Re-Envisioning Teacher Preparation for Science in Washington State

The challenges in U.S. science education are often stated in crisis terms,

> At no time in history has improving science education been more important than it is today. Major policy debates about such topics as cloning, the potential of alternative fuels, and the use of biometric information to fight terrorism require a scientifically informed citizenry as never before in the nation's history. (NRC 2012a, p. 16)

Despite this urgency to expand opportunities to learn science, historically little attention has been paid to science education, or the preparation of teachers to teach science, in the elementary years. While there are no clear standards or universally accepted expectations for elementary science methods courses (Smith & Gess-Newsome, 2004), science in the elementary grades is starting to receive more attention due to an understanding that it is crucial that young learners have opportunities to build a strong foundation in science prior to middle school. Recent works have supported the case that young children are powerful thinkers who are capable of sophisticated scientific reasoning (Duschl, Schweingruber, & Shouse, 2007) and that our models and assumptions of reaching elementary children need to be examined (Quinn, Lee, & Valdes, 2012). This new emphasis on elementary science education, and recent research on the needs of preservice teacher education programs to address these issues, has guided our science education faculty to develop Methods of Research-based Education for Teachers (M.O.R.E.), a new model for science teacher preparation here in Washington State,

Issues in Elementary Science Education

Recent research focuses on elementary school science teaching and learning and seeks to address and resolve some longstanding challenges in elementary school science nationally and here in Washington State. Among some of the most important of these findings are:

Infrequency of science instruction in Washington's elementary classrooms: Despite the increasing attention on the need for science education, science is not taught regularly in many Washington public elementary schools. Survey data of Washington teachers detail the challenge. Of the 45 states surveyed, Washington had the highest proportion of teachers reporting teaching less than one hour of science per week, "Clearly, relative to other states, Washington's students are receiving significantly less science instruction in fourth grade and possibly in other elementary grades" (Wheeler & Ebert, 2011, p. 2). A clear finding from this data is that Washington elementary teachers and principals must have opportunities to teach science more frequently to improve student access to science and technology-related fields.

Teachers' inadequate science content knowledge: Science teaching in our elementary classrooms is often approached with inadequate rigor and without a focus on what matters most. In a national study, fewer than three in ten elementary teachers reported feeling well prepared to teach the sciences but 77 percent indicated that they were well qualified to teach reading/language arts (Appleton, 2007). If teachers do not feel comfortable with science and if it is not emphasized in high-stakes assessments, it will likely not be taught well or often.

Similarly, preservice elementary teachers (PSTs) often take a random assortment of science classes to fulfill their science content requirements (Banilower, Cohen, Pasley,

& Weiss, 2010). These classes are often delivered in large lectures, covering an encyclopedic breadth of content. Consequently, PSTs lack a coherent vision of how individual science concepts coalesce around bigger ideas. Teacher candidates also may not have had opportunities to study many of the science topics explored in elementary science curricula. As a result, it may be beneficial to generate preservice teacher education experiences where candidates are intentionally taught the science content that they will be responsible for teaching in ways that are developmentally appropriate and consistent with how children learn science.

The achievement gap: Student achievement in science depends on many variables, one of which is socio-economic status. In 2012, 66 percent of Washington State's fifth graders passed Science Measurement of Student Progress (OSPI, 2012). As we disaggregate the numbers further, however, they reveal that only 19.4 percent of the fifth graders who are English language learners passed this assessment. Similarly, in the authors' local school district, approximately 20 percent more of students attending more affluent schools passed the state science assessment than students at Title 1 schools. This trend is common across the nation, particularly among disadvantaged and non-Asian minority students (National Research Council, 2012a).

One of the reasons for this achievement gap also involves the challenging language demands in the field of science that may have particular impact on students for whom English is not a first language. The authors of the new Next Generation Science Standards (National Research Council, 2012b) acknowledge that these language demands are substantial, and researchers identify a wide range of science and engineering conceptual language that demand careful attention and may be very challenging to students for whom English is not a first language (Quinn et al., 2012). Research-based science teaching models how scientists generate new knowledge and provide a meaningful context for students to develop their own understandings. However, this approach places large demands on the acquisition of language. Ideally, “a practice-oriented science classroom [will] be a rich language-learning as well as science-learning environment, provided teachers ensure that ELLs are supported to participate.” (Quinn et al., 2012, p. 1). As a result of this pressing need to attend to the intense academic language demands in science and the need to support all students’ science learning, PSTs must have a strong understanding of how to make science language and concepts meaningful for every child.

