TPC PROJECT DESCRIPTION

Project Title: Development of K-8 Teachers' Knowledge and the Transition from University Student to Professional

Sponsoring Institution: University of Delaware, Newark, DE 19716

TPC Project category: Research

Goals

To educate scientifically literate citizens (Bybee, 1993), several influential K-16 STEM education reforms urge teachers to use inquiry-based approaches to give all students opportunities to ask meaningful questions, collect and critically analyze information, and construct understandings that inform personal and social decision-making (AAAS, 1989; NRC, 1996, 2000a, 2000b, 2001b; NSF, 1996). This change in practice is especially challenging for K-8 teachers, who have fewer opportunities, compared to science specialists, to develop the deep understandings needed to support inquiry-based practices. Moreover, inquiry approaches are unlike the science learning experiences of most undergraduates and teachers. For prospective and practicing K-8 teachers, new roles and expectations associated with inquiry-based approaches can cause confusion and frustration that can block the change process (Smith, 1999, 2000).

University science and education faculty need research that informs their efforts to redesign their courses and teacher outreach activities to help preservice and current teachers adjust to and embrace inquiry-based approaches (Siebert and McIntosh, 2001; NRC, 2001b; NSF, 1996). Existing research leaves science teacher educators with several fundamental questions about how to best to foster these changes. For example, how do sustained inquiry learning experiences shape prospective and practicing K-8 teachers' understandings of science and teaching and learning science? How do teachers' beliefs about the nature of science, about teaching and learning, and about themselves as teachers affect their views of what they need to know to be teachers, and therefore whether they will embrace or resist unfamiliar, inquiry-based approaches? And how does a collaborative, inquiry-based professional development strategy like lesson study foster ongoing adaptation and growth in teachers' beliefs and practices?

This research project will use pedagogical context knowledge (PCxK) as a theoretical lens to critically examine the influence of the promising approaches advocated by STEM teacher education initiatives. Our reform-based Professional Continuum sets as a goal helping teachers move from views of learning as the *transmission* of knowledge to views of learning as the *creation* of knowledge. We will study students' and teachers' experiences with this transition in our Continuum, the intellectual and personal barriers they encounter, and what teacher educators can do to help. This project has elements that align with each of the eight objectives of the TPC Program (Table 1, Next page). The intellectual merit of this study is its use of a robust model of teacher knowledge in a mixed method, longitudinal design to critically examine the influence of promising approaches in STEM teacher education. The broader impact of this study will be to inform models of STEM teacher education that account for the interwoven intellectual and personal dimensions of the challenging transition to inquiry-based teaching.

Rationale and Related Literature

A critical step in K-16 STEM education reform is to provide prospective and practicing teachers with opportunities to learn STEM content and pedagogy through "perspectives and methods of inquiry" (NRC 1996, p. 59), like those we hope they will use with their own students (NRC, 1997, 2000a). The authors of the *National Science Education Standards* (NRC, 1996) clearly stated the connection between undergraduate science education and the prospects for improving K-12 science education:

> "Teachers of science will be the representatives of the science community in their classrooms, and they form much of their image of science through the science courses that they take in college…College science faculty therefore must design courses that are heavily based on investigations, where current and future teachers have direct contact with phenomena, gather and interpret data using appropriate technology, and are involved in groups working on real, open-ended problems" (NRC, 1996; p. 61).

Our group at the University of Delaware (UD)–including science and teacher education faculty, and teacher outreach professionals–proposes to study the effects of our reform-based Professional Continuum on preservice and practicing teachers' knowledge.

Table 1. Alignment of TPC Program Objectives and Proposed Research on PCxK

TPC Program Objectives	Project Goals & Characteristics
Advancing the knowledge base on the preparation, induction, enhancement, & retention of STEM teachers,….	To advance understandings of the development of science PCK across a reform-based teacher development continuum.
Fostering effective collaborations between the communities of STEM education…..	The integrated research & programmatic components of this project are a model collaboration among stakeholders.
Promoting scientifically based research that examines teacher learning of STEM content & pedagogy,…..	How future & practicing STEM teachers develop & integrate content & pedagogical understandings & practices.
Encouraging research on effective professional development experiences that enhance STEM teachers…..	Examine the impact of lesson study as a way to reflective practice in undergraduates and teachers.
Identifying, researching and piloting effective models & systems that enhance STEM teacher learning and…..	We study the impact of a model reform-based professional development continuum.
Understanding, through research, those instructional practices that enhance student learning in STEM disciplines.	Longitudinal & cross-sectional studies of the development of undergraduates' & teachers' science content knowledge.
Developing innovative resources, materials, tools & ideas for preparing and supporting STEM teachers and those who educate them.	Develop, implement, & disseminate instructional approaches & research tools & designs that support other researchers and practitioners.
Disseminating research findings, …..	A project website, conference presentations, practitioner & research publications and a national workshop on interdisciplinary

	collaboration in STEM teacher education.

