Structures and Strategies for Science Teacher Education in the 21st Century

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ABSTRACT: In order to determine the ways in which teacher preparation programs will need to change in order to meet the needs of preparing STEM teachers in the near future, it is necessary to ascertain what STEM teacher preparation programs are actually doing in the present. This article presents a comparative analysis of six different science teacher education pathways in order to portray, compare, and contrast the structures and strategies used by each. The central premise is that there is much to learn from what is already being done in this field from the different visions of science teacher education currently being enacted, and that calls to reform STEM teacher education often overlook these practices. No claims are made about the effectiveness of one structure, strategy, or pathway over another, but rather these science teacher education structures and strategies are presented as consequences of pragmatic choices about the strategic use of resources and decisions about what values to prioritize. Efforts to improve STEM teacher education can benefit from a richer understanding of these choices.

The core question of this special issue of Teacher Education and Practice asks the question: What will teacher preparation programs need to change in order to meet the needs of preparing STEM teachers? Yet in order to answer this question is necessary to ascertain what STEM teacher preparation programs are actually doing.

Recently a national foundation grant to prepare more STEM teachers for high-need schools was awarded to my home state of New Jersey. The announcement invoked the low comparative scores on international assessments, the dearth of qualified applicants for STEM industry positions, and the difficulty in staffing STEM teaching positions in many urban districts. Few will disagree that we as a state, like the rest of the United States, face a shortage of well-prepared highly-qualified STEM teachers, even if the public understanding for these reasons is not always accurate (Ingersoll, 2007, 2011).

Yet, there is also no shortage of rhetoric that the preparation of STEM educators (and teacher education generally) is broken and needs significant overhaul in order to provide adequate numbers of high-quality STEM teachers. Critiques include attention to the applicant pool, issues of disciplinary specialization, social disparities masked as teacher effects, and cumbersome bureaucratic requirements to teach (National Council on Teacher Quality, 2010; Tate, 2011; Walsh, 2006). “Traditional” teacher preparation programs for science education are often cast as partly to blame for this situation, but it is fair to ask if this is indeed the case.

Over the past three decades, a considerable number of pathways have opened for qualified individuals to become certified to teach in the United States. While an increasing number of these programs bypass university-based preservice teacher education programs altogether (e.g. Kopp & Farr, 2011), many of them make use of university resources in a variety
of ways (Grossman & Loeb, 2008). As a result, the label of “alternate route certification,” is much less descriptive today than it has been historically.

In the imagination of the public, it appears that there remains a vision of the stereotypical teacher education preparation program in which new teachers take courses in the rarefied air of the university, only to set foot in real classrooms for a few observations and the trial-by-fire of student teaching. In actuality, science teacher preparation as a field appears to be undergoing its own Cambrian-like explosion of diversity as institutions try out new structures and strategies for preparing science teachers. The purpose of this article is to explore the implications of this diversity for the question posed by this special issue. It is by no measure a strict empirical study, but in discussing this issue I draw upon my recent research in science teacher education (Larkin, 2010, 2012a, 2012b) at different institutional settings in the Midwest and Northeast U.S. to provide examples of the variety of programmatic elements and strategies currently in use.

In this article I present a comparative analysis of six such science teacher education pathways in order to portray, compare, and contrast examples of the structures and strategies used by each. The argument I wish to make is that there is much to learn from what is already being done in this field from the different visions of science teacher education currently being enacted. I make no claims about the effectiveness of one pathway over another, but rather present these science education structures and strategies as consequences of pragmatic choices about the strategic use of resources and decisions about what values to prioritize.

Methodology

The data for this analysis was gathered primarily from public programmatic documents and from my prior and ongoing research on studying individuals learning to teach in science teacher education programs. With the exception of one program described here, none explicitly framed their population using the term STEM as an identifier, yet all cast their program’s mission of producing qualified science teachers as consistent with the broader 21st century goals of STEM education (Bybee, 2010; Partnership for 21st Century Skills, 2009).