Insufficient preservice preparation experiences: Teaching is a professional practice. Refining one’s teaching practice comes from the ongoing dynamic between personal beliefs, university coursework, and experiences in classrooms. Although PSTs often reference their field experiences as the most important element of their preservice programs (Bryan & Abell, 1999), extended field experiences do not always lead to more sophisticated instructional practices (Fullan, 1985; Orland-Barak & Leshem, 2009). Unfortunately, PSTs often align themselves exclusively with the practices of classroom teachers and unless experiences are coordinated with university science coursework and opportunities for metacognitive practice, teaching practice can fall into an exclusive “apprenticeship of observation” (Lortie, 1975, p. 61), remain traditional, and reduce the potential of being effective for supporting all learners (Ohana, 2004).

Another recognized challenge with PST education is field supervision (Marshall, 2005; Paris & Gespass, 2001; Power & Perry, 2002; Slick, 1997, 1998). Many elementary teachers feel uncomfortable teaching science, making it particularly challenging to mentor PSTs toward rigorous and developmentally appropriate science instruction. Mentors should support different facets of novices' professional development including pedagogical content knowledge (Shulman, 1986), but unfortunately, many generalist primary teachers either teach science inadequately or not at all and many primary teachers who become mentors "may not have mentoring expertise to guide effectively the PSTs' learning in primary science education" (Hudson, 2007, p. 201). Hudson (2007) also reveals that a substantial number of mentors for science instruction do not emphasize crucial areas like instructional planning, questioning strategies, or providing quality feedback following instruction. Thus, there is a need to focus on explicit professional development to enhance mentors' ability to focus PSTs on effective science teaching in ways that are developmentally appropriate for novice and beginning professionals. In order to be effective, such professional development opportunities should not be one-shot workshops, but rather more longitudinal in nature, with opportunities to mentor PSTs in the midst of guided practice over time (Bradbury & Koballa Jr, 2008; Meyer, 2002).

Re-Envisioning Teacher Preparation for Science

In order to address the issues of effective science learning and teaching for every student, the science education faculty, drawn from the College of Education and science departments at our university, re-designed its science preparation program. The faculty structured this work around three core principles of Bransford (2000). We chose this conceptual framework because it organizes a vast array of research into principles that helped us construct our courses and develop our instructional strategies. Three core principles that guide this conceptual framework are:

- Students enter the schools with preformed ideas that must be acknowledged and confronted before their ideas can change
- In order to retrieve and apply information, students must develop a rich conceptual framework that organizes a rich base of factual knowledge
- Student learning improves if the students understand the questions and monitor their own understanding.

We realized that there were two layers to this realignment work. First, our own teaching of preservice candidates had to be consistent with these principles and second, we needed to foster our preservice candidates' ability to develop and deliver instruction that was consistent with these principles.

PSTs often arrive to their science classes with an "array of preconceptions based on their everyday experiences" (Donovan, Bransford, & National Research Council, 2005, p. 399) that work against their efficacy. For example, while PSTs have often accumulated some basic science facts and concepts, they also have some common scientific misunderstandings (for example, confusions about phenomena like the cause of seasons or phases of the moon). PSTs have also frequently been exposed to the "scientific method" in their p-12 science education and believe, as a result of their previous experiences in science, that scientific knowledge advances via a rigid set of steps instead of opportunities to model and teach students how to confront and test their ideas. This is deeply embedded in our culture and our schools (Windschitl, Thompson, & Braaten, 2008).

Banilower et al. (2010) counter the idea of science being a series of procedural steps and describe research-based components of effective science teaching that include:

Motivation: Students do better if they are interested or invested in a subject. Discrepant events, a personal connection or real-life application can serve to boost motivation.

Eliciting prior knowledge: Students learn better when they connect their previous experiences to new knowledge. Students must also contemplate their existing understandings in order to bring ideas to the surface.