The Professional Continuum for K-8 Science Teachers - The Focus of Our Research. The Professional Continuum at the UD is a graduated series of key elements designed to spur development of critical understandings, skills and attitudes as students move from being passive recipients of traditional instruction to being active participants in reform-based approaches. The Continuum extends beyond the undergraduate years by providing support for new and experienced teachers in two local school districts. The sum of these experiences is intended to engage students in a gradual, supportive process of building science understandings, identities as professional teachers, and enthusiasm for their profession.

The undergraduate portion of the Continuum forms the core curriculum of a new K-8 science major for elementary teacher education (ETE-science), as mandated by the No Child Left Behind Act. The first year Continuum courses, called Gateway courses, introduce students to active learning, guided inquiry, and problem-based learning (PBL) [Duch et al. 2001; Levin, 2001] approaches to learning earth, life or physical science. These early experiences begin the process of moving students toward new understandings of science, and of teaching and learning science. Along with an interdisciplinary perspective, there is a strong infusion of the nature of science and quantitative reasoning skills. In the new ETE major, all students will enroll in a Gateway science course, whether or not science will be their content major. To broaden the participation of underrepresented groups in science teaching, Continuum faculty will work with ASPIRE, UD's minority teacher education recruitment program, to actively recruit minority students in the Gateway courses to stay in the Continuum and to pursue an ETE-science major.

During the second year, students who stay in the Continuum (approximately 60, including all ETE-science majors and some ETE majors with other subject matter concentrations) take the Science Semester, previously developed with NSF support by the Senior Personnel on this proposal. The Science Semester integrates the science disciplines with an elementary science curriculum/methods course as a semester-long, 11-credit experience. The Science Semester features PBL-based interdisciplinary investigations (Allen et al., 2004), team instruction, field experiences, and student investigations of science topics and K-8 curriculum materials.

In the third year, ETE-science majors take a 'Bridge' science course that strongly links students to school-based experiences. The Bridge course builds on the content and instructional techniques of the Science Semester by engaging students in PBL investigations of interdisciplinary science and classroom applications. A middle school science curriculum and instruction course is taught concurrently and integrated with the Bridge course. Bridge courses are scheduled so that they allow for participation of inservice teachers seeking formal course work to build their professional qualifications.

A new component that we propose to add to the Bridge course is to link students with middle school science teachers in existing lesson study teams in local schools. Lesson study is a collaborative, teacher-driven method of instructional improvement and professional development (Stigler & Hiebert, 1999; Lewis, 2002; Takahashi & Yoshida, 2004). Through careful observation and reflective revision of instructional practice (Schon, 1987), lesson study creates school-based communities of teacher/learners focused on improving their classroom practice using evidence of student understanding. For nearly two years, middle school science teachers in Brandywine and Christina School Districts have been doing lesson study in partnership with the UD Mathematics & Science Education Resource Center (MSERC), led by Donham. These districts will be our partners in this research project. They were chosen based on their proximity, a history of successful collaboration in lesson study, and the diversity of their student populations. Brandywine School District is located in the suburban northeastern section of New Castle County, serves about 11,000 students, with nearly 40% African American or Latino/a students. Christina School District serves urban Wilmington and suburbs. It is Delaware's largest school system, with about 19,000 students, of which 38% are African American or Latino/a.

We propose to create Teacher-Scholar positions to help us implement the lesson study component and to serve as part of the research team. These experienced, exemplary teachers from our partner districts will teach a reduced course load in their home classrooms. Their classrooms will become educational laboratories as Teacher-Scholars serve as co-teaching and lesson study mentors for students in the Bridge course. As a component of their field experiences, Bridge course students will be full participants in co-teaching and lesson study, not just observers on the sidelines. The Bridge course and middle school curriculum and instruction courses will explore the science content (at a college level) and pedagogical approaches that underlie middle school science. We view lesson study as a natural extension into professional practice of the inquiry skills and attitudes we seek to cultivate through PBL approaches in the Continuum courses (Levin, 2001; Stigler & Hiebert, 1999).

As student teachers in their senior year, ETE-science majors are mentored by cooperating teachers who participate in other aspects of the Continuum, such as the Bridge courses, or as lesson study team members. The topics, curriculum materials and instructional approaches that students use as student teachers are strongly aligned with the Continuum course experiences they have had since their first year as undergraduates. The faculty involved in the Continuum will also serve as mentors to assist with content and pedagogical issues that may arise during the student teaching experience.

Finally, the Continuum includes support for new and experienced teachers in our partner distircts, who may be UD graduates, as they move from university-based teacher preparation into school-based practice. Lesson study will be the central element of this support system. By including school-based lesson study in our Continuum, we intend to foster fruitful connections between the communities of ETE-science majors and K-8 teachers.