I use pseudonyms to maintain the confidentiality of the programs because of commitments of confidentiality made in these other research studies. The selection of these programs for the purposes of this paper is not intended to represent a quantifiable or generalizable sample of science teacher education programs, nor is any intended to represent fully an exemplar of a particular type of program. Rather, these programs were selected for analysis because they offer a sufficient contrast between the structures and strategies employed in science teacher education and thus offer an opportunity to learn from them as cases (Stake, 1995). Details about these programs are shown in Table 1, but a brief description of each is provided below:

RschOne: This program is a two-year certification program for undergraduates and post-baccalaureate certification only. It is located at a flagship institution of a state university system, with a carefully crafted dual-cohort model in both secondary and science education and increasing hours of fieldwork as candidates progress through each semester of the program.

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1 Efforts to compare science teacher education structures against teacher learning effects across multiple programs have generally been inconclusive in their findings. Research done by the SALISH consortium in the early 1990s (Salish I Research Project, 1997) and the more recent IMPPACT study partners (Tillotson & Young, 2010) has been methodologically and logistically complex, and correlations between particular practices and outcomes has proven difficult to establish.

2 They are also quite different in terms of recruitment, admissions criteria, and admissions processes, but owing to space limitations these programmatic elements are not discussed here, though such differences remain quite important.
NormState: This program is located in a medium-sized state university with historical roots as a normal school/state college, and its science teacher education course sequence accommodates those in undergraduate, post-baccalaureate, and masters degree programs. A 30-hour urban school fieldwork experience course is one of the prerequisites of the program.

AltRoute: This program is run by a four-year state university through its state-sponsored community college system. Candidates become eligible through demonstrating a content-area BS degree, passing the PRAXIS II exam in their content, and the successful completion of a pre-admission field-based course. Candidates in this program must first gain paid employment at a school district as a teacher, and then complete the preparation coursework during this initial year of teaching.

STEMprep: Located at a large research university, this program is an intense one-year course designed to address the pressing need for STEM teachers across a wide metropolitan area, and seeks to recruit and prepare science teachers coming from careers in science and industry. Its science teacher education course sequence accommodates those in undergraduate, post-baccalaureate, and masters degree programs, but provides all of the coursework within a structured cohort that stays together for nearly all university classes.

UrbanRes: This program is one of the original 28 Urban Teacher Residency programs funded by a 2009 U.S. Department of Education’s Teacher Quality Partnership grant, which seeks to create teacher preparation programs based on a medical residency model. In this type of program, a rigorous screening process identifies high-quality preservice science and mathematics teacher candidates (“residents”) and places them in the classroom of a master teacher (“mentor”) for a one-year clinical apprenticeship (e.g. Boggess, 2010; Solomon, 2009), making the selection of schools and mentors a critical element of the program. Residents are also provided with on-site coursework from tenure-track faculty, district partners, and other university instructors in the schools where they are placed. The UrbanRes program in particular was developed in equal partnership with the large urban school district, and upon successful completion of the program, residents are hired into available district science or mathematics teaching positions.

SciCert: This program is designed to recruit previously certified teachers in other areas (such as social studies or physical education) and certify them in a 12-18 month program in either physics or chemistry. The centerpiece of the program is a research-based 3-year curricular sequence of physics-chemistry-biology grounded in the College Board’s Advanced Placement program that is adopted by the schools in which SciCert graduates teach.

Comparing the Structures and Strategies of Science Teacher Education Pathways

Each of these six certification pathways is likely to appeal to different prospective science teachers, and an individual who successfully completes any of them will be considered highly-qualified to teach science by national criteria (United States Department of Education, 2002). Some are undergraduate pathways, and others culminate in a master’s degree or simply post-baccalaureate certification alone. Most focus primarily on initial teacher certification, but at least one aims to provide a science-area certification to teachers already certified in other areas.

In this section I discuss five aspects of difference between these six programs. The first describes the absence or presence of coursework explicitly designed to develop candidate’s pedagogical content knowledge within a disciplinary context. The second concerns elements of

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3 The program also recruits a parallel cohort of math teachers.
fieldwork-based experiences, including opportunities to develop critical understandings around issues of school and society and reform-based science teaching. A third difference pertains to the role of supervisors, cooperating teachers and mentors as teacher educators in these efforts. The fourth addresses the various ways in which the task of preparing teachers for diversity is incorporated into the programs are discussed. The fifth aspect concerns the role of time that is allocated for the components of preparation in each of these programs. The tradeoffs resulting from decisions about programmatic structures and strategies of these programs will be discussed as a series of program design questions in the subsequent section of the paper.