Engagement with phenomena: Students must engage with important science content that requires serious intellectual work. The method of engagement, whether an investigation, a reading, or lecture is not important as long as the learners are meaningfully engaged in important content.

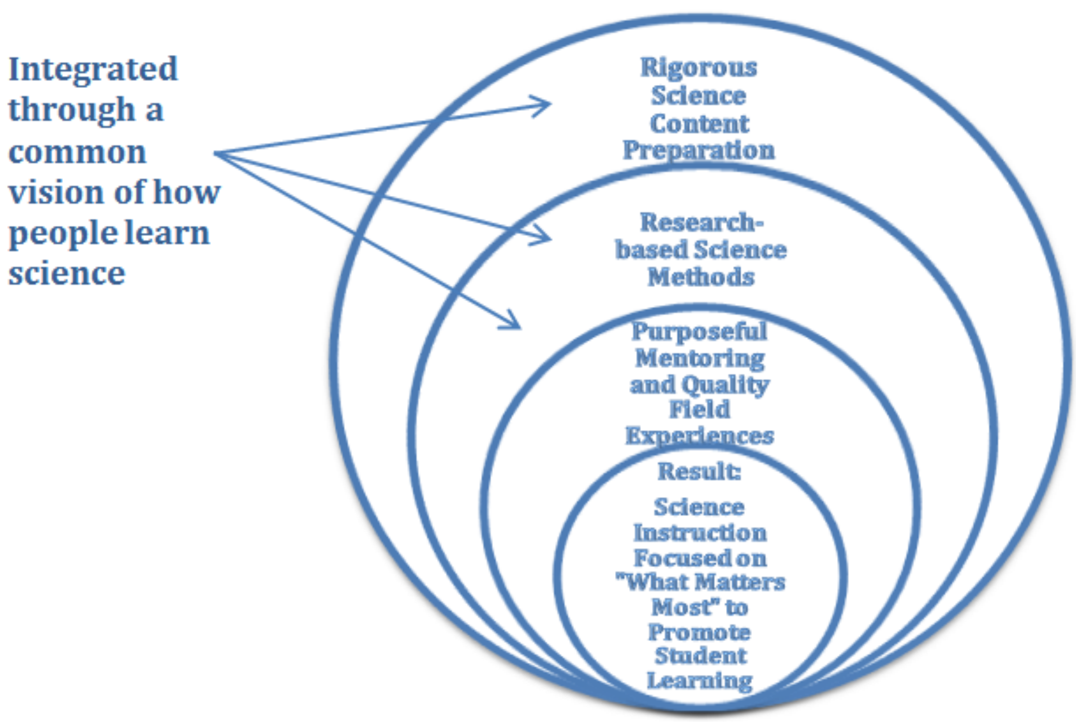
Using evidence to critique claims: As students use evidence to critique claims or inferences, they are more likely to change existing ideas and be able to retrieve and apply the ideas that they encounter.

Sense-making: Students need the opportunity to reflect and connect their emerging ideas. In sense-making, students reflect on their learning and how their ideas have changed. They also think about what other evidence they may still need that could change their claims.

In an audit of our preservice program, we found that we did not emphasize or coordinate many of these elements of effective science instruction. The following narrative describes some of the program revisions we created to make these elements more intentional and transparent to PSTs.

Program Context

The science component of the preservice teacher education program at Western Washington University includes content courses, a science-specific methods course, and a ten-week science practicum. The science sequence is based on a model of rigorous science content preparation, science methods courses that emphasize “what matters most” for exemplary science instruction, and high-quality field experiences that are coupled with strong and purposeful mentoring. These different components of this research-based preparation infrastructure are integrated through a common vision of how people learn science (Figure 1).