Pedagogical Context Knowledge - The Theoretical Framework of our Research. The focus on inquiry-based science *content* and *pedagogy* across our Continuum presents an opportunity to examine the development of teachers' scientific and pedagogical understandings as they participate in a series of reform-based experiences. We will use science pedagogical context knowledge (PCxK) [Barnett and Hodson, 2001] as our theoretical framework. PCxK integrates two complementary research perspectives, pedagogical content knowledge (PCK) [Gess-Newsome and Lederman, 1999] and teachers' personal practical knowledge (Clandinin, 1985; Clandinin and Connelly, 1995). Combining these complementary theoretical perspectives makes for a robust framework for research on science teachers' knowledge.

Barnett and Hodson (2001) describe four interwoven elements of PCxK:

a) *Academic and research knowledge* refers to formal understandings acquired through structured experiences (courses, readings, conferences, etc) and reflection on those experiences. This includes science content knowledge, knowledge about the nature of science, and theories of student learning.
b) *Pedagogical Content Knowledge* refers to teachers' understandings of how to teach particular science topics effectively, such as sequencing topics, planning lessons, instructional strategies, likely student difficulties, and assessment techniques.

c) *Professional knowledge* is distinguished from the previous categories as "unconsciously reflected experience" (Barnett and Hodson, 2001; p. 438). Professional knowledge can be thought of as teacher 'lore' (Schubert, 1992), not to put its value into question, but to emphasize that these orientations to practice are held and reproduced within and among teacher communities (Wenger, 1998), and that they are often tacitly held.
d) *Classroom knowledge* includes "the knowledge that a teacher has of their own classroom and students" (Barnett and Hodson, 2001; p. 438). This knowledge is "rooted in the day-to-day experience of particular educational situations" and it "enables teachers to 'think on their feet'…" (Barnett and Hodson, 2001; p. 439). This shares qualities with what others call teachers' craft knowledge (Grimmett and MacKinnon, 1992).

Since our Continuum consists predominantly of prospective teachers' undergraduate experiences, it is important that the PCxK model accommodate their developing understandings, as well as those of practicing teachers. *Academic and research knowledge* is a category of teacher knowledge that is relevant for both future and practicing teachers. Deep and flexible science content and pedagogical understandings and skills are needed to implement inquiry-based approaches.

PCK (Shulman, 1986, 1987) has been a fruitful model for science teachers, science teacher educators, and researchers (Gess-Newsome, 1999; Loughran et al., 2001, 2004), and has informed efforts to improve teacher education and professional development programs (Smith, 2000; NRC, 1996; Zembal-Saul et al., 1999). Beliefs about how particular topics ought to be taught are shaped long before prospective teachers set foot in their own classrooms (Holt-Reynolds, 1992; Knowles and Holt-Reynolds, 1991). To break the cycle of reproducing traditional science pedagogies (NRC 1996), we need to better understand how traditional and inquiry-based undergraduate learning experiences differentially influence the development of teachers' PCK.

Teachers' *professional knowledge*, the craft lore that develops and circulates in teacher communities (Schubert and Ayer, 1992), is an extension of student lore that develops during K-12 and undergraduate experiences. We know from our experiences teaching reform-based courses like the Science Semester, and from research literature (Knowles and Holt-Reynolds, 1991; Holt-Reynolds, 1992), that that the way students make sense of instruction is mediated by beliefs about the roles of students and teachers. For many prospective teachers', inquiry-based approaches initially generate confusion and frustration, because the nature of teaching and learning are distinctly different from what they have come to understand as 'the way to learn science.' (Smith, 2000). Under these new circumstances, students' embodied lore about how to be a 'good' student is challenged. Some students experience this as a liberating release from learning science as a bunch of dull and unrelated facts. Others struggle to make sense of the new roles and expectations for teachers and learners. We propose to study students over several years that include inquiry-based and traditional experiences, to examine how their understandings of student and teacher roles change, and how teacher educators can help them transform traditional student lore into inquiry-based teacher lore.

Finally, *classroom knowledge*, teachers' practice-based understandings of their own classrooms and students, has precursors in prospective teachers' images of their future classrooms. We will explore how through coursework, field experiences, and professional practice, teachers' general images of classrooms shape and are shaped by firsthand experiences in particular classrooms.

Building on Existing Research. Existing work on PCK has empirical and theoretical shortcomings that our research will address. Despite the widespread reference to PCK in STEM education research literature and reform documents, the familiar boundary between 'content' and 'pedagogy' remains influential (Gess-Newsome, 1999; Zeidler, 2002). Most studies of science teachers' knowledge focus primarily on content *or* pedagogy (Gess-Newsome, 1999). Loughran et al. (2001, 2004) suggest that past challenges of accessing and representing science PCK have left us with few well-developed empirical studies. They develop a protocol to deal with these difficulties, which we adopt in our research design.

PCK also has theoretical limitations that reflect its historical context. The notion of PCK was developed during projects that sought to identify the knowledge held by expert teachers and to use that knowledge base to inform teacher education (Shulman, 1986, 1987, 1999). Much research on PCK, including that in science education, is oriented to what teachers *ought to* know, and to frame the outcomes of teacher education as formal, propositional knowledge and technical skills. This is a valuable, but limited, perspective. We seek to better understand what prospective and practicing teachers' *actually* know and how it develops in the contexts of their life histories and evolving identities as science learners and teachers. To include this perspective in our PCxK theoretical framework, we draw from research on personal practical knowledge (Clandinin, 1985; Clandinin and Connelly 1995; Barnett and Hodson, 2001).