**Opportunities to learn in a science methods course**

These six programmatic pathways differ in the presence, extent, and nature of what are commonly termed “methods” courses. These courses commonly seek to develop candidates’ pedagogical content knowledge (Gess-Newsome & Lederman, 1999; Shulman, 1987), though the course itself may or may not be situated within a specific discipline, as will be shown below.

University-based science methods courses are employed in the NormState, RschOne, and STEMprep programs for varying durations, and candidates from across the secondary disciplines of biology, chemistry, physics, and earth science are assembled together in these classes. NormState offers a single science methods class, taken by candidates prior to student teaching, usually during the semester of an observational practicum. RschOne has a two-semester sequence of science methods courses taken during the second and third semesters of the program. The STEMprep program has a total of three methods courses. The first course is offered in the first semester of the program—prior to any fieldwork—and the next two are taken concurrently in the following semester while students are in their urban middle school practicum. While the STEMPrep Methods of Teaching Science II is taught in a university classroom, Methods of Teaching Science III is a field-based experience where the cohort of science teacher candidates visits a different high school science classroom every week. The program coordinator organizes these classes, and many of the classrooms visited are those of highly respected cooperating teachers and graduates of the STEMprep program.

The content of the methods courses in the NormState, RschOne, and STEMprep programs is similar in some respects, but quite different in others. All address the topics of lesson planning, curriculum, assessment, instructional technology, and the role of student thinking and misconceptions in science learning in some way. With more time to devote to specific methods of teaching science, the RschOne and STEMprep programs address these topics in more depth. Yet while the RschOne program emphasizes teaching for conceptual change, the development of reflective practice, and attention to the needs of learners in diverse classrooms, the STEMprep program focuses more on hands-on learning, pragmatic aspects of curriculum design, and specific strategies and activities to be exported to student teaching classrooms.

In contrast, the UrbanRes program integrates its methods course instruction into a weekly course co-taught by three tenure-track faculty onsite in the schools where the candidates (“residents”) have been placed. The structure of the UrbanRes program is such that the residents are in frequent contact with university faculty, and though the time allocated to science methods activities is significantly less than in the RschOne and STEMprep programs, the activities and assignments of the science methods instruction are designed to fit the circumstances of the individual residents. The science methods instruction in the UrbanRes program draws upon the approaches and tools developed by the Tools4Teaching Science Project (Windschitl, Thompson,
and is also integrated into the other aspects of the program that emphasize inquiry approaches to science teaching, planning and assessment using the Understanding by Design Framework, reflective practice and teaching for social justice.

While the AltRoute program offers its candidates a general pedagogical methods course—which they take with other candidates being certified across grade levels and disciplines—there is no opportunity for science or discipline specific methods instruction as part of this pathway. In the best cases, it is possible for science methods instruction to occur in the school setting with a mentor. Yet, mentors may not be in the same content area as the candidate, or even in a science discipline at all. Further, there is almost no programmatic control over the substance of these mentoring sessions, and research suggests that classroom management issues often take up the largest proportion of time in new teacher mentoring sessions (Achinstein & Barrett, 2004). While this may be appropriate in certain circumstances, the relevant point is that there is only a small chance that AltRoute candidates will have the opportunity to gain the pedagogical content knowledge learned through the science methods coursework in the other pathways.

In each of these first five programs, the development of teachers’ science content knowledge is not an explicit part of methods courses, except perhaps in relation to developing a deeper understanding of the nature of science, an element of science teacher preparation that has grown in importance over the past decades (Abd-El-Khalick, Bell, & Lederman, 1998; Lederman, Abd-El-Khalick, Bell, & Schwartz, 2002). In this respect, the SciCert program stands in stark contrast to the other programs described here. Unlike certification pathways where candidates are required to demonstrate their content knowledge prior to entry with sufficient credits or a degree in a science major, the SciCert program only accepts previously certified teachers in a non-science certification, and aims to provide them with both the content knowledge and pedagogical content knowledge necessary to teach chemistry or physics. The program is predicated on the use of the SciCert curriculum, and prospective physics and chemistry teachers learn the content through instruction in the same curriculum they will be expected to teach.