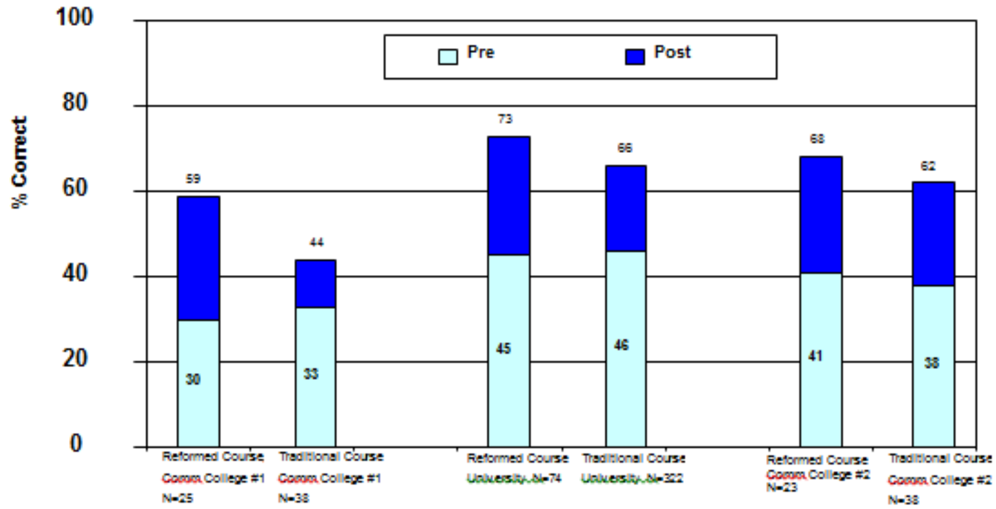
Improving PSTs’ Understanding of Science Content

In order to prepare competent elementary science educators, PSTs benefit from 1) learning science in a way that is consistent with how they will be expected to teach, and 2) learning the science content that is foundational to concepts taught in elementary schools. Funding from a previous grant from the National Science Foundation (NSF), the North Cascades and Olympic Science Partnership (NCOSP) provided resources to restructure and focus the teacher education program's science content sequence for PSTs. Teacher candidates at our institution have long been required to complete three natural science classes with labs. This led PSTs to complete a potpourri of science courses that usually were heavy in the "101" courses – large lecture-based classes for non-majors, modeling instruction that contradicted current research-based understandings of how children learn science. In response, we designed new general education courses in physical science (SCED 201), earth science (SCED 202), and biology (SCED 203).

The re-structuring of these science courses for preservice elementary teachers served multiple purposes: to improve their understanding of some big ideas in science, to connect how the PSTs learn science to how their future elementary students learn science (a model continued in the methods sequence), and to provide conceptual coherence around the big ideas in several scientific disciplines. Students are now required to complete these courses before they can register for their required course in science methods. These content courses borrowed heavily from the structure of Physics and Everyday Thinking (PET) from San Diego State University (PET Project, 2012) that uses an activity framework that leads students in a cycle of eliciting initial ideas, engagement with relevant phenomena, the use of evidence to critique claims, and sense-making. At the beginning of each activity, students are prompted to record their initial ideas about a concept and discuss them as a small group, allowing facilitators to elicit preconceptions and participants to hear the variety of initial ideas. The students then complete a series of activities designed to engage with examples and phenomena, confronting their initial ideas and using data to support conclusions. These steps lead to a sense-making process, where students reconsider ideas they held before the activity, document changes in their thinking, and relate ideas to broader concepts in science.

This activity framework (PET model) was a good choice for our content courses because 1) an external evaluation reported a significant improvement in student learning both in terms of test scores and in the depth of qualitative explanations of physical events when compared to more traditional lecture-based courses (Science and Mathematics Program Improvement, 2008) and, 2) the instructional materials were structured in ways known to be effective in science instruction (Banilower et al., 2010).

Our ongoing research on the effects of the three-course science content sequence reveals substantive increases in students' science content knowledge in physics, earth science, and life science in comparison to traditional lecture/lab science courses, even when the same instructor taught both courses (Blickenstaff & Hanley, 2007; Landel, Nelson, & Hanley 2011). For example, Figure 2 shows that students in the reformed science courses and the traditional science courses had similar pretest scores on an earth science content assessment, but the science education students had higher post-test scores and greater gains from pre- to post-test than their traditionally taught peers, even though both courses were taught by the same professor and the study was conducted at three different higher education institutions (two community colleges and one four-year undergraduate university).



Elementary Science Methods

In addition to understanding the science content they will be expected to teach, PSTs must study effective methods of teaching science. They must also be motivated to teach science and appreciate the value of a scientifically literate citizenry. Although the need is great, there are no clear standards or universally accepted expectations for elementary science methods courses (Smith & Gess-Newsome, 2004).

