December). *Preliminary results for the national doctoral program survey: 32,000 student experiences*. Paper presented at the Council of Graduate Schools 40th Annual Meeting, New Orleans, LA.
- Feiman-Nemser, S. (2001). From preparation to practice: Designing a continuum to strengthen and sustain teaching. *Teachers College Record*, 103(6), 1013-1055.
- Friedrichsen, P., & Dana, T. (2003). Using a card sorting task to elicit and clarify science teaching orientations. *Journal of Science Teacher Education*, 14, 291-301.
- Golde, C. M., & Dore, T. M. (2001). *At cross purposes: What the experiences of today's doctoral students reveal about doctoral education*. Available: <http://www.phd-survey.org>.
- Grossman, P. L. (1990). *The making of a teacher: Teacher knowledge and teacher education*. New York: Teachers College Press.

Harlen, W. (2001). *Primary science...taking the plunge: How to teach science more effectively for ages 5 to 12* (2nd ed.). Portsmouth, NH: Heinemann.

Harlen, W., Macro, C., Reed, K., & Schilling, M. (2003). *Making progress in primary science: A study book for teachers and student teachers*. New York: RoutledgeFalmer.

Jablon, P. C. (2002). The status of science education doctoral programs in the United States: The need for core knowledge and skills. *Electronic Journal of Science Education*, 7(1). Retrieved 11/30/06 from <http://unr.edu/homepage/jcannon/ejse/ejse.html>

Koch, J. (1990). The science autobiography. *Science and Children*, 28(3), 42-43.

Lederman, N. G., Kuerbis, P., Loving, C., Ramey-Gassert, L., Roychoudhury, A., & Spector, B. S. (1997). Professional knowledge standards for science teacher educators. *Journal of Science Teacher Education*, 8, 233-240.

Lortie, D. C. (1975). *Schoolteacher: A sociological study*. Chicago: University of Chicago Press.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Examining pedagogical content knowledge: The construct and its implications for science education* (pp. 95-132). Boston: Kluwer.

National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.

Nyquist, J. D., & Woodford, B. J. (2000). *Re-envisioning the Ph.D. What concerns do we have?* Seattle: University of Washington Center for Instructional Development and Research. Available: <http://depts.washington.edu/envision/about.html>.

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educational Researcher*, 15(2), 4-14.

Figure 1: A model of teacher knowledge (adapted from Grossman, 1990 and Magnusson et al, 1999)

