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Teaching, Learning and Leading with Schools and Communities: Preparing Sophisticated, Reflective, and Resilient Elementary STEM Educators

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ˈeaching, Learning, and Leading Vith Schools and Communities: ˀreparing Sophisticated and ₹esilient Elementary STEM Educators

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3STRACT: Loyola University Chicago's Teaching, Learning, and Leading With :hools and Communities (TLLSC) program is an ambitious break from traditional ıiversity-based teacher preparation models. This clinically based initial teacher ·eparation program, fully embedded in local schools and community organi- ıtions, takes an ecological perspective on the development of sophisticated, flective, and resilient elementary STEM (science, technology, engineering, and athematics) educators who are able to prepare and inspire students and act as ȝents of change in their schools. This article describes how TLLSC leverages ne for STEM across elementary teacher candidates' entire program through ı emphasis on practitioner inquiry and integrated (inter- and transdisciplinary) aching and learning. TLLSC's innovative approach is designed to foster STEM ıbits of mind, integrate scientific practices, and support candidates' ongoing ·lf-examination of personal and social applications of STEM for themselves and eir future students.

A The past decade has witnessed marked growth in the understanding of what science teaching and learning should consist of to support the :hievement of all students. However, there remains significant concern with oubling gaps in the performance of students from varied ethnic, socioeco- ɔmic, and language backgrounds (National Center for Education Statistics,)12) as well as with the United States' international standing in STEM ·lds (i.e., science, technology, engineering, and mathematics; National enter for Education Statistics, 2012; National Science Board, 2007). The ational Science Board's (2007) *National Action Plan for Addressing the Criti- l Needs of the U.S. Science, Technology, Engineering, and Mathematics Education ıstem* candidly acknowledges that, as a nation, we are failing to provide all udents with the STEM background that they need to be responsible, sci- ıtifically literate citizens empowered to take action in their lives and make ɔsitive contributions in a society that is increasingly influenced by and liant on science and technology. There is government and public recogni- ɔn that current and future local and global challenges require knowledge ıd understanding of these disciplines, as well as a fear that the nation will : uncompetitive in international markets without highly skilled scientists, ıgineers, technologists, and technicians (National Research Council, 2012).

The National Science Board (2007) also put forth recommendations for ensuring coherence in STEM learning and an adequate supply of well-prepared, highly effective STEM teachers. There has been considerable movement on the first, but the latter is only vaguely laid out. In alignment with the first recommendation's call for creation of "a national road map" (National Science Board, 2007, p. 1) to improve STEM education, the National Research Council's Committee on Conceptual Framework for New Science Education Standards released *A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* in 2012. This document also provides the framework for national Next Generation Science Standards, (NGSS Lead States, 2013). Together, the framework and the standards offer a plan for coordinating what, when, and to whom STEM subjects are taught, horizontally across states and vertically across grade levels.

The National Science Board (2007) acknowledges in its second recommendation that the vision put forth in the framework will not be realized without the teachers and school-level structures needed for successful implementation. Improving K–12 student learning requires addressing several closely related challenges, including those at the intersection of teacher preparation, classroom practice, and policy. Novice teachers are often critiqued for not being prepared to handle the array of challenges that they face in the classroom (Darling-Hammond & Baratz-Snowden, 2007). These concerns are compounded when such teachers are not provided adequate mentoring, support, and professional development during their first years of teaching (Ingersoll, 2003; Roehrig & Luft, 2006). Some authors offer detailed, research-based summaries of the more specific challenges facing beginning elementary science teachers (preservice and early career; Davis, Petish, & Smithey, 2006; Davis & Smithey, 2008). They report that novice teachers often struggle with understanding core scientific ideas and the nature of science and that they shy away from teaching science. During science lessons that beginning teachers do teach, the focus is typically on hands-on activities that target student engagement, interest, or motivation but do not necessarily lead to deep student learning. Novice teachers recognize the importance of knowing about their students' backgrounds or ideas but lack skills for utilizing this information to inform instruction. They also typically have limited experience translating their own ideas and intentions into practice.

There are additional systemic challenges that must be considered as well (Judson, 2010; Kahle, 2007). The No Child Left Behind Act (2002) was intended to use high-stakes testing in core subjects as a means to ensure that schools are held accountable for making adequate progress toward educating all students at the same level of academic rigor. However, there have been unintended negative consequences for science education. There is a perception that science is a lower-priority subject area because state testing and accountability reporting are not as frequent for science in elementary and middle grades as they are for reading and math (Judson, 2010). Classroom attention has been so drastically shifted to focus on literacy and mathematics that fewer than 3 hours per week is set aside for elementary science on average (National Center for Education Statistics, 2007). As a result, teachers have limited time devoted to supporting students' development of the various dimensions of science learning and their scientific identities and efficacy (Britton & Schneider, 2007). Or, in grades where science is tested, "science is being reduced to a myriad of facts" (Taylor, Jones, Broadwell, & Oppewal, 2008, p. 1072), and teachers' focus tends toward preparing students for high-stakes tests, which typically assess lower-level knowledge rather than critical thinking and application of deep conceptual understandings or disciplinary practices (Pellegrino, Chudowsky, & Glaer, 2001; Smith & Southerland, 2007).

