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Field Experience as the Centerpiece of an Integrated Model for STEM Teacher Preparation

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ABSTRACT: The purpose of this study was to provide a descriptive account of one pathway for preparing high-quality STEM (science, technology, engineering, and mathematics) teachers for work in high-need urban schools. In this account, we discuss the supports that STEM majors need in learning how to think about the content that they know well, through an educational perspective that focuses on teaching and learning. We also describe the approach that we use that integrates content knowledge, pedagogical content knowledge, and three extensive teaching co-op experiences to facilitate the transition from successful STEM undergraduate students to effective teachers of STEM content. We suggest that by using the teaching co-op experiences to both filter and reflect on content and pedagogical content knowledge, the STEM undergraduates develop a particularly strong foundation of knowledge for teaching.



President Obama has called for the creation of a national science, technology, engineering, and mathematics (STEM) master teacher corps as a first step toward achieving his ambitious goal of preparing 100,000 STEM teachers over the next decade (Office of the Press Secretary, 2012). By focusing on STEM education, President Obama aims to improve U.S. student achievement in mathematics and science and ensure that U.S. students are adequately prepared to compete in and contribute to an increasingly high-tech global economy. Results on the Program for International Student Assessment and Trends in International Mathematics and Science Study science and mathematics exams show that U.S. students fall behind their peers in other developed countries in science and mathematics abilities (Russell, Hancock, & McCullough, 2007). In addition, scores on the National Assessment of Education Progress indicate that too few U.S. students perform at or above proficient levels in mathematics and science (National Center for Educational Statistics, 2009). To keep pace with a global economy that trends toward an increase in science, technology, and innovation and compete with the growing number of European and Asian professionals already working in these expanding science and technology fields, we must do more to adequately prepare our own K–12 students in STEM fields (National Science Board, 2010).

One way to improve STEM education is to recruit, prepare, and retain highly qualified STEM teachers. The president's plan not only provides funding for high-quality pathways for the preparation of STEM teachers; it also reflects the belief that "excellent STEM teaching requires both deep content knowledge and strong teaching skills" (Office of the Press Secretary, 2012). Over the past 30 years, educational researchers have explored the knowledge needed for teaching, conceptualizing it as a unique blend of knowledge of content, pedagogy, curriculum, and student learning (Grossman, 1990; Grossman & Richert, 1988; Grossman, Wilson, & Shulman, 1989; Shulman, 1986, 1987). Because research consistently shows that teacher knowledge is an important factor that closely relates to teacher practice and student learning and achievement (Borko & Putman, 1996; Darling-Hammond, 2000; Hill, Rowan, & Ball, 2005; Mewborn, 2003; Rivkin, Hanushek, & Karin, 2005; Sowder & Schappelle, 1995), teacher education programs must design their preparation in such a way as to assist prospective teachers in acquiring and strengthening the different forms of knowledge needed for teaching.

The purpose of this article is to provide a descriptive account of one pathway for preparing high-quality STEM teachers. In it, we discuss the supports that STEM majors need in learning how to think about the content they know well, through an educational perspective that focuses on teaching and learning. We also discuss the integrated approach that we use, which includes content knowledge, pedagogical content knowledge, and an extensive teaching co-op in a high-need urban school, to facilitate the transition from successful STEM students to effective teachers of STEM content. We believe that this approach addresses and strengthens the content knowledge and teaching skills needed for successful STEM teaching. We suggest that by using their teaching co-op experience to filter and reflect on content and pedagogical knowledge, the students who followed this pathway developed a particularly strong foundation of knowledge for teaching.

