MORE for Teachers: A Program for Science Teacher Preparation

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ABSTRACT: This article summarizes how a group of undergraduate regional university faculty built a program for rigorous and research-based science teacher preparation at the elementary level—namely, the "Model of Research-Based Education for Teachers" (MORE for Teachers). First, we discuss the research upon which the program is built: (1) a preparation infrastructure that includes rigorous content, focused teaching methods, and integrated field experiences with an emphasis on quality mentoring from cooperating teachers and (2) a conceptual framework for how people learn science. Next, we describe how our science teacher education program is grounded in these two research-driven strands. The article concludes with a description of a 5-year longitudinal study, funded by the National Science Foundation, that is researching the impact of these components of effective science teacher preparation.

Learning to teach science, with a focus on improving student learning, is a challenging endeavor likely to produce challenges for even the most accomplished prospective teacher. The kind of practice needed to effectively teach science is a "complex, knowledge-intense undertaking" (Darling-Hammond, 2006a, p. 301) that requires novice candidates to bring substantive understandings of science content and teaching pedagogy to support students' learning. During their preparation, teacher candidates must straddle the "two worlds pitfall" (Feiman-Nemser & Buchmann, 1985; E. R. Smith & Avetisian, 2011), wherein they find themselves torn between the practices and pedagogies advocated at the university and those supported by their mentors and schools during their first teaching experiences.

In recent years, there has been a strong articulation of the importance of powerful and impactful science teaching to support students' learning. Standards and frameworks for science learning are now more rigorous than they have ever been (National Research Council, 2012), and there are increasing calls to emphasize the need for an active and scientifically literate citizenry that has the ability and disposition to think scientifically, to use scientific knowledge in problem solving, to intelligently participate in science-based issues to appreciate and feel a comfort with science, and to think critically about science to engage in the challenges that face our nation and world (Holbrook & Rannikmae, 2009, p. 276). Unfortunately, traditional science teacher preparation has provided an inadequate intervention to meet these rigorous goals, particularly in the preparation of science teachers at the elementary level. Typical preparation for science teaching has included activity structures that convey "either a passive and narrow view of science learning or an activity-oriented approach devoid of question-probing and only loosely related to conceptual learning goals" (National Center for Education Statistics, 2006, pp. 9–3).

This article summarizes how a group of undergraduate university faculty at a midsized regional university in the Pacific Northwest built a program for rigorous and research-based science teacher preparation at the elementary level. The program—the "Model of Research-based Education for Teachers" (MORE for Teachers)—is built on a conceptual framework based on research that synthesizes (1) what we know about how people learn science with (2) a preparation infrastructure that includes rigorous content, focused teaching methods, and integrated field experiences with an emphasis on quality mentoring from cooperating teachers. While there is ample information about the disparate components of highly effective teacher education, science teacher education, and quality mentoring programs (see Banilower, Cohen, Pasley, & Weiss, 2010; Darling-Hammond, 2006a, 2006b; Hudson, 2003, 2007; Luera & Otto, 2005; National Research Council, 2012; E. R. Smith & Avetisian, 2011; Windschitl, Thompson, & Braaten, 2011), these findings have rarely been coalesced and considered from a program design perspective and implemented within an undergraduate teacher preparation program.

Over the course of the last 6 years, a group of faculty situated in "Western Regional University" and three regional community colleges has collaborated to research and implement a teacher preparation program focused on what is most essential to prepare elementary teachers that are ready, willing, and able to engage in rigorous and ambitious science teaching to support students' learning. The purpose of this article is to describe the theoretical underpinnings that have led to the MORE for Teachers program's emphasis on a course and practicum design that includes rigorous science content preparation, instructional methods that emphasize how people learn science, and high-quality field experiences that are coupled with strong and purposeful mentoring. This article concludes with some information about how we are researching this interwoven approach to elementary science teacher preparation through a 5-year longitudinal study funded by the National Science Foundation.