These challenges have been lamented for years. Solutions will come only from breaking with traditional mind-sets and approaches. Loyola University Chicago's ambitious teacher preparation program—Teaching, Learning, and Leading With Schools and Communities (TLLSC)—is strategically designed to produce teachers that will foster meaningful STEM learning through excellent practice. As described in this article, TLLSC's competency-based, developmental growth model aims to cultivate teacher candidates who enter their careers as sophisticated, effective, and resilient novice educators well equipped to meet current and future professional demands and challenges. In the case of elementary STEM teacher candidates, this includes developing deep understandings of STEM concepts and practices aligned with the framework and how children learn science. It also includes developing skills in assessing student progress and making evidence-based decisions, as well as a commitment to taking a reflective stance toward teaching science interwoven with other disciplines to diverse classrooms of students (Darling-Hammond & Baratz-Snowden, 2007; Freedman & Appleman, 2009; Hollins, 2011). The TLLSC program represents a bold acceptance of the challenge to take a new perspective on teacher preparation.

This article begins with a review of what approaches to reforming STEM teacher preparation are reported in the literature, as well as the shortcomings of these fragmentary approaches. Next, the conceptual framework for TLLSC's comprehensive approach is introduced. Specific examples describing core experiences that all elementary education candidates complete during their years in the program are provided as examples of how TLLSC responds to challenges facing schools and teacher preparation programs alike.

Approaches to Reforming STEM Teaching

Numerous efforts have been taken to better prepare effective STEM teachers. Common approaches in teacher preparation programs include altering teacher candidates' coursework and arranging for authentic field experiences. Altering teacher candidates' coursework has often meant adding more

science-specific or STEM-specific content to address areas where candidates' knowledge is perceived as lacking. The logic is that teachers will be unable to teach STEM content adeptly to their students if they do not have a strong foundation in these subject areas. Others cite problems with this approach to reform, arguing that increasing teacher candidates' coursework related to STEM will not necessarily guarantee the development of strong content knowledge or the skills needed to teach that content to their students (Frykholm & Glasson, 2005; National Center for Research on Teacher Learning, 1993). This may be attributed to the fact that college course content is not often aligned with the knowledge and skills that candidates will teach their students (National Science Board, 2007).

Others have included an increasing emphasis on interdisciplinary connections (Frykholm & Glasson, 2005; O'Brien, 2010; Sanders, 2008). Proponents of this modification argue that engaging in an active learning opportunity—such as collaborating with peers to design an authentic, interdisciplinary mathematics and science unit—can increase teacher candidates' STEM content knowledge, build candidates' pedagogical content knowledge, and encourage implementation of interdisciplinary units in candidates' future classrooms (Frykholm & Glasson, 2005).

A final common modification to teacher preparation coursework is creating a more fluid integration of content and pedagogy to develop candidates' pedagogical content knowledge for teaching STEM. This is often addressed through the promotion of collaboration between education faculty and arts and sciences faculty at the university (Ford & Strawhecker, 2011), as well as through hands-on field learning and teaching experiences, where candidates learn STEM content and pedagogy simultaneously, as they have opportunities to engage in STEM as both learners and teachers (Marcum-Dietrich, Marquez, Gill, & Medved, 2011).

Some STEM teacher preparation reform efforts have focused not on increasing candidates' content knowledge through modifications to coursework but instead on engaging candidates in authentic learning experiences outside the university classroom. Informal science learning experiences—such as participating in family science and engineering nights (Harlow, 2012) or interning in informal after-school science programs (Katz et al., 2011)—are often used as a way to counter teacher candidates' negative feelings about science teaching, alter their beliefs about themselves as science teachers, and build professional identities and pedagogical skills outside the university classroom. However, a significant limitation of studies reporting on these efforts is they do not contain evidence that the experiences actually influenced candidates' future teaching or had any impact on their future students' learning.

Finally, partnering with scientists to learn about scientific inquiry and practices of science has been another promising approach to developing effective STEM teachers but has primarily been employed with in-service teachers as a form of professional development (Dresner & Worley, 2006; Hayden, Ouyang, Scinski, Olszewski, & Bielefeldt, 2011; Siegel, Mlynarczyk-Evans, Brenner, & Nielsen, 2005). Similar programs implemented with teacher candidates have not proven as successful in helping candidates apply their newly developed content knowledge to their future teaching (Langford & Huntley, 1999). For experiences like these teacher–researcher partnerships to have an impact on teacher candidates' pedagogical practice, meaningful connections must be made between candidates' experiences and how these experiences might be translated for students in their classrooms.

Need for a More Comprehensive Approach

The reforms described so far have had some positive effects on teacher and student learning, which can inform future STEM teacher preparation efforts. Yet, the question remains, why have these reforms failed to have a significant mpact on preparing future teachers to be effective STEM educators? We ırgue that while focusing on strengthening specific areas—such as teacher candidates' content knowledge, pedagogical skills, comfort with science teachng, and familiarity with authentic scientific practices—is a beneficial approach o reform, these piecemeal efforts are not well coordinated or cumulative n their approach to teacher learning. We argue that there is a need to take more systemic perspective when addressing the shortcomings of teacher reparation, especially to prepare effective 21st-century STEM educators.

By *comprehensive*, we do not mean to imply that any approach does or could ope to include everything that candidates would ever need to be successful. Rather, we use the term *comprehensive* to describe programs that ensure that eacher candidates have a wide mental grasp of what it means to be a teacher, ıcluding the specific knowledge and skills necessary to embody the disposiions of the profession, as well as an understanding of the varied roles and esponsibilities of educators who work in collaboration with their school and ırger communities.