Content Knowledge

Researchers and teacher educators agree that teachers must have a deep knowledge of the content they teach (Darling-Hammond, 2000; Munby, Russell, & Martin, 2001; Shulman, 1987; Wilson, Floden, & Ferrini-Mundy, 2001). The No Child Left Behind Act (2001), which requires that teachers of core academic subjects such as science and mathematics be "highly qualified," has intensified the focus that traditional and nontraditional teacher preparation programs have placed on teacher content knowledge. An increasing amount of research conducted over the past several years has explored the relationship among teacher content knowledge, teacher effectiveness, and student learning and achievement. For example, in secondary mathematics, Begle (1979) and Wilson and colleagues (2001) documented how teacher

content knowledge positively affected student learning. Goldhaber and Brewer (2000) further noted that teacher content knowledge and teaching certification positively influenced student achievement in mathematics. Monk (1994) found a positive relationship between the number of college courses completed by secondary mathematics and science teachers and gains in student achievement. At the elementary level, Hill and colleagues' (2005) empirical study of over 3,000 elementary teachers demonstrated that not only was teacher content knowledge a predictor of student achievement in mathematics; it also had a substantial effect on student learning of mathematics.

Although the aforementioned research highlights the importance of teacher content knowledge, many argue (Ball & Bass, 2003; Ball, Hill, & Bass, 2005; Grossman, 1990; Grossman & Richert, 1988; Grossman et al., 1989; Shulman, 1986, 1987) that content knowledge alone is not sufficient knowledge for teaching. Teaching requires knowledge of pedagogy, student learning, and curriculum, as well as an understanding of how these forms of knowledge relate to and build on one another.

General Pedagogical Knowledge and Pedagogical Content Knowledge

Historically, prospective teachers enrolled in a teacher preparation program have prepared for their own practice by completing content-specific courses and education methods courses to acquire the general pedagogical knowledge needed to teach their subject matter effectively to students. In this configuration, general pedagogical knowledge is conceptualized as generic knowledge of theories and methods related to the tasks of teaching (i.e., instruction, learning, assessment, and classroom management; Shulman, 1986). Since the mid-1980s, however, Shulman and colleagues (Grossman, 1990; Grossman & Richert, 1988; Grossman et al., 1989; Shulman, 1986, 1987) have argued that general pedagogical knowledge is not sufficient for teaching. Rather, teachers use a specialized form of knowledge—pedagogical content knowledge—which blends knowledge of content with knowledge of general pedagogy. This specialized pedagogical content knowledge, they contend, is unique to teaching because it entails knowing content as well as knowing how to teach content to students.

Over the past several decades, teacher educators in different disciplines have begun to explore and articulate what pedagogical content knowledge looks like. In science education, for example, pedagogical content knowledge is often defined as comprising knowledge of science and how to teach particular science content to students. Magnusson, Krajcik, and Borko (1999) expanded this definition to include (1) orientations toward science teaching, (2) knowledge and beliefs about science curriculum, (3) knowledge and beliefs about students' understanding of specific science topics, (4) knowledge

and beliefs about assessment in science, and (5) knowledge and beliefs about instructional strategies for teaching science. Van Driel, De Jong, and Verloop (2002) argued that prospective teachers develop pedagogical content knowledge for teaching science when engaged in an integrated sequence of courses that includes content, pedagogy, and field experiences. During this sequence, prospective teachers benefited from working directly with science education faculty and cooperating teachers who explicitly revealed their own pedagogical content knowledge for teaching science when working with prospective teachers.

Field Experience

Many of the education methods courses that prospective teachers take during their preparation include a field experience designed to provide the opportunity to work directly with K–12 students. The university-based methods courses have been created to provide prospective teachers with theoretical knowledge as well as practical application of that theoretical knowledge through field experiences. However, this combination often results in a disconnect between what prospective teachers learn about content and what they learn about pedagogy in the different locations (Clift & Brady, 2005; Ebby, 2000; Wilson et al., 2001; Zeichner, 2010). Over the past 30 years, teacher educators have implemented a number of approaches to assist prospective teachers in explicitly making more connections between what they are learning in methods courses and what they are learning in field experiences.