For example, in the SciCert methods course called “Teaching Algebra-based Physics,” a teacher previously certified to teach in a discipline other than physics (e.g. high school social studies) might be taught a physics lesson on Newton’s Second Law. The electronic white board slides and problems she would use as a student in that particular session of the methods course would be the same ones that would be made available to her to teach that same lesson the following semester to a ninth-grade physics class. In the methods class, the SciCert methods instructor then follows this physics content instruction with a pedagogical discussion about the various ways such a lesson might unfold in a class of high school students.

In this manner, prospective science teachers learn the content concurrently with strategies to teach that particular content. Subsequent courses in the SciCert program focus on teaching Advanced Placement physics and chemistry courses, which similarly focus on strengthening teachers’ disciplinary content knowledge while developing the skills to teach specific lessons within those curricular constraints.

Opportunities to learn in field-based experiences

These science teacher preparation pathways also differ in the nature, duration, and quality of field-based experiences. There is a growing recognition that teacher preparation has a greater
impact when prospective teachers are able to situate their learning in the day-to-day realities of schooling, and many teacher education programs have responded to this recognition by making field-based experiences an ongoing part of the curriculum, rather than just a culminating experience with student teaching. In this way they are intended to represent the integrated, purposeful field experiences called for by teacher education researchers like Darling-Hammond (2006) and Feiman-Nemser (2001).

Candidates in AltRoute and the undergraduate NormState pathways are required to undertake this fieldwork as a prerequisite for applying to the certification program. In both cases, this is an institutional requirement that holds for all subject areas—not just for science teachers—and the rationale relates to ensuring that individuals are aware of the modern realities of teaching as a profession and are able to make an informed choice about whether or not to pursue teaching as a career. The AltRoute requirements are minimal in that only four hours of observation are required. For the NormState program, this program component is grounded in the university’s commitment to a nearby large urban school district where prospective teachers observe teachers, attend professional meetings, and engage in service at the host school for a total of 30 hours.

With the exception of the SciCert program, all of the science education programs have an observational component built into the fieldwork, commonly known as a “teaching practicum.” The typical intent of a teaching practicum is to immerse individuals gradually into the complexities of teaching by giving them limited exposure to classroom tasks, which they can then connect in various ways to the substance of university coursework. As noted above, in the SciCert program, this observational component is built into the coursework.

Field experiences are often greatly influenced by the specific classroom placement, and there may be as much variation among individual experiences in a particular program as seen between programs. In addition to classroom observation, this experience often provides some opportunity for candidates to engage in individual tutoring or small group instruction, though the opportunity to plan and teach full-class lessons is not uncommon in the practicum experience. Yet each program under consideration here takes a slightly different approach to structuring this practicum, and one salient difference between programs is the extent to which candidates experience teaching—science discipline specific and otherwise—in different settings.

The RschOne program is longer than most of the other programs, and incorporates a field-based experience into each of its four semesters over two years, each of which takes place in a different setting. During the first semester when collaboration and inclusive education are the focus of the program, candidates spend 40 hours observing at a school, with half of this time devoted to observation in a classroom where inclusive practices are being used. In the second semester the duration of the practicum is the same, but candidates are placed in a classroom aligned with their certification area. They also complete a separate tutoring component where they are required to work with students who come from a different cultural or socioeconomic background from themselves.

Such placements require careful planning by a teacher education coordinating center as well as by the science education program faculty at the university, and a certain level of care and vetting is done to ensure that teachers are placed in classrooms that are consistent with the program goals. In contrast, the practicum experience in the AltRoute program is almost entirely in the hands of the candidates themselves, who must make their own arrangements for the required 15 hours of classroom observation in the first stage of the program.
Like the NormState program described above, the university housing the STEMprep program has an ongoing and historic relationship with a large urban center that includes a commitment that all prospective teachers being certified at the university have a field experience in the city. Yet a shortage of science-certified cooperating teachers at the district’s middle school level (most were elementary generalists with minimal science education backgrounds) led the program to design a somewhat unique practicum structure. The STEMprep program places all of its practicum students in a single classroom in a public magnet school for the arts. One sixth-grade teacher serves as the cooperating teacher for fifteen preservice science teachers, who are distributed across sections of her general science classes. Over a period of ten weeks, the STEMprep students assume increasing degrees of control over the planning and teaching of each class under the supervision of the cooperating teacher. Each of the 3-4 practicum students in each class had the opportunity to teach a lesson at least once per week. When not teaching, STEMprep practicum students observed class, operated video equipment, or provided instructional and classroom management support. Candidates in the program received regular feedback on their practicum efforts from the cooperating teacher as well as from the science education faculty.