Teachers' personal practical knowledge "is that body of convictions and meanings, conscious or unconscious, that have arisen from experience (intimate, social, and traditional) and that are expressed in a person's practices…It is a kind of knowledge that has arisen from circumstances, practices, and undergoings that themselves had affective content for the person in questions" (Clandinin and Connelly, 1995, p. 7). Personal practical knowledge links the development and expression of knowledge about science teaching to teachers' personal histories and identities (Bullough et al., 1992; Danielewicz, 2001; Kozoll and Osborne, 2004; Lave and Wenger, 1991; Lipka and Brinthaupt 1999; Nias, 1989; Wenger, 1998). This research documents how that teachers' experiences as learners shape their understandings as teachers (Holt Reynolds, 1992; Knowles and Holt-Reynolds, 1991). Smith's (2000) studies of preservice elementary teachers demonstrates how their science learning experiences "have been inextricably interwoven into their identities about who they are, whether they belong in scientific arenas, and what they can do" (p. 33). Reform-based experiences that challenge prospective and practicing K-8 teachers' understandings of science teaching and learning sometimes also challenge their understandings of themselves. To move science education reform forward, we need to better understand how teachers' self-understandings constrain and enable new understandings of teaching and learning science.

Research Questions

Using the Continuum as a setting for research, and PCxK as a theoretical framework, this project will address questions about the development of K-8 teachers' understandings of science and pedagogy that, in turn, inform unresolved challenges in K-8 science teacher education and professional development. We want to better understand how teachers' knowledge develops across repeated experiences with inquiry learning, and to account for the complex, personal dimensions of changing how science is taught. The questions fall under the four elements of PCxK outlined by Barnett and Hodson (2001): academic and research knowledge (ARK), pedagogical content knowledge (PCK), professional knowledge (PK), and classroom knowledge (CK):

- ARK#1 - How do prospective K-8 teachers' understandings of (a) science concepts, (b) the structure of science subject matter, and (c) and the nature of science change during undergraduate experiences in the Continuum?
- ARK#2 - How do new K-8 teachers' science subject matter understandings change to reflect their new roles and the contexts of classroom practice?
- PCK#1 - How does prospective K-8 teachers' science PCK take shape and change during undergraduate experiences in the Continuum?
- PCK#2 - How does the science PCK of new middle school teachers who participated in the Continuum change during their early years of teaching?
- PCK #3 - How does lesson study influence new and experienced middle school teachers' understandings of content, pedagogy, and their transformation into PCK?
- PK#1 - What is the relationship between prospective K-8 teachers' beliefs about being a good student (i.e., their 'student lore') and their beliefs about good science teaching (i.e., their 'teacher lore') during undergraduate experiences in the Continuum?
- PK#2 - How are prospective K-8 and practicing middle school teachers' personal histories and ongoing experiences related to their self-understandings as science learners and teachers?
- PK#3 - How does lesson study support individual and community change toward teacher beliefs and practices that are consistent with current STEM reform initiatives?
- CK#1 - How do prospective K-8 teachers' beliefs about effective science classrooms change during their undergraduate experiences in the Continuum?
- CK#2 - How do firsthand teaching experiences (e.g., field placements, student teaching, induction years) influence prospective K-8 and new middle school teachers' content and pedagogical understandings?
- CK#3 - How does participating in a lesson study community influence how new and experienced middle school science teachers' adapt general orientations to science teaching to particular classrooms and students?

Research Design

This project will use an interpretive research paradigm (Gallagher, 1991) and a mixed methods design (Creswell, 1994; Cohen and Manion, 1994; Frechtling and Sharp, 1997). This research is 'interpretive' (Erickson, 1986) in the sense that our primary interest is in the *meanings* that prospective and practicing teachers make of science, teaching and learning, and of themselves in the Continuum. We will use a mixture of qualitative and quantitative methods that are appropriate to our research questions, that bring different facets of teacher knowledge to the surface, and that offer complementary perspectives (Creswell, 1994).

Study Populations. This project has three study populations that are distinguished by the extent and location of their engagement in the Continuum (Table 2). Study Group I is comprised of students who enter the Continuum via the Gateway (freshman) course in years 1-4 of the project. Study Group II consists of middle school teachers who participate in lesson study in our partner districts. Study Group III contains three student cohorts that completed the Science Semester prior to the beginning of this project and who we will follow into their first years of teaching. These populations give us access to freshman preservice through 5^{th}-year teachers who have experienced some or all of the undergraduate Continuum components, as well as new and experienced teachers in lesson study groups. This effectively extends the longitudinal dimension of the study well beyond 5 years.