Many teacher educators use reflective models to assist prospective teachers in paying attention to and analyzing the important elements of teaching and learning discussed in methods courses and observed in field experiences. (Dewey, 1933; Rodgers, 2002; Schön, 1983; van Manen, 1977; Zeichner & Liston, 1987). Others have created clinical laboratories on campus where prospective teachers enact their practice with students, receiving immediate feedback about their teaching under the guidance of knowledgeable teacher educators (Ball, Sleep, Boerst, & Bass, 2009; Kazemi, Franke, & Lampert, 2009; Lampert, Beasley, Ghousseini, Kazemi, & Franke, 2011). Still others have found that asking prospective teachers to examine student thinking during field experiences not only supports prospective teachers in connecting what they are learning in methods courses and field experiences but also assists them in developing more sophisticated beliefs about teaching and learning, thus increasing their knowledge of content (Philipp, 2008; Philipp et al., 2007). These examples illustrate how methods courses and field experiences can provide a powerful way for prospective teachers to connect theory and practice while beginning to use the content, pedagogical, and pedagogical content knowledge they will one day bring to their teaching.

Integrated Models

Model 1: Content Knowledge, General Pedagogical Knowledge, Pedagogical Content Knowledge, and a Teaching Co-Op

[Q1]The Robert Noyce Teacher Scholarship Program supports undergraduate STEM majors and professionals in becoming K–12 mathematics and science teachers. The program provides funding to institutions of higher education in the form of scholarships, stipends, and academic programs for undergraduate STEM majors and postbaccalaureate students holding STEM degrees to obtain a K–12 teaching certification. Scholars enrolled in the program at an institute of higher education complete academic courses and teacher preparation courses while fulfilling a commitment to teach in a high-need urban school.

The Noyce scholar program at the private Midwestern university discussed in this article was launched in 2009, with its first cohort graduating in 2012–2013. The program was designed to integrate the strengths of three colleges (education, arts and sciences, and engineering) in developing a unique program for training highly qualified majors in STEM fields to teach in high-need urban middle or high schools. The program is modeled after the university’s engineering cooperative education program, the fifth-oldest co-op program in the United States, founded in 1919. Cooperative education is a program combining academic study and practical work experience—a learning and training partnership among the university, employer, and student—beneficial to all participants. Engineering co-op students at the university alternate semesters of school attendance with semesters of employment, after completion of their sophomore year. Students are required to complete a minimum of three alternating work terms with their co-op employer, typically extending the student’s undergraduate program from 4 to 5 years. The Noyce scholar program is an extrapolation of this engineering industry co-op model. The “work” terms for the *teaching* co-op model take place in three high-need urban middle and high school settings and involve extensive educational field experiences that allow students to meet teacher education standards.

Noyce scholars are recruited through promotion and participation in a series of Future STEM Teachers seminars for students who are open to a potential career as STEM teachers. At these informal gatherings, students meet with practicing teachers from local schools, STEM advocates, faculty members, and current Noyce scholars. These potential Noyce scholars, as well as current scholars, are invited to participate in paid summer STEM internships with local on- and off-campus STEM partners. The summer projects involve curriculum development, outreach projects, and working directly with K–12 students.

[Q1: “Model 1” and “Model 2” added to provide for B-heads, under “Integrated Models”—alright?]

In the spring of their sophomore year, STEM students interested in teaching enroll in a special section of the first course in the traditional teacher preparation program. This course is an essential introduction to education and is a foundational course before any teaching co-op experiences. The prospective Noyce scholars participate in a service learning project involving STEM tutoring at a high-need school, as well as specific reflection sections to discuss STEM education and teaching careers. This preliminary experience helps students determine whether to apply to the Noyce scholar program and commit to the three teaching co-op work terms.