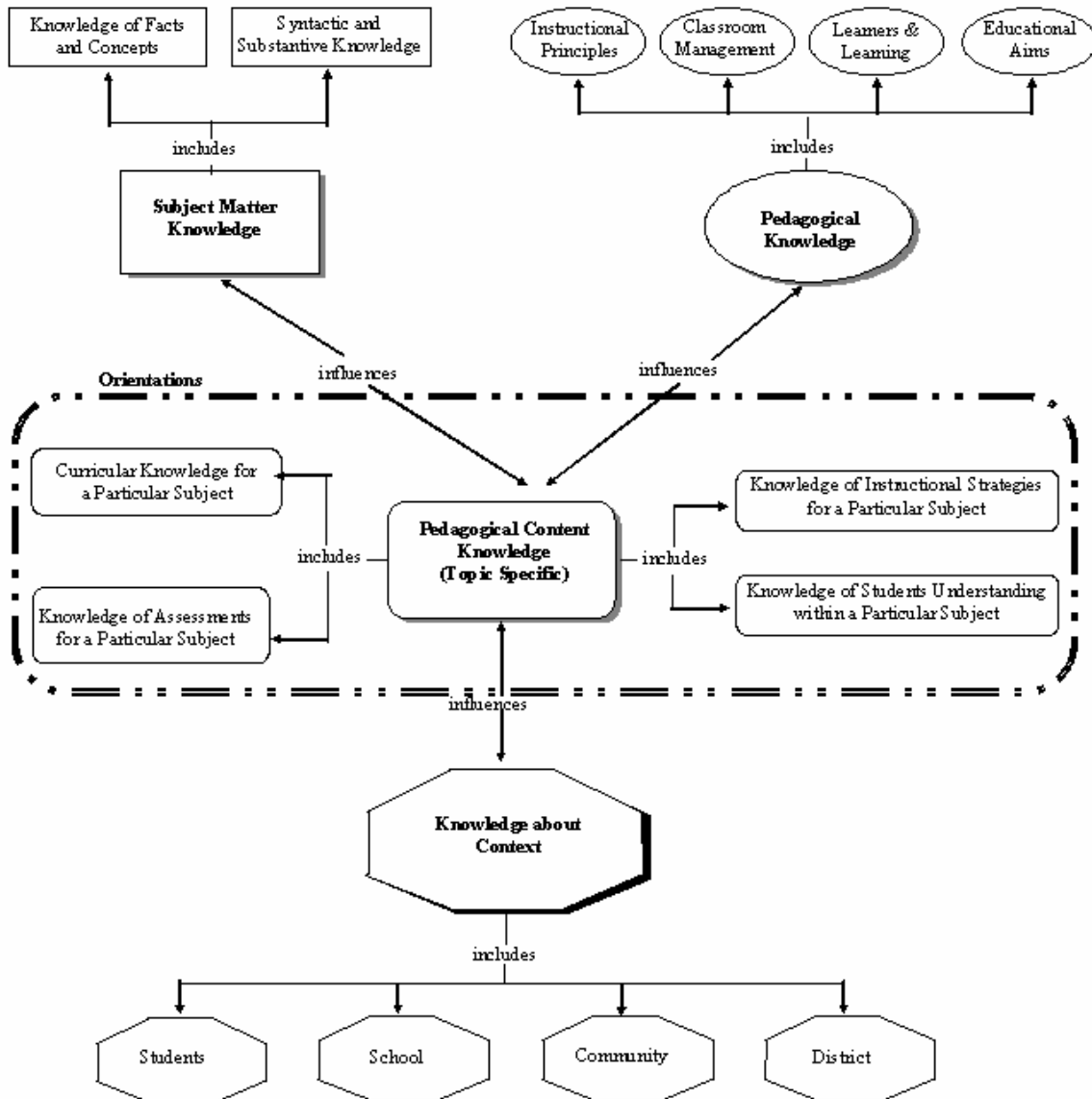


Figure 2: A model of elementary science teacher educator knowledge

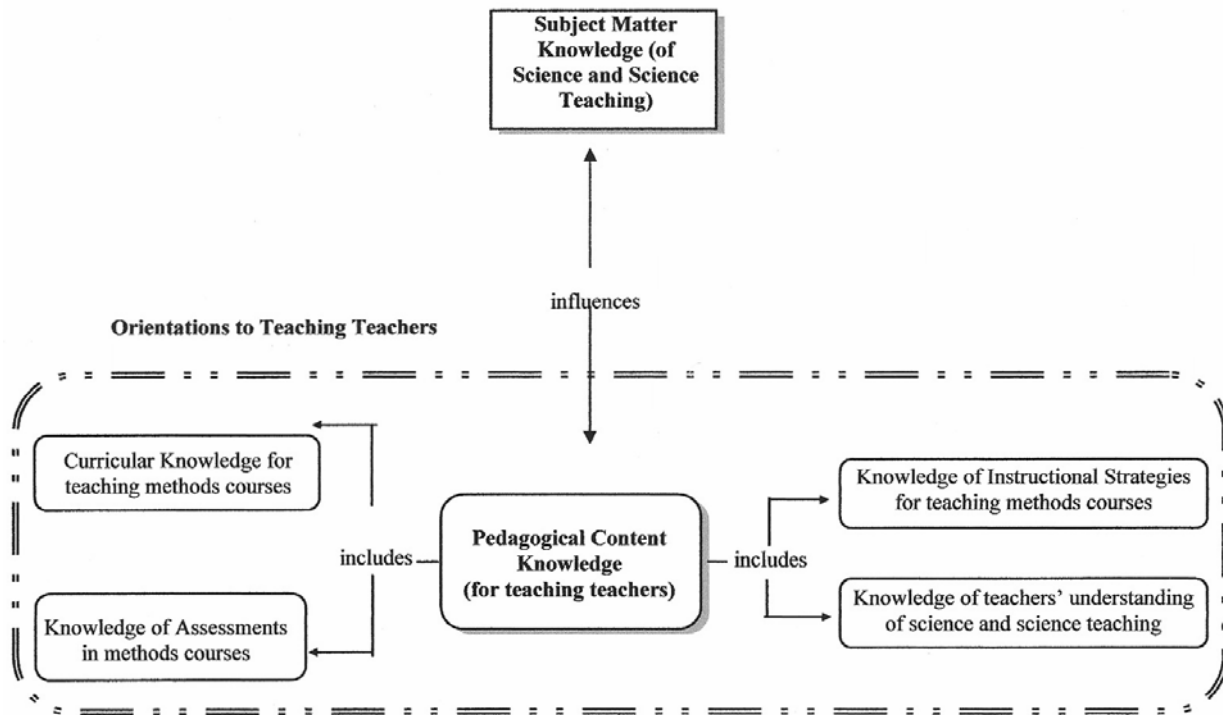
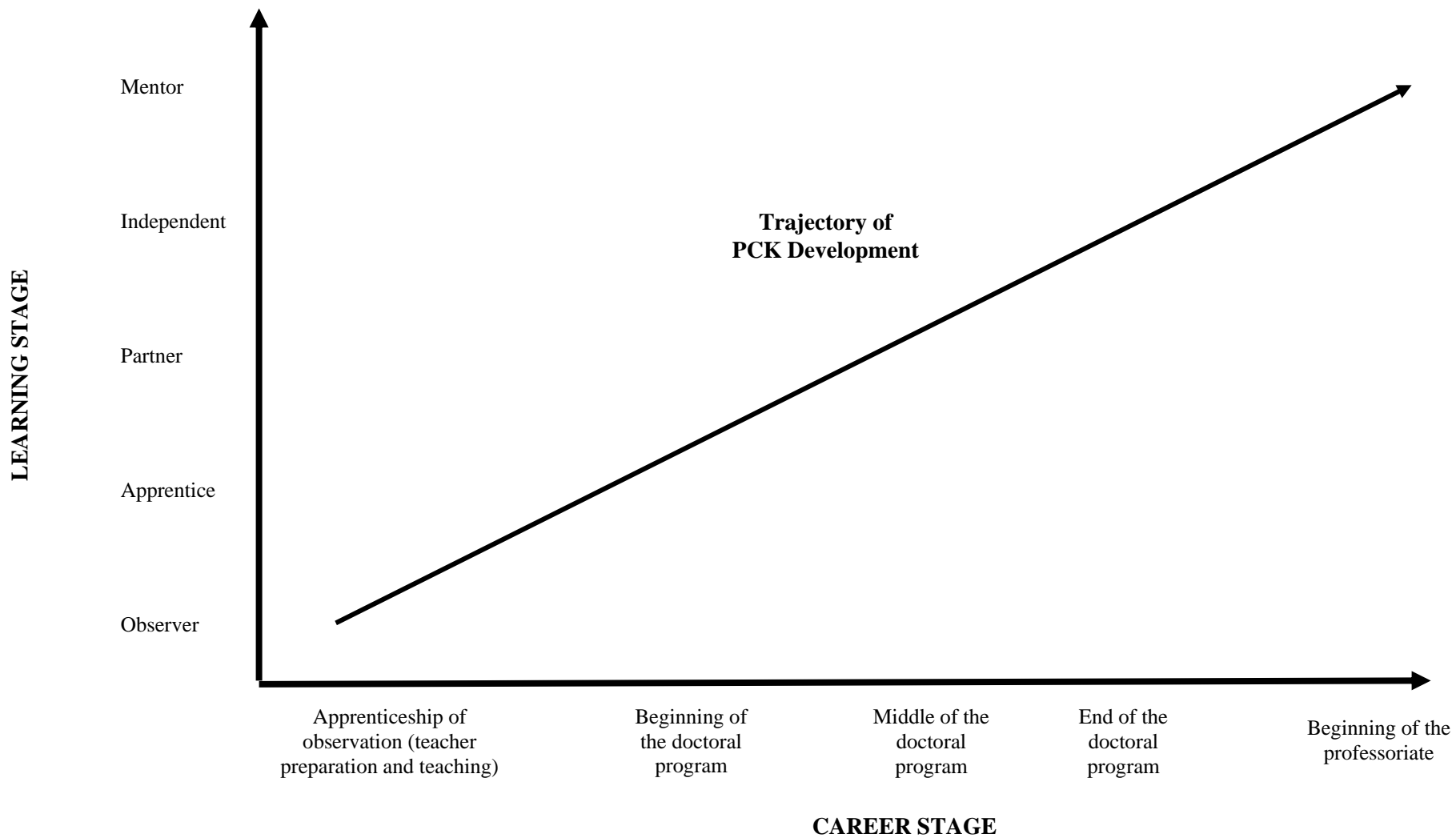