Theoretical Framework

Reconceptualizing and redesigning our elementary science teacher education program required us to draw from theoretical and research about effective

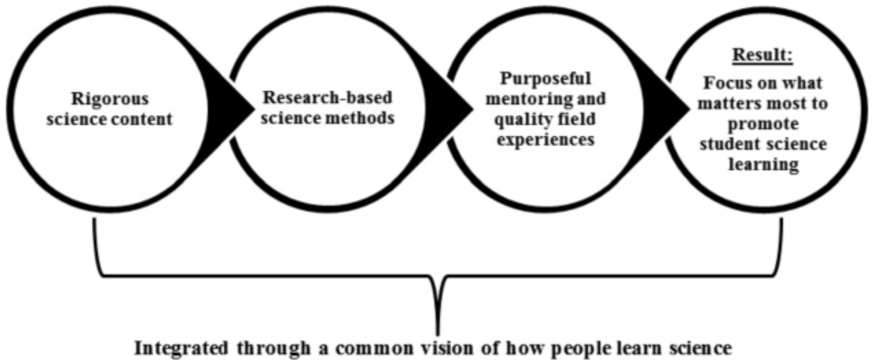

Figure 1. MORE conceptual model for research-based science teacher preparation.

teacher education (e.g., Darling-Hammond, 2006a), how people learn (e.g., Bransford, Brown, & Cocking, 2000), and high-quality science instruction (e.g., Banilower et al., 2010). These lessons include the need for coherence in a teacher education program design, 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).

The following sections highlight the lessons learned about these different spheres of teacher preparation.

Lessons Learned About Effective Teacher Preparation

Darling-Hammond (2006a, 2006b) has articulated research-based components of effective teacher education programs that will support the kind of learning necessary in the 21st century. Several of these components are very useful and directly applicable to a reconsideration of elementary science teacher education and include emphases on the following: conceptual alignment; opportunities for faculty to coplan across courses; closely interrelated courses involving applications in classrooms where observations occur; core ideas that are reiterated across courses and theoretical frameworks animating courses and assignments that are consistent across the program; extensive clinical work, intensive supervision, and expert modeling of practice; and extensive and intensely supervised clinical work integrated with course work using pedagogies that link theory and practice (Darling-Hammond, 2006a, p. 306). Darling Hammond also articulates the need for a "common, clear vision of good teaching that permeates all course work and clinical experiences" to create a coherent set of learning experiences and "strong relationships, common knowledge, and shared beliefs among school- and university-based faculty jointly engaged in transforming teaching, schooling, and teacher education" (p. 305). This emphasis on a common vision, a tight coherence and integration among courses, and an alignment between coursework and clinical work in schools exemplifies the model described here and developed by the MORE for Teachers team.

Lessons Learned About Quality Science Instruction

In recent years, researchers have articulated a "common vision of science instruction" (Banilower et al., 2010, p. 3). This vision is focused on teachers' abilities to foster scientific literacy: the ability to ask, find, or determine answers to questions derived from curiosity about everyday experiences and the ability to describe, explain, and predict natural phenomena (National Research Council, 1996). Recently, the National Research Council (2012) articulated several practices that are essential elements of K–12 science and engineering curriculum—such as asking questions; developing and using models to help develop explanations about natural phenomena; planning and carrying out investigations; analyzing and interpreting data; constructing explanations that provide explanatory accounts of features in the world; engaging in arguments from evidence; and obtaining, evaluating, and communicating information (p. 49). Rather than emphasizing the primacy of a single mode of instruction (lecture, demonstration, hands-on inquiry, etc.), a priority is given to the act of thinking about scientific ideas that are aligned to concrete learning goals and then relating those ideas to real-life phenomena.