During the summer, Noyce scholars enroll in the next foundational course and complete an introductory educational placement. This placement provides the scholars with initial exposure to the teaching profession in a middle school environment or with middle school students participating in an outreach program. The goal of this field placement is to develop the scholars' emerging understanding of child and adolescent development through their formal and informal interaction with students in Grades 6–8. This summer experience serves as a critical induction into the preservice phase of their teacher education program and directly prepares scholars for the upcoming fall semester when they are immersed in their first official teaching co-op.

The Noyce scholars begin the first teaching co-op in the fall of their junior year. This teaching co-op is a full-immersion experience at a high-need high school in which the Noyce scholars take nine credits of education coursework *on-site* while being assigned to a mathematics or science high school classroom and a supervising teacher. Scholars function under the supervision and direction of the classroom's cooperating teacher and a designated university mentor. The latter serves as the primary instructor for the related education coursework, which includes classroom management, lesson and unit plan preparation, student assessment, effective patterns of communication, understanding how to meet the needs of diverse learners, and teaching literacy across the content areas. The classroom teachers serve as important sources of support and mentoring as the scholars develop their skills to work competently with diverse students in small group settings, leading to a gradual transition into large group instruction. Scholars are encouraged to reflect on the reality of the classroom in comparison to the theories presented in their courses and to discuss their practices with one another and their instructors.

The Noyce scholars then return to campus for the spring semester of their junior year and fall of their fourth year of undergraduate study, working toward completion of their primary STEM major and the university core requirements for graduation. The second teaching co-op experience takes place during the spring of this presenior year.

This article focuses on the second teaching co-op, which addresses teaching science in secondary schools and is linked to two education courses: a general methods course and a middle–secondary science methods course. This teaching co-op focuses more tightly on the unique skills that the schol-

ars must acquire to become effective STEM teachers. This immersion experience occurs at a high-need middle school and high school. The scholars' areas of study and practice during this time include advanced science methods, effective teaching strategies, adapting instruction to meet the individualized needs of all learners, and designing, administering, and analyzing authentic assessments.

In the fall term of their fifth year of undergraduate study, the Noyce scholars participate in their third teaching co-op, which is the traditional student-teaching semester, again in a high-need high school. The scholars are under the direction of an assigned classroom cooperating teacher and a university mentor. The Noyce scholars then complete any remaining requisite courses toward their STEM major (or majors) in the spring term of their fifth year.

Model 2: General Methods and Middle-Secondary Science Methods

We designed the second co-op experience, which includes general methods and middle-secondary science methods, using the framework provided by the National Research Council (2010)[Q2] and the research related to content knowledge, pedagogical content knowledge, and field experiences discussed in this article. Taught jointly by two faculty from the College of Education, the integrated courses included a required 80-hour teaching co-op in a high-need urban school. The Noyce scholars learned about general pedagogy in the general methods course, such as lesson planning, using a variety of instructional strategies, and differentiating for the diverse needs of learners. In the science methods course, the scholars considered theoretical foundations for science learning, inquiry-based instruction, content considerations regarding scientific literacy, and constructivist teaching practices.

[Q2: Please include National Research Council (2010) in list.]

The purpose of the integrated course was to provide the Noyce scholars with opportunities to make direct connections between science content and teaching pedagogy by linking their pedagogical learning to direct work with students in a high-need urban school. We incorporated Kirchhoff and Lawrenz's (2011) sources of support to scaffold the Noyce scholars' learning. First, we structured the integrated courses so that the Noyce scholars worked with a cohort of their peers who were undergraduate students in the traditional teacher preparation program. This provided the Noyce scholars the opportunity to brainstorm ideas for lesson planning and teaching. Second, the science methods course was conducted on-site at the high-need school, which served as the location for the teaching co-op. Accordingly, the science teacher educator reflected with the Noyce scholars on their experiences and observations in the teaching co-op to support their understanding of the challenges of teaching science in a high-need urban school. This integrated model provided the Noyce scholars with authentic opportunities to reflect on their personal content knowledge and teaching practice.