Sampling and Comparison Groups. Data collection and analysis will occur at two sampling levels: aggregated populations and group/individual case studies (Stake, 1995). At the population level, we will use techniques like content assessments, surveys, and reflective writing to collect data from a relatively large number of individuals (~200 respondents/yr). For preservice teachers in the study, population-level data collection will typically be embedded in course activities. The case studies will take our data collection and analysis to deeper levels of detail with a smaller number of groups and individuals. For example, we will use in-depth interviews to develop longitudinal case studies of 25-30 students from *each* of the four cohorts that begin the Continuum during this project (Study Group I). All ETE-science majors will be invited to participate, and we will invite a diverse sample of non-science majors to participate, based on demographics, their interest/comfort with science, and the grade level they want to teach. In our studies of the Science Semester, targeted invitations like these have worked well.

Table 2. Research Study Groups During each Year of the Project.

	Year 1 ('05)	**Year 2 ('06)**	**Year 3 ('07)**	**Year 4 ('08)**	**Year 5 ('09)**
Study Group I Students Entering Thru Gateway Course	Gateway course	Science Semester	Bridge course	Student teaching	1st year teaching
		Gateway course	Science Semester	Bridge course	Student teaching
			Gateway course	Science Semester	Bridge course
				Gateway course	Science Semester
Study Group II Teachers	Lesson study in middle schools	→	→	→	→
Study Group III Already Completed Science Semester	Cohort A 1st yr of teaching	→	→	→	5th yr teaching
	Cohort B Student teaching	1st yr of teaching	→	→	4th yr teaching
	Cohort C Junior Year	Student teaching	1st yr of teaching	→	3rd yr teaching

Our design incorporates opportunities for critical comparisons among groups and individuals with different levels of participation in the Continuum, and who are at different stages in their professional development. In general, the same instruments and techniques will be used to collect data from preservice, new, and experienced teachers, which will permit longitudinal and cross-sectional comparisons. At the population and case study levels, we will also include comparison groups with limited or no exposure to elements of the Continuum. For example, many ETE majors who do not concentrate in science will be exposed to only the Gateway (freshman) course, the remainder of their studies being in more traditional courses outside the Continuum. We will collect population-level data (using activities embedded in coursework) from samples of this group, and individuals from this population will be included in the long-term case studies.

Methods and Instruments. We will use a mixed method approach (Cohen and Manion, 1994; Creswell, 1994) to develop complementary perspectives on our research questions. All of the techniques and instruments are grounded in published research and/or have already been developed by us in our teaching and research.

<u>Subject matter diagrams</u>. To examine participants' understandings of science concepts, the structure and relationships of science disciplines, and general pedagogical concepts and practices, participants will be asked to draw diagrams to represent a concept or body of knowledge (White and Gunstone, 1992). For example, "Draw a diagram that represents the components of the concept of watersheds." This approach is adapted from studies of science PCK in preservice and inservice secondary biology teachers (Gess-Newsome and Lederman, 1993, 1995; Lederman et al., 1994).

<u>Content understanding essays</u>. These essay questions ask students to describe their understandings of fundamental science concepts. This approach is used in research on students' alternative conceptions in science (Osborne and Freyberg, 1985; Wandersee, et al., 1994). The questions will be embedded in course activities, and the data will complement the subject matter diagrams. Using methods that are well established in science education research (Wandersee, et al., 1994), the essays will be analyzed quantitatively to yield an overall score, and qualitatively to explore patterns in participants' conceptions.

<u>Standardized Surveys</u>. The Science Teaching Efficacy Belief Instrument form B (STEBI-B) [Enochs and Riggs, 1990; Riggs and Enochs, 1990] will be used to assess participants' beliefs about their abilities to effectively teach science. This yields a quantitative score that will be compared between groups and tracked over time in the aggregate and case studies. The Views on Science-Technology-Society (VOSTS) survey (Aikenhead and Ryan, 1992) has questions about many aspects of the nature of science. We will use a selection of VOSTS items to examine preservice teachers' beliefs about ways of knowing in science and the interactions of science and society.

<u>Reflective Writing</u>. This includes a formal written 'biographical survey' of students views of the nature of science (e.g., What is it that scientists produce when they do science?), and beliefs about science teaching and learning (e.g., What do you think you as a teacher will need to know and/or do to help students learn science?). Co-PI Ford and others in our group have used this survey for several years as a pre/post measure of belief change, including in the Science Semester. It is useful for population-level data collection and to complement other methods in case studies. Additional reflective writing will be collected on a regular basis as a part of courses and professional development activities.

<u>Interviews</u>. Two types of interviews (Seidman, 1991; Weiss, 1994) will contribute to the case studies. Semi-structured 'biographical interviews' draw on participants' learning histories and ongoing course/professional experiences to explore their beliefs about science, and about teaching and learning science (Bullough et al. 1992; Trumbull, 1999). These interviews explore how participants make sense of and/or resist the reform-based approaches to teaching and learning science they are experiencing firsthand. These 'critical conversations' make tacit understandings more tangible by grounding reflections in participants' life experiences. Videotapes of participants' teaching (see below) will also be employed to trigger and deepen discussions of classroom decision-making and actions (Shavelson et al., 1986).