Drawing on existing scholarship, what elements might a comprehensive pproach to STEM teacher preparation include? First, effective programs ıust recognize that being apprenticed into a complex profession such as aching requires that teacher candidates experience teaching and learning in ıthentic contexts, such as schools, informal education institutions, and comunity organizations. Studies have shown the benefits of preparing effective TEM teachers by engaging them in experiences outside the university assroom and so call for universities to incorporate these types of experiıces into teacher preparation programs (Harlow, 2012; Katz et al., 2011). oing this will naturally require universities to build strong partnerships th schools (Kruger, Davies, Eckersley, Newell, & Cherednichenko, 2009; errill & Daugherty, 2010; Zeichner, 2010), informal learning institutions isiel, 2013), and other community organizations (Forbes, 2010) so that

these experiences may be interwoven with coursework in meaningful ways to support teacher candidates' learning.

In addition to bringing teacher preparation out into schools and communities, comprehensive programs must prepare teacher candidates to teach multiple disciplines to diverse student populations in a variety of contexts, including settings with high percentages of minority students, students of lower socioeconomic status, and English-language learners. This requires programs to provide sustained support to teacher candidates (Kirchhoff & Lawrenz, 2011). Allowing teachers opportunities for collaboration has proven essential to providing this support and developing their practice as STEM educators (Dresner, 2002; Dresner & Worley, 2006; Frykhom & Glasson, 2005; Hayden et al., 2011; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2012). Professional learning communities have also been shown to enhance teacher collaboration (Vescio, Ross, & Adams, 2008), provide necessary support (Curry, 2008; Masuda, 2010; Thibodeau, 2008), and increase teachers' self-efficacy for teaching science (Mintzes et al., 2012) and thus should be an essential component of a comprehensive teacher preparation program. Additional support would entail helping teacher candidates develop the knowledge, skills, and dispositions of reflective practitioners and teacher leaders, including posing questions about their own practice, collecting and analyzing data related to those questions, and using data to inform instructional decisions. There is agreement in the literature that practitioner inquiry should be an essential part of a comprehensive teacher preparation program (Cochran-Smith & Lytle, 2009; Merrill & Daugherty, 2010).

A comprehensive teacher preparation program would also include teacher candidates making meaningful connections not only between the STEM disciplines but also between STEM and other disciplines and seeing how taking an interdisciplinary approach to problem solving might be beneficial in addressing local and global issues. For example, Forbes (2010) describes an experience for teacher candidates in which they designed and executed interdisciplinary, collaborative, problem-solving projects addressing issues of sustainability, which she argues "actively [involved] students in understanding middle level pedagogy, STEM content areas, and problem solving" (p. 94). Over the course of 2 years, candidates first designed and conducted their own projects and then translated these experiences into developing and executing similar projects for their own students during their student teaching. While no data are presented on the long-term impact that this has had on teacher candidates, Forbes argues that the experience helped teacher candidates integrate and put into practice their knowledge of pedagogy and students' development, their knowledge of STEM and other disciplines, and their knowledge of creating interdisciplinary curricula and effective learning environments. Candidates were making meaningful connections among disciplines, translating their learning experiences into learning experiences for their students, and effecting change in the local community by addressing issues of sustainability. This example is a model for the kinds of experiences that should be an essential part of comprehensive STEM teacher preparation programs.

What is absent from current reforms in STEM teacher preparation is inclusion of all the essential elements detailed here. In the following sections, we outline how Loyola University Chicago's TLLSC program embodies the aforementioned essential elements. We also detail how it provides an ongoing emphasis on teacher candidates' self-examination of how they use scientific understandings, practices, and habits of mind in their general practices as educators and how doing so might strengthen their abilities to teach STEM to their students. Inherent in this view is that the knowledge, skills, and dispositions of effective educators have strong connections with scientific thinking and practices.

Conceptual Framework of TLLSC

The teacher education program in the School of Education at Loyola University Chicago is grounded in our school's conceptual framework of professionalism in service of social justice. This idea is at the core of the program and shapes our decision making. In the recent redesign of our teacher education program, we kept the question of how to better prepare all teacher candidates to teach all students at the forefront of our work. This commitment to social justice and our drive to prepare teachers who serve all students is informed by our location. Chicago is in one of the largest and most complex metropolitan areas in the United States. We are home to a diverse set of birth–Grade 12 schooling options, including the Chicago Public Schools, the Catholic schools of the Archdiocese of Chicago, charter schools, suburban public schools, private and independent schools, and many others. We also have a vibrant network of community organizations and a thriving museum education community.

Another important contextual factor about Loyola's School of Education is our governing structure. We do not have academic departments. Instead, we have affinity groups who work in a shared governance system. In teacher preparation, this means that all areas are part of one group—Teaching and Learning. Elementary education, secondary education, special education, and more are included in the same affinity group with master and doctoral programs in curriculum and instruction. This allowed us to engage all faculty members in Teaching and Learning in the redesign of our teacher preparation program.