Similarly, researchers have drawn on the work of Bransford and colleagues (2000) to articulate a process for science learning (Banilower et al., 2010) that includes the components of the following

Eliciting initial ideas: Instruction is more effective when it takes students' initial ideas into account and when these ideas are later confirmed or disconfirmed by engaging in relevant phenomena.

Intellectual engagement with relevant phenomena: Opportunities to investigate meaningful questions, engage with appropriate phenomena, and explicitly consider new experiences and knowledge in light of their prior conceptions: "designed to provide evidence for the targeted idea" (Banilower et al., 2010, p. 9).

Use of evidence to critique claims: Students will best understand science content and the scientific process if teachers encourage them to use evidence to support their claims and help them make sense of new, developmentally appropriate ideas in the context of their prior thinking and their understanding of related concepts.

Sense making: Opportunities for students to make sense of the ideas that they have encountered and explored by reflecting on initial ideas, engaging in metacognition regarding how their thinking may have changed, and connecting new ideas to what they have learned previously, thereby placing the lesson-learning goals into a larger scientific framework and organizing them into existing cognitive frameworks.

Explicit and transparent attention and practice with these four elements during disciplinary science courses, methods courses, and mentored field observations are described later as a cornerstone of the MORE for Teachers program.

Lessons Learned About Quality Preservice Science Teacher Preparation

As the evidence shows, we are coming to a more sophisticated understanding of how people learn science. The next question is how we can best prepare preservice teachers to teach science effectively, as there are no clear standards or universally accepted expectations for elementary science methods courses (L. K. Smith & Gess-Newsome, 2004). Research about elementary science teaching does not have a long academic history, and since educational research tends to be done by university professors engaged in teacher preparation, research into elementary science is an emergent area. The research that does exist suggests that the preparation of elementary teachers in science is not strong. Many elementary teachers feel underprepared to teach science—where fewer than 3 in 10 elementary teachers reported feeling well prepared to teach the sciences, more than 7 in 10 indicated that they were very well qualified to teach reading/language arts (Appleton, 2007).

This lack of preparation to teach science well has major implications. For example, in a large-scale study of elementary classrooms, Pianta (2012) found that the average fifth grader "received five times as much instruction in basic skills as instruction focused on problem solving or reasoning; this ratio was 10:1 in first and third grades" (p. 1795). Essentially, the author found that elementary teachers spend about the same amount of time per week in managing classroom materials as they spend on science instruction.

There is, however, a growing body of evidence on which to build an effective elementary science program that will support students' learning in the classroom. The following research-driven components have served to guide the development of our elementary science program.

Attention to explicit teaching of the nature of science. Elementary preservice teachers often have a naïve view that science is "static, memorized and authoritative" (D. Smith & Anderson, 1999, p. 774) instead of being dynamic and creative. 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 (D. Smith & Anderson, 1999). Methods courses that are constructed to challenge candidates' naïve views of science, and those that are empirical, tentative, inferential, theory laden, social, and cultural produce teachers who are capable of engaging in substantive science investigations with their students (Akerson & Volrich, 2006; Lederman, Fouad, Bell, & Schwartz, 2002).

Use of quality elementary science curricula used in schools. Teachers who use a quality curriculum experience greater student learning. The results are better with published, standards-based curricula than with teachers who write their own lessons (Weiss, Pasley, Smith, Banilower, & Heck, 2003). With a few exceptions, local schools use FOSS (i.e., Full Option Science System; Lawrence Hall of Science, 2007) in the elementary and middle school classrooms. While popular and considered one of the best materials available, there are issues. Teachers often use the materials mechanically with little attention to higher-order thinking (Pasley, 2002). Other elements of effective science teaching, such as eliciting initial ideas and sense making, are not strong in these materials. Therefore, we must teach preservice teachers how to examine and improve instructional materials. Preservice (and in-service) teachers require careful scaffolding and facilitated analysis to make reform-based modifications. While there are several ways to scaffold this, the use of curriculum topic study (Keeley, 2005) has proven to be a reliable way for professionals to critically examine science curricula.