The second type of interview, the ‘Content Representation (CoRe) interview,’ is a technique developed by Loughran et al., (2001, 2004) to document and portray science teachers’ PCK. CoRe is a structured interview that explores specific aspects of participants’ PCK for a particular science idea/concept, including the ‘big’ ideas in the concept, knowledge of students’ thinking, teaching procedures, anticipated teaching challenges and possible solutions, and ways of assessing student understanding. We will use the same CoRe protocol in case studies across the entire Continuum. (We will also modify the CoRe interview protocol into a ‘CoRe worksheet’ for use as a course assignment to collect population-level data.) For practicing teachers, we will add the complementary Professional and Pedagogical Experience Repertoire (PaP-eRs) protocol, in which researchers and respondents collaboratively produce written narratives of actual classroom practice that illuminate particular aspects of teachers’ PCK. PaP-eRs link the content knowledge represented in the CoRe to particular teaching decisions and classroom actions, to create multidimensional representation of PCK in action (Loughran et al., 2001, 2004).

<u>Classroom Observations</u>. Some of the case studies of students in the Bridge course, student teaching, and practicing teachers will include classroom observations of teachers’ practices. Results of the observations will be used in biographical and CoRe interviews to deepen the discussion, and to bring the relationship between what teachers say about teaching and what they actually do to the surface. The Reform Teaching Observation Protocol (RTOP) will be used to guide the observations, and to provide data that are comparable over time and across cases (Piburn et al., 2000). The RTOP was developed in an NSF-supported teacher education project at the Arizona State University. Using RTOP, classroom observers produce a quantitative rating that reflects the extent to which teachers incorporate reform approaches in their instruction (Adamson et al., 2003).

<u>Videotaping and Stimulated Recall Interview</u>. As part of the case studies, videotapes of participants’ teaching (e.g., field experiences, student teaching, and inservice teachers) will be recorded during the classroom observations. The tapes will be used in the interviews as sources of ‘critical incidents’ to stimulate teachers’ memories and prompt reflection on particular classroom decisions and actions (Shavelson et al., 1986). The tapes will then be saved and used in subsequent annual interviews to allow teachers to look back at their past performances and to reflect on patterns of change and stability in their beliefs and practices.

<u>Analysis of Coursework & Teaching Documents</u>. A variety of student coursework will be collected to supplement other sources of data in this study. Examples of these course materials include informal reflective writings, course projects and papers, and drafts of lesson plans. Teaching materials from practicing teachers include lesson plans, student handouts, lecture notes, and notes and reflections from lesson study sessions.

Data collection & analysis. Table 3 aligns our research questions with methods and instruments, the Continuum study groups and time of data collection, and sampling designs for population-level, case study, and comparison group data. For the research questions about academic and research knowledge (ARK#1-2), we use subject matter diagrams, content knowledge essays, VOSTS survey, and CoRe interviews. The pedagogical content knowledge research questions (PCK#1-3) rely primarily on CoRe interviews and worksheets, PaP-eRs teaching narratives in combination with CoRe interviews and classroom observations, classroom observations (RTOP), and videotaping/stimulated recall biographical interviews. Questions about professional knowledge (PK#1-3) and classroom knowledge (CK#1-3) will draw on data from all these sources, plus biographical interviews/surveys, and the STEBI survey.

In general, during the undergraduate portion of the Continuum (Study Group I), data collection will occur annually in the Continuum courses (i.e., Gateway, Science Semester, Bridge, and student teaching). Case study data (e.g., from interviews) will be collected pre/post- in the Gateway course, and then once annually near the end of subsequent Continuum courses. For practicing teachers in lesson study in our partner districts (Study Group II), primary data collection (e.g., interviews and observations) will take place near the beginning and end of each school year, with supplemental data collected throughout the year. Data collection for Study Group III cohorts will occur in years 1, 3 and 5. For Continuum graduates, data collection (e.g., surveys, interviews) will occur once near the middle of their first year of teaching (in late 2009).

Table 3. Methods and Instruments, Time and Group within the Continuum, and Sample Design to Address Research Questions. (Study Groups are described in Table 2.)