In reenvisioning our teacher preparation program, we drew on the literature on field-based teacher education, our school and community partners, and the strengths of our particular context and culture. We developed TLLSC as a growth model to move candidates from beginning to developing to mastering phases over eight learning sequences (see Figure 1). The first three sequences in the beginning-to-developing phase place candidates in a variety of birth–Grade 12 settings. This allows teacher candidates the opportunity

to learn about, experience, and work with the full developmental continuum. In the next three sequences, the developing phase, candidates begin focusing on an age range and area of specialty: early childhood special education, elementary education, bilingual/bicultural education, special education, or secondary education. In the final two sequences, candidates delve deeply into their specialty and complete a 1-year internship in a school at the mastering level, where they complete the edTPA[1] and student teaching. TLLSC's eight sequences are made of two to three modules each, which teacher candidates take in succession (see appendix for sequence descriptions). These modules are embedded in schools and community organizations, offering teacher candidates an unparalleled experience of learning to become effective educators with the support and guidance of teacher educators from the university and from cooperating teachers and community professionals in the field.

Teacher candidates' experiences in the individual modules and overall sequences are further supported through professional learning communities. At the end of each sequence, candidates participate in a professional learning community with a university faculty member in their area of specialty, such as elementary education, secondary science, or special education. This is a unique feature of the program that allows candidates to engage in area-specific communities of inquiry with a faculty member and other professionals in the field, as well as candidates from across the program. The support that candidates receive through this dedicated and ongoing reflection time is unique to TLLSC's comprehensive approach to preparing future STEM teachers. Candidates meet regularly with their professional learning communities to continually synthesize teaching and learning experiences, theory and practice, as well as content

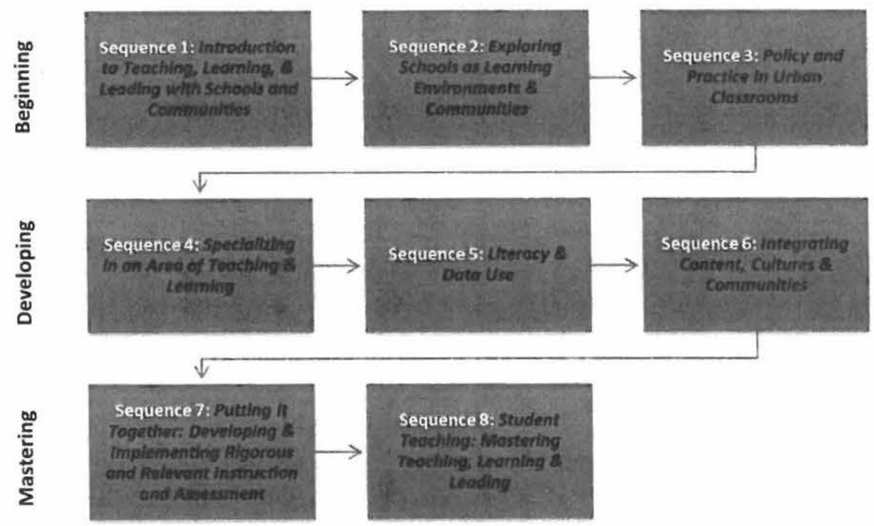

Figure 1. TLLSC learning sequences.

and pedagogy. Professional learning communities also support candidates in making the sort of meaningful connections that were lacking in many of the other programs reviewed earlier. Finally, translating candidates' experiences into purposeful learning experiences for their students is significantly facilitated when candidates are able to make and apply the connections in a timely fashion. The end goal of TLLSC's innovative approach is for graduates to enter the field with greater professional resiliency, having already made an impact on children, families, schools, and communities.

To achieve this complex goal, we used backward design to develop the program. We began by generating enduring understandings (Wiggins & McTighe, 2005) to serve as the foundation of our teacher education program. We eventually agreed on 11 understandings that reflected our core principles, beginning with our central commitment to social justice. The Teaching and Learning faculty took an ecological perspective on teacher preparation to envision a program that would teach all teacher candidates to be teachers of all students with an in-depth understanding of English-language learning, special education, and literacy in addition to their area of specialty—special education, early childhood special education, bilingual/bicultural education, elementary education, or secondary education. After establishing the enduring understandings, the teacher preparation faculty worked on breaking those down into core knowledge and skill indicators and then program-level dispositions that all teacher candidates would be expected to know and do. These were then mapped to our state professional teaching standards and the principles of the International Baccalaureate program. Additionally, these were mapped to our School of Education's conceptual framework standards and schoolwide dispositions. This outcomes-based approach to our program allowed us to then design rich birth–Grade 12 school- and community-based educational experiences that met multiple expectations, described in subsequent sections.

Leveraging Time for STEM in Loyola University Chicago's TLLSC Program

It would be unrealistic to think that the entirety of a teacher preparation program could be solely dedicated to the knowledge, skills, and dispositions specific to elementary science STEM education. Recognizing the challenge of having a limited amount of time with elementary teacher candidates, we felt the need to ensure that time is leveraged across the program to prepare elementary teachers to be effective, reflective, and internationally minded STEM educators. It is possible to do so because the structure of TLLSC is unique among teacher preparation programs in that candidates' experiences are highly coordinated across the years they spend with us. We leverage time at the program level, with a continuing emphasis on practitioner inquiry, as well as within the Sequence 4 semester, with time dedicated to methods for teaching elementary science integrated with other subject areas.

TLLSC's approach is designed to

- foster STEM habits of mind—including curiosity, openness to new ideas, and informed skepticism;
- integrate scientific practices throughout all teacher candidates' experiences—such as questioning, collecting and analyzing data, observing and drawing inferences, formulating logical evidence-based argumentations, and using results to inform future actions; and
- emphasize personal and social applications of science content and skills—promoting the reflection on how science connects with other disciplines and how it can be used to enact local and global change.