Figure 3: The professional continuum for learning to be a science teacher educator



Appendix

Science Teacher Education Internship Guidelines
University of Missouri-Columbia

Doctoral students in the elementary and middle/secondary tracks are encouraged to seek teaching assistantships to develop their knowledge and skills as teacher educators. The teaching assistantships are associated with the following courses: Early Childhood (TDP 4130); Elementary Science Methods (TDP 4280); Middle/Secondary Science Methods I (TDP 4630 or C&I 8717), II (TDP 4640 or C&I 8718), and Secondary Methods III (TDP 4650 or C&I 8917). Teaching assistantships are associated with teaching internships, which occur in two phrases:

Phase 1: Apprenticeship

During this phase, the student will apprentice with the assigned faculty mentor. The apprenticeship will consist of attending all class sessions of the methods course, as well as assuming limited teaching responsibilities as designated by the mentor. Students should enroll in C&I 8941 *Internship in Science Education* (3 credits). As part of the internship course, the faculty mentor and the student will develop a contract specifying the expectations for internship credit. This apprenticeship phase should occur prior to becoming a teaching assistant. In special cases, the apprenticeship may occur concurrently with the teaching assistantship. During the internship course, the student should also have the opportunity to partner teach some parts of the methods course.

Phase 2: Teaching Assistantship

After a successful apprenticeship, the student is eligible for an independent teaching assistantship. As a teaching assistant, the student assumes primary responsibility for teaching the assigned methods course. Teaching assistants should enroll concurrently in C&I *Internship in Science Education* for 1 credit hour. The following requirements are designed to support the teaching assistant:

- Before the semester begins, the teaching assistant must submit his/her syllabus, course reading and major assignments to the faculty mentor for approval.
- During the semester, the faculty mentor will complete a minimum of two classroom observations and hold follow-up conferences with the teaching assistant.
- The teaching assistant is responsible for administering both a mid-term and final course evaluation to elicit student feedback.
- At the end of the course, the teaching assistant will submit a course dossier consisting of the following materials: course syllabus, major assignments, student work samples, student evaluations, and a 3-5 page paper reflecting on the teaching experience.
- The faculty mentor will contribute a written, summative feedback to this course dossier.