Integration of the elements of effective instruction into lesson planning. Sense making (described earlier) helps students transition from their initial ideas to more scientifically based conceptions (Quinn, Lee, & Valdes, 2012) and needs to be built into the preservice science methods courses. In general, teachers (whether preservice or in-service) struggle with incorporating sense making into science lessons. In a large-scale study of science and math teachers, researchers found that fewer than 17% of U.S. classrooms attended to sense making (Weiss et al., 2003). Elementary teachers often confuse a teacher's summary of the collected data for sense making (Duschl, Schweingruber, & Shouse, 2007). Since most elementary science curricula also fail to include adequate attention to sense making, it must be structured into the lesson plan template that preservice teachers use. Preservice teachers need to understand the content, elicit students' initial ideas, and engage students in the collection and analysis of data to make sense of the big ideas in science.

Assessment for learning. Current research views see science assessment as seamless, without borders from preassessment to formative and postassessment (Abell, 2006) and set minute by minute versus weekly or monthly (Stiggins, 2005). Assessment is a critical skill for teachers to make instructional decisions to guide learning. Yet, teachers often lack the skills necessary to understand students' thinking. Preservice teachers require carefully designed experiences so that they can learn and apply assessment practices. In-class instruction on assessment can assist preservice teachers to understand assessment, but classroom practica can also undermine their implementation of research-based assessment practice (Buck, Trauth-Nare, & Kaftan, 2010).

Attention to academic language. Quinn and colleagues (2012) identify a host of science and engineering practices in the new science standards that demand careful attention. Inquiry-based science teaching models how scientists generate new knowledge; it also provides a meaningful context for students to develop their own understandings. This approach places huge demands on the acquisition of language:

> A practice-oriented science classroom can be a rich language-learning as well as science-learning environment, provided teachers ensure that [English-language learners] are supported to participate. Indeed it is a language learning environment for all students, as the discipline itself brings patterns of discourse and terminology that are unfamiliar to most of them. (p. 1)

Carefully supervised field-based learning. Teaching is a professional practice. Practice is based on a variety of elements, such as personal beliefs, university coursework, and experiences in classrooms. Teachers often reference their field experiences as the most important element of their preservice program (Bryan & Abell, 1999). But extended field experiences do not always lead to a more sophisticated practice (Fullan, 1985). Preservice teachers often align themselves with the classroom teachers, and unless experiences are coordinated with university science coursework, teaching practice remains traditional (Ohana, 2004).

The construction of the classroom community. A classroom community can dramatically affect student learning. Even in reform-minded classrooms, the type and quality of interactions between teacher and students and among students affect student understanding. Wood, Williams, and McNeal (2006) found that a classroom culture focused on inquiry and argument had the greatest chance of involving all students and providing common opportunities for all students to learn, "where children's thinking is extended to include the pulling-together of ideas to make a judgment, identifying flaws and strengthening arguments . . . as a process for establishing shared . . . meaning" (p. 248).

Lessons Learned About Quality Mentoring

Learning to teach poses a number of challenges for novices, including developing conceptions of science content and how to teach it, developing a conception of teaching and learning in the role as a teacher, learning to manage student behavior, and learning to work with colleagues (Smagorinsky, Cook, & Johnson, 2003). Mentors are uniquely positioned to support these different facets of novices' professional development, but unfortunately, the expertise that cooperating teachers bring to mentoring novice candidates varies widely. For example, 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 preservice teachers' learning in primary science education" (Hudson, 2007, p. 201). Hudson (2007) revealed that a substantial sample of mentors for science instruction did not emphasize crucial areas, such as instructional planning, questioning strategies, and providing quality feedback following instruction (p. 206). Thus, there is a need to focus on explicit training to enhance mentors' ability to focus preservice teachers on what matters most for support science learning. Researchers have also described how the best mentor development is not "one-shot" professional development but rather is more longitudinal and includes opportunities to practice mentoring preservice teachers in the midst of guided practice over time (Bradbury & Koballa, 2008; Meyer, 2002).