TLLSC intends to accomplish these three goals through a programmatic emphasis on practitioner inquiry, as well as through the specific promotion of integrated teaching and learning with elementary education candidates.

Program Emphasis on Practitioner Inquiry

As candidates progress through the continuum of experiences, they are exposed to, and have the opportunity to reflect on, the ways in which all educators draw on scientific attitudes, values, and behaviors to better understand and improve their practice. While the questions and problems of scientists and engineers differ from those that educators ask and explore about their practice, there are similarities in the approaches taken. We feel that emphasizing these similarities can provide a gateway to enhancing teacher candidates' knowledge and appreciation for scientific values, attitudes, and behaviors. Thus, candidates' experiences consistently emphasize that teachers, like STEM professionals, are inquirers of their own practice. These experiences are purposefully designed to enhance all candidates' understanding of how teachers and other school professionals work through a similar iterative process as STEM professionals, involving questioning, collaborative and critical investigation, and analysis and action.

The TLLSC program operates from the perspective that teaching itself is a form of inquiry (Tabachnick & Zeichner, 1999) and that teacher education is a carefully scaffolded apprenticeship into that inquiry. That is, effective resilient teachers form a commitment to lifelong and collaborative questioning, investigation, reflection, knowledge generation, and dissemination (Cochran-Smith & Lytle, 2009). They rely on critical problem-solving skills to reflect on and respond to the inevitable changes and fluctuations that will occur throughout their career (Freedman & Appleman, 2009). Thus, in TLLSC, examination of one's understanding of teaching, learning, leadership, research, policy, and practice begins early on and remains a critical component of the entire program. Teacher candidates consider, in their first semester, what it means to take an "inquiry stance" (Cochran-Smith & Lytle, 1999, 2009) on the challenges that they face in their classrooms, schools, and ommunities, as well as how their empirical questions are balanced by other thical, philosophical, and ideological questions (Cochran-Smith & Fries, 2005). Over the course of their program, candidates participate in planned nd carefully mentored experiences that serve as examples of what it means to roblematize the work that we do as educators, as well as the social, political, nd cultural contexts within which we work. These experiences are designed o develop candidates' engrained commitment and desire to continually reexmine, expand, and deepen their professional knowledge as they work toward ducational and social change.

Because all TLLSC's instructional experiences are embedded within chools and communities, this ensures that candidate learning does not hapen only at the university and then potentially gets applied in schools. Rather, andidates learn firsthand about the types of research questions—grounded n the problems and contexts of authentic practice—that teachers and other chool practitioners ask, as well as the intentional, systematic, and recursive ays that they "collaboratively theorize, study, and act on those problems in he best interests of the learning and life chances of students and their comunities" (Cochran-Smith & Lytle, 2009, p. 123). Doing so also ensures that LLSC addresses the need articulated by Cochran-Smith, Barnatt, Friedan, and Pine (2009) for an inquiry stance to be "integrated into all courses nd all fieldwork experiences, rather than a procedural activity carried out t the program's completion" (p. 30), as is typical for certification programs. s we describe next, TLLSC provides meaningful and authentic practitioner quiry experiences throughout the program that emphasize using STEM abits of mind and practices, in community and school settings.

ommunity-Based Experiences Emphasizing TEM Habits of Mind and Practices

line with our ecological view of schooling, we deem it essential for teachs to consider how schools, families, and communities can be united in the fort to educate all students. Thus, an early experience in Sequence 1, durg candidates' first year, includes an authentic exploration of the inherent lationships between schools and the surrounding community. The program gins with candidates considering the general elements that contribute community (i.e., businesses, universities, schools and educators, families d residents, citizen groups, public and private agencies, government), the rious issues that influence community members (i.e., education, culture, ligion, economics, housing, health, recreation, transportation, environment, litics), and how these issues influence schools and conditions for learng. Geographic information systems (GIS) mapping is then introduced as a ol for visualizing, analyzing, and understanding patterns and relationships. ndidates collect and enter data into GIS community maps, analyzing the dings and providing evidence to support conclusions about questions such

as the following: What types of resources and community-based organizations are located in the neighborhood? What community and school needs do these organizations meet or respond to? Where do spatial mismatches exist between the location of resources and community-based groups and the needs of the families attending the school? The maps and the conclusions are then shared and discussed with local school and government officials.

While this community-mapping project does not specifically address questions about the natural or constructed world, involvement in authentic, informal learning experiences such as this requires that candidates employ some of the same knowledge and skills that will be necessary for helping their students learn. Candidates are paralleling the investigative approaches, habits of mind, and norms of participation that scientists and other STEM professionals take in their work. Specifically, candidates are engaged in asking questions and defining problems; collecting, analyzing, and interpreting data; and communicating and defending their conclusions (National Research Council, 2012). Additionally, candidates are using digital tools to gather, evaluate, utilize, and communicate information and to collect and analyze data to identify trends, forecast possibilities, and identify solutions, as called on in the *National Educational Technology Standards for Students* (International Society for Technology in Education, 2007). For these reasons, the project also serves as a model for one that candidates might conduct in their future classrooms.