Research questions	Methods and Instruments	Continuum Time & Group	Sample design
ARK#1	Subject matter diagrams; Content understanding essays; VOSTS survey	Study Group I: pre/post assessments in Gateway course, then once/yr	Population-level: All students in Gateway, Science Semester, Bridge courses & Student teaching. Over 5 yrs ~820 total. Comparison group: Non-continuum, non-science education majors in junior yr methods course (30).
ARK#2	CoRe interview; Subject matter diagrams	Study Group III and Study Group I graduates that are teaching ('09)	Case studies: 5 per each Study Group III cohort (total of 15); 5 Study Group I graduates in 1st yr of teaching ('09). Comparison group: 10 students who completed 1-2 yrs of Continuum in their 1st yr teaching in '09.
PCK#1	CoRe worksheet; CoRe interview	Once/yr in every Gateway, Science Semester, and Bridge course and Student teaching	Population-level: CoRe worksheet for all students in Gateway, Science Semester, Bridge courses & Student teaching. Over 5 yrs ~820 total. Case studies: CoRe interview with all science majors (~20) in each Study Group I cohort (~80 total). Comparison groups: Population-level: CoRe worksheet for non-Continuum students in junior yr methods course (30). Case studies: CoRe interview with 10 non-science education majors per Study Group I cohort (40 total).
PCK#2	CoRe interview or worksheet; Subject matter diagrams; Classroom observation, video-taping & biographical interview	Study Group III: once in yrs 1, 3, 5 of teaching Study Group I graduates: once in yr 1 of teaching ('09)	Population-level: CoRe worksheet for Study Group III and Study Group I graduates ('09) (by email). Case studies: CoRe interview, diagrams, classroom obs./taping w/5 students from each Study Group III cohort (15 total) & 10 Study Group I graduates in yr 1 of teaching ('09). Comparison group: 5 students who completed 1-2 yrs of Continuum in 1st yr teaching in '09.
PCK #3	Same as PCK#2; plus PaP-eRs	Study Group II: twice/yr.	Case studies: CoRe interview w/~10 lesson study participants (~5 from each of two

	narratives to accompany CoRe interview		partner school districts). Comparison group: Cases from PCK#1 (for comparison of prospective and practicing teachers).
Research questions	**Methods and Instruments**	**Continuum Time & Group**	**Sample design**
PK#1 & PK#2	Biographical survey; Biographical interviews; STEBI survey	Study Group I: once/yr Study Group II: twice/yr	Population-level: Biographical & STEBI surveys for all students in Gateway, Science Semester, Bridge courses & Student teaching. Over 5 yrs ~820 total. Case studies: Preservice: Biographical interview w/all science majors (~20) in each Study Group I cohort (~80 total). Practicing: Biographical interview w/~10 lesson study participants (~5 from each of two partner school districts). Comparison groups: Population-level: Biographical & STEBI surveys for non-Continuum students in junior yr methods course (30). Case studies: Biographical interview w/10 non-science education majors per Study Group I cohort (40 total).
PK#3	Same as PCK#3; plus Biographical survey	Study Group II: once/yr	Case studies: CoRe interview w/~10 lesson study participants (~5 from each of two partner school districts) annually for 5 yrs.
CK#1	Same as PK#1&2	Preservice only: once/yr	Same as PK#1&2 above (preservice teachers only)
CK#2	Same as PCK#1&2 and PK#1&2; plus Reflective writing on field experiences	Study Group III: once in yrs 1, 3, 5 of teaching. Study Group I: once in yr 1 of teaching ('09)	Population-level: Preservice: Reflective writing, CoRe worksheet & Biographical survey w/ Science Semester students (60) New teachers: CoRe worksheet and biographical survey for all students from Study Group III cohorts & Study Group I graduates in yr 1 of teaching ('09) (by email). Case studies: All science majors (~20) in each Study Group I cohort (~80 total). New teachers: 5 students from each Study Group III cohort (15 total) & 10 Study Group I graduates in yr 1 of teaching ('09). Comparison group: Population-level: non-Continuum students in junior yr. methods course (30) & Student teaching (10). Case studies: 5 students who completed 1-2 yrs of Continuum in their 1st yr teaching in '09.
CK#3	Same as PCK#3 & PK#3	Study Group II: twice/yr	Case studies: CoRe interview w/~10 lesson study participants (~5 from each of two partner school districts).

Concentrating data collection within one or two periods each year leaves the remaining time to focus on analysis. Data analysis will begin with the first data collection and will be ongoing thereafter. Continuous data analysis will inform emergent decisions regarding research protocols and refinements in data collection strategies. In support of our plan for data collection and analysis, our budget includes funds for faculty teaching buy-outs and summer salary; ongoing support for a research coordinator (Fifield), Postdoctoral Fellows, Teacher-Scholars, and graduate research assistants.

Work Plan

Administrative Plan. Allen will have overall administrative responsibility, and three of the Co-PIs will be responsible for coordinating different areas of the project. All Co-PIs will serve on an executive committee that reviews major project 'deliverables' on an ongoing basis; this committee will also review applications for Postdoctoral Fellows, Teacher-Scholars, and Teacher-Leaders. A research committee, chaired by Fifield and including all members of the research team, will meet to present and discuss the latest data and analyses. A Continuum curriculum team, chaired by Madsen and including all Co-PIs, Teacher-Scholars and Nancy Brickhouse, Associate Director of the School of Education, will meet approximately three times a year to monitor effective implementation of the components of the continuum. Course teams will convene weekly meetings. Donham will coordinate lesson study along with 2-4 middle school Teacher-Leaders, and liaison with the Teacher-Scholars (see Personnel). The executive and research committees will communicate and meet with the external project evaluator designated by the NSF.