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: first, developing mentors' expert pedagogical knowledge (Darling-Hammond & Youngs, 2002; Hudson, 2007; Meyer, 2002); second, developing mentors' ability to use a palette of coaching and consulting strategies (Lipton & Wellman, 2007; MiraVia, 2012); third, 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 describe later, these three attributes of high-quality mentoring are not a usual part of a teacher's professional development, so we are approaching them deliberately in a series of professional development experiences for our cadre of mentor teachers.

MORE for Teachers: A Science Teacher Preparation Program

The research highlighted in our literature review indicates that effective science teacher preparation must include attention to several overlapping spheres of professional development that include (1) rigorous science content preparation, (2) instructional methods emphasizing what is most important for science learning, (3) course-connected field experiences to provide a venue for application, and (4) a focus on preparing highly qualified mentors who bring to the table nuanced understandings of science instruction and student learning as well as ways to engage in evidence-driven conversations. The following paragraphs describe the MORE for Teachers program as driven by these overlapping research-based spheres, and they conclude with a description of how we are investigating these various treatments through a 5-year longitudinal study.

Program Context

Our work in MORE for Teachers focuses on preparing elementary teachers to teach science. The program is situated in the Pacific Northwest at a medium-sized regional state institution with about 14,000 students. Students generally apply for admission to the elementary education endorsement program in their junior year after completion of their general university and academic major requirements. Each year, approximately 90 teachers are matriculated to the profession. Admission to the program is competitive, where generally half to a third of the students who apply are admitted. The math and science methods courses are taught in the College of Science and Technology, versus the College of Education, and faculty often hold joint appointments in education and these colleges.

Rigorous Science Content Preparation for Preservice Teachers

Funding from a previous Math Science Partnership grant from the National Science Foundation, entitled the North Cascades and Olympic Science Partnership, provided resources to restructure and focus the teacher education program's science sequence for preservice teachers. This sequence includes a set of three content courses, followed by two science methods courses. As in many institutions, the faculty members teaching the methods sequence were generally dissatisfied with the content preparation of elementary preservice teachers. At our institution, there was a requirement for a minimum of three science courses with labs before students could register for the science methods sequence; this represented a potentially rigorous foundation for science content. However, as in many institutions, the open-ended nature of the science course requirement led students to complete a potpourri of science courses, usually heavy in the "101" pool of courses—that is, large lecture-based classes for nonmajors. These courses modeled instruction that was largely incompatible with current research-based understandings of how people learn science. The classes were focused on breadth over depth and led to a classic case of student understanding that was "an inch deep and mile wide." The mishmash of courses also lacked a conceptual framework to give students a sense of coherence in science as they entered their teacher preparation.

As a result of the lack of coherence and depth in the science-focused courses for prospective teachers, we designed new general education courses in physical science (SCED 201), earth science (SCED 202), and biology (SCED 203). These courses were developed for a three-quarter sequence, taken by students before their science-teaching methods courses. These courses borrowed heavily from the structure of Physics and Everyday Thinking from San Diego State University (PET Project, 2012), which uses an activity framework that follows the science learning cycle (Banilower et al., 2010) described in the literature review (eliciting initial ideas, engaging with relevant phenomena, using evidence to critique claims, and sense making). This learning cycle was approached through earth science topics (e.g., plate tectonics), biology topics (e.g., cellular respiration), and physical science topics (e.g., force, motion, and energy). This restructuring of science courses for preservice elementary teachers served multiple purposes: to improve their understanding of some big ideas in science, to connect how the preservice teachers 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.