The intent of our elementary science methods course is to help improve the teaching and learning of science in elementary schools by graduating PSTs who appreciate the value of elementary science and are prepared to teach science effectively. In the initial activities, PSTs engage with science as a way of knowing. They extend their understandings from the content courses and are led to recognize that the instructional methods used in their content courses were intentionally designed around the tenets of how people learn science and effective science teaching. Elementary PSTs often have a naïve view that science is "static, memorized and authoritative" (Smith & Anderson, 1999, p. 774). The good news is that carefully constructed experiences can help students engage in a process of questioning and expanding their ideas about the nature of science

(Smith & Anderson, 1999). Methods courses are constructed to challenge candidates' naïve views of science and produce teachers who are capable of engaging in substantive science investigations with their students (Akerson & Volrich, 2006; Lederman, Fouad, Bell, & Schwartz, 2002).

Faculty also connect the knowledge gained in the science methods course to candidates' science teaching through direct application of the principles described by Bransford, Brown, and Cocking (2000) and elaborated in *Effective Science Instruction (2008),* where teachers solicit initial ideas, present a set of experiences to confront those ideas, and then lead students to generalize, make sense of, and apply those ideas. This theoretical framework undergirds the science methods and the science practicum courses, where PSTs experience then construct lesson plans using a template based on effective science instruction. Each of the elements of effective science instruction is tied deliberately to students' course experiences and their resulting plans for instruction.

After successful completion of the science methods course PSTs must then apply what they have learned in a science practicum. Usually situated in a local school, PSTs are assigned, with two peers, to an elementary classroom. PSTs are expected to use much of what they are taught in the methods course when they teach a science unit in the practicum. To reinforce concepts from the methods course, a common lesson template is used, as is a common observation rubric that focuses on eliciting initial ideas, engaging and analyzing evidence, and making sense of the content in the lesson.

One of the most important adapted components of the course is a new focus on supporting students' academic language. PSTs investigate the achievement gap in elementary science, confront assumptions, and propose solutions. They apply Guided

Language Acquisition Design (Chavez, 2012) and Sheltered Instruction Observation Protocol (Echevarria & Graves, 2011; Short, Vogt, & Echevarria, 2011) strategies to differentiate instruction in their lesson plans. Instructors focus on academic language in every lesson presented to the class, modeling effective academic language strategies for PSTs and helping to prepare them for the state-mandated Teacher Performance Assessment in their internship.

Preservice students are placed in pairs or threesomes to teach a district science unit. Preservice students are expected to modify these units in an effort to attend to such things as eliciting initial ideas, formative assessment, and sense-making. By the end of the yearlong internship, the PSTs in our teacher education program have completed over 250 hours of field experiences. Course evaluations indicate the science education practicum is powerful, with PSTs in charge of science teaching and learning in an elementary classroom for up to ten weeks.

In many institutions, supervision for both practica and student teaching is delegated to adjuncts. This often leads to a disconnect between the goals of the preservice program and the adjuncts' advice to the preservice students (Miller & Carney, 2009). At our institution, tenure-track faculty teach academic courses, supervise students in practica and the internship, and provide inservice professional development to cooperating teachers. Supervision of the preservice elementary science practicum by tenure-line faculty provides a consistent message to students, consistent support to cooperating teachers, and a continued experience in elementary classrooms to the faculty.

Mentoring Development

Although the research on mentoring is limited, it does reveal three components of effective mentoring to truly support candidates' early forays into science instruction to support learning. These include 1) developing mentors' expert pedagogical knowledge, 2) developing mentors' ability to use a palette of coaching and consulting strategies, and 3) developing mentors' ability to provide a dedicated focus on the components of effective science instruction to support science learning (Banilower et al., 2010; Hudson, 2003). As we will describe, these three attributes of high-quality mentoring are not a usual part of a teachers' professional development, so we are approaching them deliberately in a series of professional development experiences for our cadre of mentor teachers.