In the NormState and UrbanRes programs, the line between practicum and student teaching is much less defined than in these other programs. Candidates remain in the same classroom for two consecutive semesters in all but the most exceptional cases, partly as a result of careful selection of cooperating teachers but also owing to the extraordinary difficulty of finding adequate placements. In the case of the NormState program, this practicum experience is supplemented by a seminar course taught on-site in a second school, where additional practicum opportunities are offered. In the case of the UrbanRes program, cooperating teachers (“mentors”) are selected from schools that have agreed to work with the UrbanRes program in consultation with district and school partners, and must be approved through visits of university faculty to ensure that their practice as a science teacher is consistent with the program goals. Residents begin daily co-teaching from the beginning of their placements, and thus the role is less observational than field experiences in the other programs described here.

All of the programs under consideration in this analysis have a fieldwork component in which candidates take on the primary responsibility for planning and teaching course sections, which is sometimes called “full-time teaching” or “student teaching.” Yet these labels may mask important differences between programs. In the UrbanRes program there is no sharp transition for residents in their responsibilities from the fall to the spring. In the case of the SciCert and AltRoute programs, this component is fulfilled by paid employment for which candidates are considered the teacher of record in their classrooms.

The RschOne program actually requires two semesters of student teaching. The first is a “half-day” student teaching experience, where candidates take responsibility for one or two of their cooperating teacher’s classes in the morning, and then return to campus for afternoon coursework. The second is a full-time student teaching semester, similar to that required by the NormState and STEMprep programs. One of the features that differentiate these programs is the level and nature of support that individuals receive during this time, a topic to which I now turn.

Opportunities to learn from supervisors, faculty, and school mentors

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4 This is also a consequence of a large number of teacher education programs in the metropolitan area competing for a limited pool of available cooperating teachers.
Opportunities to learn from a cooperating teacher will always depend on the availability and willingness of qualified individuals who agree to take on a student teacher in their classes. Much of this learning takes place through day-to-day interactions, but receiving specific and targeted feedback may be one of the most powerful aspects of the student teaching experience. Recent research has confirmed the role of formative feedback as a powerful educational intervention (Black & Wiliam, 1998; Hattie & Timperley, 2007), and there can be little doubt that receiving this feedback is a crucial aspect of learning to teach.

Clearly in all of these programs, prospective science teachers are observed multiple times by highly qualified individuals, but it is challenging to compare the nature and quality of feedback of these observers, either within or across programs. For example, candidates in the AltRoute and SciCert programs receive feedback on their teaching from mentors who are fellow teachers, and in some cases their university instructors as well. However, opportunities for receiving such feedback vary, and ultimately the burden is primarily on the school districts that employ these teachers to evaluate the quality of their teaching.

In comparison, during the final semester of the UrbanRes program, candidates receive at least eight formal observations. The majority of these are structured by the use of the Reformed Teaching Observation Protocol (Sawada et al., 2010), an observation tool designed specifically for assessment of science and mathematics teaching. At least four of these observations are conducted by tenure-track faculty. Given that the UrbanRes program draws programatically from the medical residency model, the practice of instructional rounds (City, 2011) is also used, whereby each of the residents is observed by their cohort followed by a structured discussion as a group post-conference at least once in the semester.

The NormState program requires nine observations during the student teaching semester: three from a content area specialist (i.e. science faculty), three from an education specialist (typically retired educators as adjunct faculty) and three by the cooperating teachers. Each observer communicates individually with the candidate to schedule observations. Data from these observations are recorded in a central database, and the evaluations are recorded on a standardized progress report that consists of 15 items rated on a 5-point Likert scale. Even with this level of standardization, there is little guarantee of interrater reliability, and it may be that each observer sets different norms for the carrying out the observation and post-observation conference protocols (Pajak, 2001).

The STEMprep program places candidates throughout a wide geographic area but has limited faculty resources for observations; one university faculty member and one adjunct are responsible for visiting 15-25 student teachers at their placements and conducting the state-mandated three observations of each student teacher. As a result, the STEMprep observations are usually conducted with little advance notice, and though STEMprep teachers do get feedback on their teaching they may not be able to arrange observations to get feedback on a particular lesson of their choosing.