The science learning cycle is introduced during this three-course science sequence and then expanded in the science-teaching methods courses. At the beginning of each activity within a science content cycle, students are prompted to record their initial ideas about a concept and discuss them in small groups. Using small whiteboards, the small groups then share their ideas with the class, which allows facilitators to elicit preconceptions and all participants to hear the variety of initial ideas. Following this elicitation, the students complete a series of activities designed to engage with examples and phenomena. These engagements are frequently designed to encourage students to confront their common misconceptions and to allow them to construct knowledge in a sequential manner. Throughout these activities, students are required to use evidence to consider their data and draw conclusions. At the end of their engagement with phenomena, students are prompted into a sense-making process, where they reconsider the ideas that they held before the activity, document any changes in their thinking, and relate the concepts explored to broader concepts in science.

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 that from traditional lecture–lab science courses, even when the same instructor taught both courses (Hanley, 2007; Landel, Nelson, & Hanley, 2011). For example, Table 1 shows that students in the reformed science courses and the traditional science courses had similar pretest scores on an earth science content assessment but that the science education students had higher posttest scores and greater gains from pre- to posttest—even though both courses were taught by the same professor and the study was conducted at three higher education institutions (two community colleges and one 4-year undergraduate university).

Table 1. Reformed Science Courses Compared to Traditional Science Courses Taught by the Same Instructors

	Correct, %		
Course	*Pretest*	*Posttest*	*Students, n*
Biology			
Traditional	33	44	38
Reformed	30	59	25
Geology			
Traditional	45	66	360
Reformed	44	72	97

Note. Posttest scores significantly different, $p < .05$.

Instructional Methods That Emphasize What Is Most Important

The intent of the two-course elementary science methods sequence is to help improve the teaching and learning of science in elementary schools by graduating preservice teachers who are prepared to teach science effectively. After completing the science content requirements, students take a foundational K–8 science methods course that emphasizes the effective components of science instruction. Students then take a quarter-long practicum in which they teach (in teams of two or three) a 12- to 15-lesson science unit in a local elementary class while being supported by a skilled mentor (see description of the mentoring program in next section).

In her research on exemplary teacher education programs, Darling Hammond (2006a) found that such programs share certain features. In recent years, the science teacher preparation program at our institution has undergone many changes to incorporate these features, as follows.

Well-defined standards of practice for science education. The science education program spans three colleges and seven departments. Despite this breadth, faculty from each department scaffold student experiences to maximize growth and minimize redundancy. All science education faculty have received shared professional development on the elements of effective science teaching. This shared professional development has led to the creation of common learning targets for each course in the science education sequence. These targets are based on the elements of effective science teaching (Banilower et al., 2010), *How People Learn* (Bransford et al., 2000), and a focus on academic language in science (Quinn et al., 2012). Learning targets also reflect expectations from accrediting agencies and sets of national and state science standards.

Curriculum grounded in knowledge of the learner, content, and teaching. After two preliminary courses in education psychology, faculty connect that knowledge in the science methods course to science teaching through the application of the principles described in *How People Learn* (Bransford et al., 2000). Students read the executive summary and discuss the implications for each principle in teaching science. This discussion weaves throughout the science methods and science practicum courses. Lessons in the science methods also model effective science teaching through soliciting initial ideas, presenting a set of experiences to confront those ideas, and then leading preservice students to generalize, make sense of, and apply those same ideas.

Extended clinical experiences and university faculty linked to schools. Elementary preservice teachers are immersed in field-based practica from their first quarter in the elementary program. By the end of the yearlong internship, students have completed more than 250 hours of field experiences. According to preservice students' feedback, their experience in the science education practicum is one of the most powerful, since the students are in charge of teaching science to an elementary classroom for about 10 weeks. 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 eliciting initial ideas, formative assessment, and sense making.

At our institution, tenure-track faculty teach the academic courses, supervise students in practica and the internship, and provide in-service professional development to cooperating teachers. Supervision for practica and student teaching is commonly delegated to adjuncts, which often leads to a disconnect between the goals of the preservice program and the adjuncts' advice to the preservice students (Miller & Carney, 2009). 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.