Research Plan. The schedule for data collection and analysis is described in the previous section and in Table 3. Our research team includes the Senior Personnel, two Postdoctoral Fellows (one in years 2-3 and one in years 4-5), two Teacher-Scholars (one in F06-Sp07 and one in F07-Sp08), two-four Teacher-Leaders, two graduate research assistants for the duration of the project, and undergraduate research assistants. Fifield will coordinate the research team, monitor research task assignments and implementation, play a central role in data collection and analysis, and review applications for graduate and undergraduate assistants. The science faculty (Allen, Donham, Madsen, Shipman) administer and analyze science content knowledge assessments. They will administer other population-level instruments in their courses. Fifield and other Senior Personnel will work with graduate students to analyze the population-level data. The Senior Personnel, Postdoctoral Fellows, and graduate assistants will all be involved in conducting the interviews and classroom observations. Fifield, Ford, Dagher, and Postdoctoral Fellows will analyze the written surveys, interviews, and classroom observation data. Teacher-Scholars will participate in the development of case studies of ETE majors in the Continuum. Teacher-Leaders will work with Senior Personnel to conduct and analyze interviews with practicing middle school teachers in lesson study groups.

Dissemination

Our dissemination plan includes the Internet, conference presentations, practitioner and technical publications, and hosting a national workshop on teacher education. In Year 1 we will create a project web site to share information about the Continuum, our research team and study design, and synopses of major research findings as they emerge. We will publicize the site at professional meetings, by requesting cross-links to other TPC projects, and by links to the UD's popular PBL website. The Senior Personnel, Postdoctoral Fellows, and Teacher-Scholars will present our preliminary findings at professional meetings, such as the education sections of their respective science discipline societies, the American Education Research Association, the

Association for Education of Teachers in Science, and the National Association for Research in Science Teaching. We will publish our findings in journals that span the practice-to-research spectrum. In year 4 we will host a 3-day national workshop on using PBL-based frameworks for interdisciplinary collaboration in STEM teacher education. The workshop will be in a series sponsored by the Institute for the Transformation of Undergraduate Education at the UD (see: http://www.udel.edu/itue). The workshop will include presentations about our Continuum curriculum model and our research study, a variety of activities that model PBL-based approaches in undergraduate education, and work sessions that support participants in adapting strategies for interdisciplinary collaboration to STEM teacher education at their own institutions.

Personnel

Senior Personnel. This project continues the collaboration of a team of science education scholars who have worked across traditional science department–science teacher education boundaries to design, implement, and document the Science Semester, an NSF-supported curriculum for future elementary teachers (See Results of Prior NSF Support). Allen, Dagher**,** Donham, Ford, Madsen, and Shipman will teach courses in the Continuum and participate in this research. Allen's research interests concern individuals' science content knowledge and how their self-understandings influence their acceptance of new ways of teaching and learning. Dagher's interests include preservice teachers science content understandings and how they are transformed into instructional plans. Donham's interests are effective use of PBL in a variety of classroom contexts, and on lesson study as a mechanism for peer-led professional development. Ford's research efforts will focus on preservice teachers' conceptions of curriculum and the ways in which their understandings of themselves as teachers change over the course of the Continuum. Madsen is initiating research on how teachers' knowledge of earth science concepts (e.g., watersheds, climate change) develops as they pass through the Continuum. Shipman's research expertise includes the use of semi-structured interviews and quantitative instruments to understand students' critical thinking abilities and their views of the nature of science. Fifield, a staff member at UD's education evaluation center, is interested in how teachers'/students' beliefs about the nature of science affects how they respond to reform-based science curricula.

Additional Members of the Research Team. Because of the time- and labor-intensive nature of this project, we will recruit additional research personnel. Postdoctoral Fellows in science education (2, two-year Fellowship appointments) will carry out research under the scope of the research questions. Postdoctoral Fellows will also co-teach a Continuum course each year. The Postdoctoral Fellows in this project will expand the scope of the Continuum to include a path for future university-level science educators. This is also the case for the science education graduate students (2 per year for the 5 years of the project), who will assist with data collection and analysis. Undergraduate assistants will help with logistical tasks.

Teacher-Scholars. Two Teacher-Scholars (Fall '06-Spring '07 & Fall '07-Spring '08) from the Brandywine and Christina School Districts will also participate. They will work with Senior Personnel on research involving case studies of ETE-science majors. They will continue to teach a reduced load in their middle school classrooms, where they will lead co-teaching and lesson study for Continuum students in the Bridge course. They will help ground our approaches and interpretations in teachers' realities and experiences.

Teacher-Leaders. Two-four Teacher-Leaders will work with Donham on aspects of the project related to lesson study teams of practicing middle school teachers. These individuals will be experienced middle school teachers from our two partner school districts. They will videotape the teaching of lessons by lesson study colleagues and develop vignettes that capture critical decisions and actions. These 'trigger tapes' will be used during lesson study, the Continuum bridge courses, and in biographical interviews with teachers to stimulate discussion about those choices and how they affected the lesson.

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