STEM Candidates' Reflections on Content and Pedagogy Through the Lens of the Teaching Co-op Experience

In this section, we discuss examples of two scholars (Aaron and Mason, both pseudonyms) reflecting on their content knowledge, general pedagogical knowledge, and pedagogical content knowledge through their experiences in the teaching co-op. The data are drawn from the scholars' course assignments in the science methods course in which they were required to keep a science teaching journal, develop a unit plan, and produce a detailed rationale to guide their teaching practice. We believe that this type of reflection contributes to the development of knowledge for teaching (illustrated in Figure 1). We expect that developing knowledge for teaching before the student-teaching experi-

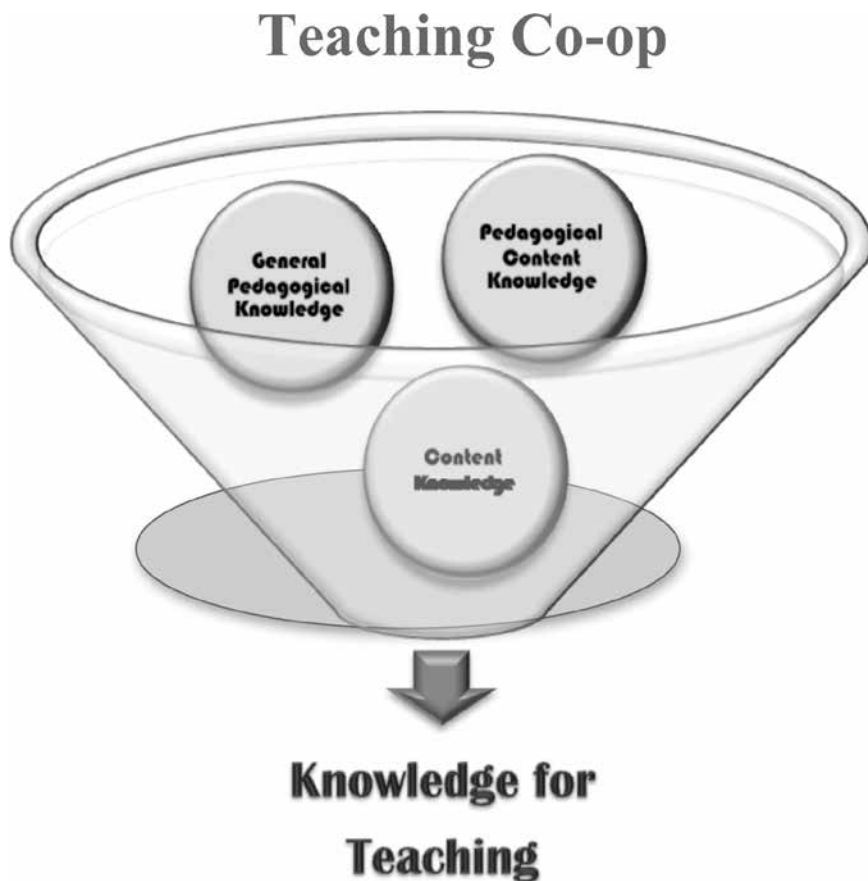


Figure 1. An Integrated Model for Preparing Effective STEM Teachers.

ence allows the Noyce scholars to strengthen their skills and approaches more extensively during the student-teaching semester.

Follow-up interviews with student-teaching supervisors, cooperating teachers, and cooperating school administrators consistently reported that the Noyce scholars were highly knowledgeable in science content, particularly comfortable working with diverse student populations, and able to adapt activities and explanations to be particularly relevant to the students with whom they worked. We attribute this comfort and adaptability in part to the way that the scholars used their extensive and integrated teaching co-ops to reflect on and accommodate education theory and teaching practices from their education methods courses.