Critical to candidates' realization of how they were involved in STEM ways of thinking and how they might use similar experiences to foster this thinking in their students is the opportunity for meaning making within professional learning communities. During their meetings, candidates consider, among other things, how projects such as the GIS community-mapping present STEM as a means of participating productively in community life (Roth & Lee, 2004; see also http://edcommunity.esri.com for examples). They also consider how their experiences might connect with their future classrooms. Perhaps more important, they have an opportunity to do so under the mentoring of faculty and experienced teachers. For example, in Sequence 6 during their third year, candidates work alongside school professionals to provide elementary students with opportunities to engage in structured investigations into issues of equity with local relevance and international connections. Regardless of whether candidates incorporate participatory GIS mapping, they will similarly emphasize students' curiosity and wondering, use of questioning, data collection and analysis, and opportunities to communicate and argue conclusions.

Evidence-Based Decision Making in Schools

Because TLLSC is a single program with a cohesive and coherent continuum of learning experiences that were designed and are implemented in conjunction with school and community partners, we can be confident that all teacher candidates will have extensive opportunities to develop and apply the data-based instructional decision-making knowledge and skills assessed with the edTPA by the time that they reach their 1-year student-teaching experience. Throughout Sequences 4–8, candidates work alongside school and community professionals across a variety of educational settings, including multiple elementary grade levels and subject areas. Candidates are required to collect and use information about students to design instruction, including grade and developmental levels and abilities, language and literacy proficiencies, overall grasp and interest in content area topics, and background and funds of knowledge related to these topics. Then, during instruction, candidates use assessment results, student work samples, and observations from continuous monitoring of student progress to identify strengths and weaknesses in instruction and adjust practices to meet the needs of each student. Finally, candidates assume leadership roles by sharing their experiences and disseminating findings and lessons learned when applicable. For example, during Sequences 4–8, candidates use analyses of their instruction, samples of student work, and further research as they develop posters to present during a formal poster session for peers, practicing teachers, other school professional personnel and university faculty.

Semester Focus on Integrated Elementary Education Teaching and Learning

In addition to leveraging time across the entirety of the program to emphasize scientific attitudes, values, and practices, TLLSC leverages the time within the semester-long Sequence 4, "Specializing in an Area of Teaching and Learning: Integrated Instruction in Elementary Classrooms." Designed especially for those teacher candidates who will become elementary teachers, this sequence adopts an integrated (inter- and transdisciplinary) approach to teaching and learning. The current realities of schools require making connections between and across disciplines, especially science and social studies, due to limited time and resources for either. By introducing teacher candidates to integrated thinking in the TLLSC program, they are better prepared to successfully negotiate these realities in their career.

There are also important pedagogical reasons for adopting an integrated approach to instruction. Because the world is immensely complex, it is unrealistic to think that its understanding could be accomplished through the knowledge, processes, perspectives, and practices of any single discipline. An inter- and transdisciplinary approach acknowledges that learning is not fragmented and confined within the boundaries of traditional subject areas but rather is supported and enriched by all of them (International Baccalaureate Organization, 2008, 2010). It also provides a more realistic picture of just how dynamic, creative, and innovative science and other disciplines are, including an appreciation for how they have been constructed and are continuously being reconstructed.

Overview of Instructional Modules

Taken in candidates' second year, the instructional modules in Sequence 4 are designed to help teacher candidates form connections between and among disciplines, compare science as a way of knowing to other ways of knowing and understanding, and approach the problem solving of local and global issues from an integrated perspective. Candidates continue to develop their understandings of how STEM knowledge, practices, and habits of mind can be used to address real-world challenges but also to see where science might be limited in understanding and addressing particular issues and how other perspectives and approaches—including those offered by the social sciences, arts, ethics, and philosophy—might complement those of science. Replacing the traditional mind-set of separate methods courses for each discipline, modules in this sequence aim to interweave instruction in literacy, science, and social studies and provide teacher candidates with more of their own meaningful inter- and transdisciplinary learning experiences that will later be used as a starting point to design similar learning experiences for their students.

Teacher candidates begin by completing an introductory instructional module with a focus on teaching written communication in elementary-grade classrooms. This module introduces candidates to some of the fundamental concepts and skills emphasized in the Common Core State Standards for literacy in the content areas. It also prepares candidates to engage in subsequent modules on teaching science and social studies in elementary-grade classrooms. The science and social studies modules are then taken back-to-back and are designed in such a way that they could be taken in any order. The goal of these modules is to introduce teacher candidates to the disciplines of science and social studies and to highlight common practices and habits of mind shared by scientists, social scientists, and historians. Together, this sequence emphasizes how each discipline is unique and how its distinct ways of knowing might complement other disciplines in addressing local or global issues. Candidates explore essential questions such as the following: What is science? What is STEM? What does it mean to learn and teach science through inquiry? What is social studies, and how does that differ from the social sciences? What is history, and what is its relationship to social studies and the social sciences? What is the importance of argumentation and writing in the disciplines of science and social studies?