Explicit strategies to confront assumptions and learn about diversity. The teacher preparation program weaves intentional strands regarding diversity and academic language throughout the program. Students research and construct a paper for an assignment entitled "Who Is Science For?" They investigate the achievement gap, confront assumptions, and propose solutions. Students apply strategies based on Guided Language Acquisition Design and the Sheltered Instruction Observation Protocol to differentiate instruction. There is a conscious focus on academic language in every lesson presented to the class, which models effective academic language strategies for preservice students and helps to prepare them for the state-mandated Teacher Performance Assessment in their internship. Several faculty have undergone professional development in strategies based on Guided Language Acquisition Design (Chavez, 2012) and Sheltered Instruction Observation Protocol (Echevarria & Graves, 2011) as well as a yearlong professional development course on academic language. These experiences are providing resources for the refinement of our courses with explicit attention to academic language.

Preparation for High-Quality Mentoring

Elementary teachers who serve as mentors to preservice teachers also need to understand the elements of effective instruction, how to conduct good observations, and how to give preservice teachers 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: an 8-hour Saturday workshop, practice observing a preservice teacher's science instruction and giving the preservice teacher feedback, and a 2-hour meeting with other mentor teachers in the building (partnering schools each have eight mentor teachers) to learn from others' 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 preservice teachers' 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) with preservice teachers around the elements of effective science instruction. Mentor teachers observe preservice teachers as they teach in their elementary classrooms, using an observation guide that includes observable indicators for the each element of effective science instruction, and they focus their observations on elementary students' understanding of the intended science concepts for the lesson. After the lesson, the mentor teacher and preservice teacher have a conversation centered on the observation guide that 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—which include opportunities to engage with the research, with the preservice teachers, and with mentor colleagues—partnering elementary teachers understand the elements of effective science instruction and have mentoring conversations centered on those elements.

Current Work: A 5-Year Longitudinal Study

Project Design

While we have a body of research that demonstrates how our science content course sequence has had a profound impact on the science content knowledge of preservice teachers, we are only beginning to understand the extent to which preservice teachers transfer and further develop their knowledge, skills, and dispositions after these science disciplinary courses. Currently, we are using a 5-year DRK-12 grant, sponsored by the National Science Foundation, to implement four concurrent studies that are researching the impacts of the various treatments described in the previous sections. In this last section, we describe our longitudinal research design that represents an investigation of the learning continuum for elementary science teachers, starting with a series of science content courses and moving through a mentored science methods/practicum sequence and into a yearlong student-teaching placement and the first few years of teaching. We will begin reporting the early and ongoing results of these concurrent research studies in the near future.

Study 1: The Impacts of the Three-Course Science Sequence

We are examining the pedagogical beliefs and skills of elementary preservice teachers within the science methods/practicum course sequence using a single-blind research design (Shadish, Cook, & Campbell, 2002) to examine the differences in the level and growth of key preservice teachers' beliefs and skills as a result of the number of courses they completed from the innovative science content sequence. The research hypothesis is that preservice teachers who successfully complete one or more of the elementary science content courses (the treatment group) will have and develop more sophisticated beliefs, skills, and products than will the preservice teachers who took none of the science content courses (the control group) in the following areas: beliefs about effective science instruction, self-efficacy as a learner of science, self-efficacy as a teacher of science, beliefs about the role of peer collaboration in learning science, ability to implement science lessons, and understanding of the important elements of effective science lessons. To determine the impacts in these areas, we are administering pre- and postsurveys, analyzing preservice teacher work samples, and videotaping science lessons that preservice teachers teach for their science practicum course.