In the context of our field-based methods, we have frequently observed that cooperating teachers who host our students most often give PSTs feedback on classroom management versus dimensions more salient to science teaching. Since the university practicum supervisor cannot observe each lesson, we rely on the classroom teachers to provide feedback. We have found that this mentoring rarely focuses on important ideas in science teaching and that the feedback is often not constructed in a way that would help move PSTs to more sophisticated ideas about science teaching and ways to impact students' learning. As a response, we developed a series of mentoring workshops to emphasize that practices that are most important.

Alongside their preservice candidates, elementary cooperating teachers, who serve as mentors to PSTs, also need to understand the elements of effective instruction, how to conduct good observations, and how to give PSTs' effective feedback. In *MORE for Teachers*, we have developed two mentoring cycles to help mentor teachers' knowledge and skills in these areas. Each mentoring cycle includes the following: 1) an eight-hour Saturday workshop, 2) practice observing a PST's science instruction and giving the PST feedback, and 3) a two-hour meeting with other mentor teachers in their building (partnering schools each have eight mentor teachers) to learn from each other's experiences facilitating mentoring conversations. We place elementary science practicum students with teachers in a school during the fall quarter, and again in the spring quarter. Correspondingly, we conduct one mentoring cycle with the mentor teachers in the fall, and one in the spring. The fall mentoring cycle focuses on developing mentor teachers' understanding of the elements of effective science instruction (Banilower et al., 2010), while the spring mentoring cycle addresses mentor teachers' skills with facilitating learner-focused mentoring conversations (Lipton & Wellman, 2007).

The key elements of science instruction that provide the framework for the elementary PSTs' science content courses and methods courses also provide the foundation for the mentoring workshops and meetings. Mentor teachers learn about the elements of effective science instruction (Banilower et al., 2010) and learn strategies to facilitate learner-focused conversations (Lipton & Wellman, 2007) around the elements of effective science instruction. Mentor teachers observe PSTs as they teach in their elementary classrooms, using an observation guide that includes observable indicators for each element of effective science instruction, and focus their observations on elementary students' understanding of the intended science concepts for the lesson. After the lesson, the mentor teacher and PST have a conversation centered on the observation guide the teacher completed for the lesson. During the mentoring conversations, the mentor teachers focus the discussion on the impacts of the instruction on the elementary students, and practice various stances of mentoring, including consulting, collaborating, and coaching (MiraVia, 2012). Through the two mentoring cycles that include opportunities to engage with the research, with their PSTs, and with their mentor colleagues, partnering elementary teachers understand the elements of effective science teaching.

Impact

In this age of accountability, we are interested in the impact of these changes on the preparation of our teachers. Many of the refinements and changes made to our preservice science program have major resource implications. For example, staffing two practica courses every quarter is expensive. It is important to identify what impact these changes have made. But, as researchers in a social science, we acknowledge that this work is intricate and complex. Changes are often made in more than one component, complicating any analysis or attribution of cause.

Our interest in studying our changes prompted us to apply for funding from the National Science Foundation. In 2011, we were successful in securing a five-year grant to study what impact these changes have made to the preparation of elementary teachers. The study is broken into four separate studies:

1. Do students who took the reformed series of content courses differ in their outlooks, attitudes, and understanding of science from students who did not complete those courses?
2. Does the training of mentors improve the performance of PSTs teaching science?
3. Can PSTs who complete our methods class recognize elements of effective science teaching?

4. What is the long-term impact of our graduates as they enter the teaching profession?

We are currently collecting data to answer these research questions. The data consist of classroom observations, PSTs' analysis of written prompts based on classroom scenarios, interviews, and surveys. We include comparison groups for each study. We have started our second year of data collection and look forward to assessing the impact of each intervention.

Conclusion

Focused and intentional course- and fieldwork, strong collaborations between universities and schools (to support expert mentoring and opportunities to teach), and the effective use of specific teacher education strategies are important elements in an effective preservice program (Cochran-Smith, 2005). At WWU, we have re-designed our elementary science program to intentionally connect faculty, schools, and PSTs through research-based strategies for effective science teaching.

We are also collecting evidence that will clarify the links between teacher preparation programs and teacher candidates' learning and their practices in classrooms. We plan to continually consider emerging evidence to continuously improve the ways we influence our graduates' teaching and to identify the factors that impact their students' learning. This work can also serve to inform the work of other programs as we all work to improve the opportunities to learn science for Washington elementary students.

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