Content Knowledge

Education professionals who observed the Noyce scholars' teaching consistently reported that their very high levels of content knowledge afforded them confidence and flexibility in teaching that was uncommon among preservice teachers. For example, the science coordinator for the high-need urban school where the scholars conducted their science teaching co-op emphasized that the scholars' content knowledge was far above average and that they were particularly ambitious in their approach to teaching, citing specifically Aaron and Mason's choice to develop and administer a unit plan on particle physics to a predominantly sophomore science class. However, this strong content background had to be focused and redirected toward helping students understand science. Early in the semester, the scholars expressed strong opinions that all students should be required to know complex physics topics and that this learning would be promoted by lecturing the students about content. Successful students, the scholars believed, would then be required to study assigned text to really "get" the complex material, much like the scholars were required to do at the university level. During the teaching co-op, the scholars were able to grapple with the relationship between their extensive content knowledge and what was appropriate and necessary for their students to learn and what science knowledge is important for a scientifically literate high school graduate. In his teaching journal, Aaron reflected on his science knowledge as opposed to what was important for his secondary students:

I think it is easy to forget the content that was covered in high school while attending college. I have often thought, while sitting in classical mechanics, when will I ever teach my students about Hamiltonian transformations? This detachment from high school often leads me to define science literacy by the standards I observe in my current [university] classroom. This is not the case for a student in high school.

Additionally, the scholars considered the ways that science concepts should be organized and delivered to students. Early in his teaching journal, Mason

discussed his thinking about these issues in light of his observations and discussions with his cooperating teacher:

Right now it seems we have plenty of content, but getting students to actually think and retain information may be best suited by focusing on certain areas. I agree with the author [Bybee, Carlson-Powell, and Trowbridge, 2008] in picking specific topics and probably providing inquiry based lessons on these fewer topics than getting as much content to them as possible. I feel this is something [my cooperating teacher] agrees with as well. On Monday he told us the important thing with teaching his class is keeping them engaged and thinking. This is why he starts out with a journal and recap, and then tries to get them discussing and participating as much as possible.

Through their observations and reflective conversations with practicing teachers, the scholars were able to make connections among the amount and extent of content, appropriate teaching strategies, and the decisions that the teachers were making regarding content and strategy in real time when working with specific groups of students.

The scholars were able to deepen their consideration of the content decisions constantly encountered in teacher work when given the opportunity to develop and deliver their own curriculum plan. Through this experience, the scholars encountered disconnections and resistance from students that they did not expect, allowing them to develop a more thoughtful perspective about their approach to selecting and delivering content. In their unit plan, Aaron and Mason reflected,

[We] sometimes had trouble seeing the material through the students' perspectives. Some of the quantitative values we gave for strength and range of force were lost on the students because of their lack of experience with scientific notation. Reflecting on that, I think it is really hard for us even to think of a number with seventeen zeros before it.

Following this experience, the scholars were able to better understand and anticipate the challenges that their students would naturally experience confronting a difficult and abstract topic such as particle physics. Where their own facility working with concepts on an extremely small scale led them to initially expect students to easily understand quarks and leptons, they found that their students were not as comfortable with both the mathematic concepts of scientific notation and the abstract thinking required in particle physics. The opportunity to plan and teach this unit with the supervision and scaffolding of a classroom teacher and a science methods professor allowed the scholars to experience firsthand some of the challenges of communicating complex and abstract ideas to students. Where most preservice teachers first encounter the responsibilities and challenges of pulling together content delivery and teaching strategy during student teaching, this experience allowed the scholars to reflectively address these challenges earlier in their training and to experience scaffolding, as more experienced teachers offered suggestions, assistance, and feedback throughout the administration of their unit.

Thus, like Shulman, Ball, Grossman, and others, we found that extensive content knowledge alone did not develop successful teachers; rather, the scholars had to consider their content knowledge and its usefulness in the context of the secondary school science classroom to develop teacher knowledge that allowed them to communicate with students about complex science topics (see, e.g., Ball & Bass, 2003; Ball et al., 2005; Grossman, 1990; Grossman & Richert, 1988; Grossman et al., 1989; Shulman, 1986, 1987).