Authentic Scientific Inquiry Experiences

A specific example of an authentic learning experience in the Sequence 4 module "Teaching Science in Elementary Grade Classrooms" involves teacher candidates applying their knowledge of what constitutes a sound scientific research question and what scientific argumentation entails. Alongside university faculty and community partners, candidates consider the importance of developing investigable questions to drive scientific inquiries, as well as how argumentation is a specific and essential practice of science. Candidates then work in an informal setting to generate an inquiry question of their own, informed by initial data collection and background research. They continue to gather data and generate claims, using the data as evidence to support those claims. For instance, candidates might work at a zoo or local nature preserve and use ethograms (behavior inventories) to collect data on animal behavior. They would then analyze the data using tools such as an activity budget or graphing software and draw preliminary conclusions about how the animal under observation spends most of its time, providing evidence and reasoning to support their claims. Drawing on their earlier introduction to literacy in the content areas, candidates would then consult other sources in a trip to the university library, using informational texts, research reports, and reputable websites to gather additional evidence related to their claim. Comparing their observations with established scientific findings, candidates would potentially revise their claims, expand on these claims in a persuasive piece of writing, as well as generate inquiry questions that could be investigated in the future.

Throughout this process, the university instructor and cooperating scientists, researchers, or institution staff assist candidates to make connections between scientists' and their own practices of science, as well as connections to practices in other disciplines. Additionally, they discuss and consider how their future elementary students might be engaged in similar practices and how literacy is integrated throughout this process. Finally, candidates identify challenges that they see to teaching science in a way that supports deep understanding, drawing from their experiences both formal and informal learning environments, and they consider how they might mitigate these in their own practice.

Candidates are then ready to join practicing elementary teachers in their classrooms. This school-based experience is designed to provide candidates with an opportunity to draw on their authentic inquiry experiences and receive guidance from experienced teachers on how they might translate these experiences into meaningful learning for their own students. Teacher candidates work in small teams with experienced classroom teachers as they engage in unit planning for their classes. Candidates contribute to the planning process by sharing insights from their inquiry experiences, as well as resources from the informal learning institutions with which they partnered. Together, teams draw on the framework as they use core ideas, cross-cutting concepts, and essential practices to frame meaningful science instruction that promotes deep understanding. The practicing teachers provide a model of the unit-planning process for candidates, as well as share performances and products that they have found are conducive to making student thinking visible and to providing evidence of student meaning making.

Authentic Social Studies Inquiry Experiences

Taken either immediately before or after the science module, the Sequence 4 module "Teaching Social Studies in Elementary Grade Classrooms" has a parallel structure intended to deepen candidates' grasp of inquiry-based teaching and connections among content areas. The experiences in this module help teacher candidates realize that in science and social studies, fundamental skills are required, including posing questions; collecting, organizing, and interpreting data; developing explanations and drawing conclusions from data; considering alternatives; and communicating ideas. Throughout this module, candidates explore essential questions about the nature and purpose of social studies but do so through writing and delivering *local to national* units of study. This approach entails using local resources (people, historical sites, museums, organizations, etc.) to make broader, abstract social studies concepts relatable within an immediate context. The local to national approach is recognized to be part of excellent social studies teaching (National Council for the Social Studies, 2011) as well as a key facet of successful historical inquiry at the elementary level (VanSledright, 2002).

Similar to the experiences in the science-focused module, candidates begin developing their understanding of how social scientists and historians work by collaborating with museums and other institutions dedicated to local history. Following this, candidates learn about the area history fair program, which collaborates with classroom teachers to organize and support student historical research on local topics. With this background, candidates work in the elementary classrooms of participating history fair teachers. With the support of practicing teachers, candidates plan and implement instruction incorporating elements of local history and history fair to teach important ideas, information, and skills. Following this school-based experience, candidates return to area museums and institutions addressing world history to broaden their content knowledge in this area. Finally, together with their peers and university instructor, candidates reflect on the role of social studies in the elementary curriculum and how it complements the study of other disciplines, such as science and literacy.

Personal and Social Applications of Learning

After finishing the science and social studies modules in this sequence, teacher candidates complete a summative performance assessment designed to assess their ability to make connections among literacy, science, and social studies and to think about how these three disciplines can be integrated into meaningful instruction. The culminating experience also serves as another model for the structured investigations on local and international issues that teacher candidates design later for their students in Sequence 6.

For this assessment, candidates choose a topic of interest and importance to them to investigate. They use the unique yet complementary inquiry-based approaches introduced in the Sequence 4 modules to investigate their particular issue of scientific and civic import, and they pull on a range of informational texts and the skills of argumentation and academic writing emphasized in all three modules. This assessment is intended to be an effective gauge for how well teacher candidates understand the complexity of STEM and social studies disciplines and how well they are able to apply necessary skills, including designing and executing scientific and historical inquiries. We anticipate that this will be a more effective and meaningful way to familiarize candidates with the discipline-specific content, skills, and habits of mind they will need to teach STEM effectively to their students—something that prior reforms to coursework and field experiences have been unable to achieve.

Concluding Remarks

Loyola University Chicago's TLLSC program, developed in partnership with local school and community stakeholders, ambitiously reconsiders what initial teacher preparation entails. Tinkering with course syllabi and fragmented learning experience has not and, we claim, will not offer a sufficient solution to the pressing need for more teachers able to enter classrooms as agents of change who will prepare and inspire the next generation of young people to pursue STEM subjects and use this knowledge in their personal and professional lives. Rather than being structured around university-based courses with affiliated but often isolated and disconnected field-based assignments (Darling-Hammond & Baratz-Snowden, 2007; Zeichner, 2010), the entirely clinically based program described in this article is embedded in schools and their greater communities and designed around those specific, purposefully coordinated engaged-learning experiences that will enhance the knowledge, skills, and dispositions of sophisticated, reflective, and resilient educators. As we have outlined, this includes the development of all candidates' identities as professionals who utilize scientific thinking and habits of mind in their everyday work. In preparing elementary STEM educators specifically, we have also attended to the more subjective components of science education, including the ways that learners identify with science, the personal and social purposes and goals of science, and the varied contexts within which science and science learning occur (Basu & Calabrese Barton, 2007).