Study 2: The Impact of High-Quality Mentoring

We are studying the impacts of the mentoring professional development on teachers and the preservice teachers they host in their elementary classrooms as part of the university science practicum course. We are also investigating teachers' interactions with preservice teachers in their practicum placements before and after professional development for the mentor teachers, focused on effective science instruction and effective mentoring stances. In addition, we are employing a one-group repeated measures design to study changes in teachers' mentoring practices, where the teachers serve as their own control group to eliminate threats to validity due to selection and history. We are further videotaping and analyzing the conversations that the teachers and the preservice teachers have after the former observe a science lesson taught by the latter, both before and after the mentoring workshops. In addition to describing the changes to teachers' mentoring practices, we are administering pre- and postsurveys to determine the impacts of the new mentoring program on teachers' and preservice teachers' beliefs about effective science instruction, effective mentoring practices, and the benefits of observations and feedback. Furthermore, we are observing the science instruction of preservice teachers who worked with trained mentors and those who did not. After continuing to study and improve the mentoring program, we intend to develop and offer a free web-based mentoring program for teachers who want to become effective mentors to novice science teachers, including excerpts from our videotapes of mentoring conversations.

Study 3: The Impacts of the Research-Based Science Methods Sequence

We are studying the impact of the university's innovative elementary science methods/practicum sequence on preservice teachers' beliefs and the quality of their science instruction during their yearlong student-teaching internship, compared to preservice teachers who complete their science methods/practicum courses through the university's off-campus program. Students in the off-campus program take a science method/practicum sequence that resembles the main campus program before the reforms to the main campus program. Our research hypothesis is that preservice teachers who successfully complete the elementary science methods/practicum sequence on the main campus (the treatment group) will have and develop more sophisticated beliefs, skills, and products than will the preservice teachers who took the comparable off-campus sequence, in the following areas: beliefs about effective science instruction, self-efficacy as a learner of science, self-efficacy as a teacher of science, beliefs about the role of peer collaboration in learning science, ability to implement science lessons, and understanding of the important elements of an effective science lessons. To determine the impacts in these areas, we are administering pre- and postsurveys, analyzing preservice teacher work samples, and videotaping science lessons that preservice teachers teach during their student teaching.

Study 4: Longitudinal Impacts During Induction

We are investigating the development of our newly inducted teachers' pedagogical beliefs about science instruction and the subsequent impacts on their students' achievement in science, in relationship to their schools' capacity to support effective science instruction. We have two hypotheses: The first hypothesis addresses the quality of the teaching and learning in the classrooms as a result of the knowledge and skills that the novice elementary teachers developed through our teacher education program; the second hypothesis addresses the extent to which a school's context and capacity support improved teaching and learning in the classrooms of our novice teachers. Our research hypothesis is that preservice teachers who graduate from our elementary teacher education program with stronger content knowledge in science and more sophisticated beliefs about the nature of learning science will demonstrate higher-quality instructional practices and student achievement in science during their first 3 years of teaching than will elementary preservice teachers who graduate from our elementary teacher education program with weaker knowledge and beliefs.

Conclusion

This article summarizes a model of science teacher preparation that is supporting our elementary candidates' learning throughout our current program at Western Regional University. The model integrates what we know about how people learn science with a preparation infrastructure that includes rigorous content, focused teaching methods, and integrated field experiences with an emphasis on quality mentoring from cooperating teachers. As we have described, MORE for Teachers is localizing these infrastructural components by situating them within science teacher preparation and attempting to weave them through a common and consistent vision of how people learn science.

Researchers have called for empirical evidence demonstrating the links between teacher preparation programs and teacher candidates' learning, between teacher candidates' learning and their practices in classrooms, and between graduates' practices and how much their pupils learn (Berry, 2005; Cochran-Smith, 2005; Darling-Hammond, 2006a; Jarvis, McKeon, Coates, & Vause, 2001). These three tiers of evidence are at the heart of our current research efforts in MORE for Teachers. We look forward to continuing our investigation of these components, separately and in concert, to improve the ways that we influence our candidates' praxis and to identify the factors that affect their students' learning. TEP

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