Teacher Knowledge

The Noyce scholars were also able to reflect on connections between pedagogical strategies they were learning in their general methods course and specific applications for science discussed in their science methods course. Through the co-op model, the scholars were encouraged to connect pedagogical strategies considered successful across disciplines to their particular implementation in the sciences and then to see the same strategies in action in the field. In a midsemester journal entry, for example, Mason discussed how cooperative learning strategies from his general methods course effectively complemented discussions in his science methods course:

Chapter 13 [from Bybee, Carlson-Powell, and Trowbridge, 2008] fits really well with what we are doing in our middle school [general] methods class as well. Our focus . . . has been on cooperative learning and cooperative learning lessons for the last couple weeks. The thing that I like about cooperative learning in science is that it almost always seems to center around inquiry based learning. One of our sample cooperative lessons in [general methods] class dealt with pennies and the effect soap would have on their water retention. This activity essentially mirrored the learning cycle in chapter 13. We had an introduction that got us interested and thinking about soap and its properties. Then we had a little time to discuss with our group and mess around with our materials. Then to finish up we followed the guided activity and filled out data tables and made graphs.

Here Mason connected readings from his general and science methods courses to make sense of how cooperative learning is often used in concert with inquiry learning. He also was able to see how a lesson taught by his general methods professor followed the learning cycle that he read about in his science methods text.

The Noyce scholars also reflected on how pedagogical strategies explored in methods courses could be effective in their teaching co-op. In his teaching rationale paper, for instance, Aaron talked about how a strategy from his general methods course would have helped resolve an issue that he had in teaching his science unit in his teaching co-op and how he planned to implement this strategy in his future classroom:

I look to make full use of individual white boards. From my advanced middle school [general] methods course, I learned that this is an effective way of personalizing the education a student receives. It allows for one on one interaction

while still incorporating everyone in the class. I believe the key for diverse learners is relating information back to their everyday lives. This was a method I struggled with while teaching the particle physics unit at [my co-op]. Diverse learners will often see you as an outsider; I must create an image of compassion in their ideas so they know I will not give up on them.

Thus, Aaron adapted his approach to teaching content, specifically problem solving in physics, based on his students' less-than-enthusiastic response to his original presentation, which consisted of a PowerPoint lecture and worksheets completed individually. His suggested adaptation, drawn from his general methods course, is known to be an effective strategy for teaching problem solving in math.

We consider the Noyce scholars' application of pedagogical strategies from methods courses in their teaching co-op particularly valuable for their success in student teaching. Their university-based student-teaching supervisor observed that the scholars were more comfortable and confident in their teaching earlier in the student-teaching semester than were traditionally prepared student teachers. Additionally, they were better able to integrate pedagogical strategies including inquiry activities, science demonstrations, and direct instruction than traditional secondary science student teachers were. In light of the often-reported disconnection between pedagogy learned in university-based education courses and application in the field (Clift & Brady, 2005; Ebby, 2000; Wilson et al., 2001; Zeichner, 2010), we consider the Noyce scholars' application of pedagogical strategies across methods courses and in the context of their teaching co-op to be promising.

Pedagogical Content Knowledge

Through the teaching co-op, the Noyce scholars were afforded opportunities to consider their approach to instruction of particular content in light of the specific population of students in the high-need urban school where they were working. In doing so, the scholars were able to anticipate challenges and design instruction to connect with the interests, beliefs, and priorities of their students. The scholars understood that the complex science content of particle physics would be challenging for students and that they must adapt the scope and delivery of their unit to maintain the disciplinary integrity of the topic while making the unit interesting and understandable to their students. In their unit plan paper, the scholars discussed the processes by which they developed their approach to teaching this unit:

We then collaborated with [our science methods instructor] about the length, depth, organization, and construction of our unit plan. This was also very helpful having an educator and person who wasn't very familiar with particle physics [to] gauge the difficulty of the concepts and how much we were going to cover. The modern physics textbook we utilized was good for concepts, but it was horrible in providing explanations and was much too difficult for our students. Thus, the accuracy and content was great from the textbook, but we definitely needed to change the difficulty and add to the comprehensiveness of the content.