The TLLSC program responds boldly to challenges that have long and ever increasingly faced beginning STEM teachers who struggle in their first years in the classroom, and it provides an alternative to programs that have not provided these teachers with ample, authentic opportunities to teach, learn, and lead in varied contexts under careful mentorship and support. The program recognizes that we cannot continue to critique beginning teachers who struggle in their first years in the classroom if we are not willing to also reenvision ourselves and our work as teacher educators. Going forward, we look to share the outcomes of the TLLSC program, including how we have grown as teacher

educators and the benefits realized not only for our beginning teachers but also for the schools and communities within which they work.

Appendix: Loyola University Chicago's School of Education Teaching, Learning, and Leading With Schools and Communities Sequence Descriptions

Sequence 1: Introduction to Teaching, Learning, and Leading with Schools and Communities

- Candidates examine the roles and responsibilities of educators within diverse school and community settings and connect those to the learning and development of PK–12 students.
- Candidates specifically investigate the role communities play in educating students.

Sequence 2: Exploring Schools as Learning Environments and Communities

- Teacher candidates explore how the school itself is a community and how the organization and environment of a school influences student learning.
- Builds upon the exploration of local communities done in Sequence 1.

Sequence 3: Policy and Practice in Urban Classrooms

- Teacher candidates explore how macro-level educational policies manifest in teachers' and students' practice in urban classrooms.
- Emphasizes the connections between all layers, processes, and actors in the educational system, from broader educational policy to urban classroom practice.

Sequence 4: Specializing in an Area of Teaching and Learning: Integrated Instruction in Elementary Classrooms

- Candidates engage in the teaching and learning of science and social studies.
- Candidates integrate literacy, with a specific focus on reading and writing, into these content areas.
- Investigate a particular issue of scientific and civic import, drawing on a range of informational texts and the skills of argumentation and academic writing.

Sequence 5: Literacy and Data Use

- Engages teacher candidates in the use of data to measure objective mastery, measure student growth, and modify instruction.

- Candidates teach and co-teach personally designed science and other content lessons utilizing sheltered strategies and informational texts and technology.
- Candidates integrate and apply assessment knowledge and skills.

Sequence 6: Integrating Content, Cultures and Communities

- Teacher candidates hone their skills in transdisciplinary/interdisciplinary teaching through the International Baccalaureate framework.
- Candidates integrate content and pedagogy to make curriculum more responsive to students' immediate and future needs.

Sequence 7: Putting It Together: Developing and Implementing Rigorous and Relevant Instruction and Assessment

- Candidates measure their growth in the areas of instruction and assessment.
- Prepares candidates for the required teacher performance assessment (edTPA).
- Represents part one of a year-long student teaching experience.

Sequence 8: Student Teaching: Mastering Teaching, Learning and Leading

- This sequence takes place in the same classroom as Sequence 7.
- Represents the full-time student teaching experience and the final sequence in the program before certification.
- Candidates complete the Teacher Performance Assessment (edTPA).

Note

1. The edTPA is an evidence-based teacher performance assessment process for teacher candidates, designed to be used for teacher licensure and to support state and national program accreditation. See http://edtpa.aacte.org.

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How Does That Work? Developing Pedagogical Content Knowledge From Subject Knowledge

JUDITH HILLIER

ABSTRACT: The development of subject knowledge and pedagogical content knowledge has been the focus of much educational research and debate in recent years. Of particular interest is the process by which preservice science teachers develop pedagogical content knowledge from their subject knowledge. In the study presented here, a process of writing narrative explanations of scientific phenomena was developed as part of a preservice teacher education course at a U.K. university. This process revealed the importance of teachers having *coherent internal accounts* to explain phenomena, which they can then share with students through meaningful discourse and joint action. Developing these coherent internal accounts would appear to be part of the process by which subject knowledge is transformed into pedagogical content knowledge.

Ask typical high school students what makes a good teacher, and their answer will usually include the response that good teachers are able to explain ideas and concepts in a way that students can understand (Wilson & Mant, 2011). However, there would appear to be a lack of science education research into teacher explanations, perhaps because of the recent focus on student learning (e.g., inquiry learning and argumentation) and the association of teacher explanations with a lecturing approach (Geelan, 2012). In this study, an "explanation" is used to denote the story that explains a particular event or phenomenon (Ogborn, Kress, Martins, & McGillicuddy, 1996) and that the teacher wishes to become the common knowledge shared by teacher and student alike and developed "through discourse and joint action" in the classroom (Edwards & Mercer, 1987, p. 161). Explanatory stories are valued, as they help learners to see science as a set of "interrelated ideas," to see the overarching ideas and not just the detail, and to develop the depth of understanding desired (Millar & Osborne, 1998, p. 2012). It is suggested that understanding the importance of such stories and learning how to develop them is a crucial part of becoming an effective science teacher and that the process of doing so should be explicit within preservice teacher education to prepare science teachers to introduce and develop the scientific story in a persuasive way that helps students