This quote demonstrates the scholars' developing pedagogical content knowledge in terms of their extensive knowledge of the content and their recognition that the content, as a packaged curriculum in the science textbook, had to be adapted for effective delivery to students.

Their pedagogical content knowledge began to move toward knowledge for teaching as the scholars took the interests and prior knowledge of the particular population of students into account as they strategized methods for instruction. Aaron discussed how he gathered information about his students' views on nuclear power and then reflected on how to engage those views in the particle physics unit in two consecutive journal entries:

Over the weekend I had the pleasure to attend [the school's] science fair. . . . You could see how the [high school] students could reason with the opposing idea. I was surprised to see the amount of students who oppose nuclear energy. I wonder if they know about the two operating plants in Wisconsin and their safety record. (Aaron, Journal 6)

I have given some thought of how to engage students in wanting to learn about nuclear physics. I could always talk about nuclear power and some of the myths that surround that form of power generation. In addition, I would also talk about nuclear weapons and how they can act as a deterrent to warfare. (Aaron, Journal 7)

In planning their unit, Aaron and Mason envisioned their students approaching the content from multiple perspectives, providing evidence of the depth with which they were considering student thinking in their instructional planning:

In our unit we mainly tried to get students to think from three major perspectives. We wanted them to think as if they were scientists, as if they were non-scientific people, and from a student's view. We first started off having them really think about physics and forces and what it meant to them as students. What had they learned in school already and how could they relate it to their past experiences.

By insisting that students position themselves from multiple perspectives in approaching their learning of particle physics, the Noyce scholars demonstrated their awareness of the diverse backgrounds that students brought to the unit and the varied uses that students might make of their science knowledge. They took student interests into account when planning their activities and approaches, and, even more impressive, they considered student thinking as a central consideration in planning instruction (Philipp, 2008; Philipp et al., 2007).

Conclusions, Implications, and Challenges

In this article, we provide a descriptive account of one pathway for the preparation of science teachers by building on the strong content foundation of STEM majors, combined with general and disciplinary methods courses in the context of closely scaffolded teaching experiences. We supported the

Noyce scholars' transition from STEM majors to STEM teachers by providing pedagogical content knowledge closely tied to teaching experiences in which the scholars were encouraged to reflect on effective teaching strategies specific to the STEM fields. The significance of the teaching co-op as a vehicle for transforming content knowledge and pedagogical knowledge into knowledge for teaching is illustrated in Figure 1. Central to this model were (1) scaffolding from the content methods instructor and the field-based cooperating teachers during the teaching co-op, (2) requirements for weekly reflections on pedagogical methods in light of their teaching co-op experience, and (3) opportunities to team teach with more experienced professionals. We assert that through these experiences, the Noyce scholars began to utilize knowledge for teaching in their approach to instruction. While the cohort is small and implications are therefore limited, this account describes one promising pathway for preparing teachers that are strong in STEM content and capable of delivering that content in powerful ways to students in high-need urban settings.

The account provided here raises several questions regarding the preparation of large numbers of STEM teachers. First is a question of replicability—would we be able to develop knowledge for teaching using this model with other scholars and in other places? Second is a question of scale—can we give this level of attention to larger numbers of students? Third, recruitment has been the most significant challenge for our Noyce program. Can we recruit sufficiently large numbers of STEM majors to preservice teaching programs to meet the needs of the STEM master teacher corps, which calls for the preparation of 100,000 STEM teachers over the next 10 years? These questions remain open, but with the national focus on scaling up and improving the preparation of STEM teachers, we are hopeful that this pathway to the development of high-quality STEM educators will be considered as a successful exemplar for others to follow. **TEP**

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