Learning to teach science in a diverse society

Given the growing cultural, racial, socioeconomic, and linguistic diversity in the U.S. school-age population, many teacher education programs have consequently increased efforts to prepare their candidates for encountering this diversity in the schools (Ball & Tyson, 2011; Villegas, 2008). For some programs such as UrbanRes and RschOne, this focus on teacher preparation for student diversity is a central programmatic thread that is woven into nearly every
aspect of the candidates’ experiences. For others such as the AltRoute program, when, how and even whether diversity is addressed in the program remains a curricular issue at the discretion of individual instructors.

The very structure of the UrbanRes program incorporates attention to issues of equity through its partnership with an urban district in a high-poverty community, and one of the explicit goals of the program is to provide high-quality teachers for the district’s historically underserved and marginalized school population. Learning the pedagogical implications of diversity (Paine, 1990) is a central tenet of the program, and one of the ways in which this occurs is through a pair of summer field placements in which the residents work with youth in a number of community settings for the purpose of developing relationships and understandings that later carry over into the classroom (Ladson-Billings, 2001). Throughout the year, residents are guided by their mentors and instructors in leveraging the diverse set of experiences and ideas that their students bring—particularly about natural science phenomena—in order to promote greater student learning.

The STEMprep, NormState, and RschOne programs all have a 3-credit course devoted to issues of diversity. The effectiveness of such “diversity” courses on dispositions and teacher beliefs has been called into question (Sleeter, 2001), but clearly the presence of such a course in a sequence sends a message about its importance, and the course itself represents an opportunity to learn to teach science to all students more effectively, as well as to become more oriented to the idea of teachers as agents of social change (Counts, 1932; Lee & Buxton, 2010). As noted earlier, these three programs each require a field experience that exposes candidates to diverse school settings. For the STEMprep students however, it is possible that the urban middle school experience is their sole exposure to a diverse school setting.5

The AltRoute and SciCert programs do not explicitly structure an experience connected with developing candidates’ abilities to teach for diversity, but it is interesting to note that both prepare a much greater proportion of the science teachers of color in their state than any other program (State Certification Data, 2010). While there is no reason to claim that students are best served by teachers of similar demographic backgrounds (Irvine, 2003; Ladson-Billings, 1994; Woodson, 1933), it is clear that these programs have diversified the teaching force in ways that may positively impact science learning outcomes for students of color (Villegas & Davis, 2008).

The role of time

The final aspect of these programs addressed here concerns the role of time. While simply comparing the durations of programs appears informative, other teacher education research suggests that the tasks and experiences of students within a program is likely to be more significant in determining teacher education outcomes (NCRTE, 1991; Zeichner & Conklin, 2005). Many preparation strategies designed to increase the numbers of STEM teachers in schools often aim to do so quickly and efficiently, yet the values of various trade-offs in terms of costs, benefits, and diminishing returns on time are often not adequately explored in the design of science teacher learning environments (Roth, Tobin, & Ritchie, 2008).

Two of the programs, STEMprep and UrbanRes, are intensive one-year certification programs, and it is possible for candidates to complete the AltRoute and SciCert programs within

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5 Though with the de facto segregation that occurs in schools in many urban centers (Kozol, 2005), it may be incorrect to characterize a racially and culturally homogenous school—such as the one where the STEMprep practicum takes place—as diverse.
a 12-15 month time frame as well. The NormState and RschOne programs are both designed to accommodate the completion of other coursework—such as content major requirements—within the duration of the two-year sequence of teacher education coursework.

To meaningfully compare workloads—defined here roughly as the tasks candidates must complete for their program within a given time—across these pathways, it is worth examining what the demands are on prospective teachers’ time during a given semester. Given that in each of these programs the final semester involves full-time teaching, it is instructive to examine what the requirements are during that time.

The most intensive are the UrbanRes and STEMprep programs, which require coursework concurrent with full-time teaching. In addition to the tasks of planning lessons, grading papers, and attending to issues in their personal lives, the STEMprep students must complete assignments for two evening courses, one on assessment and the other on inclusive classrooms. It is notable that the STEMprep program does not have a seminar course or scheduled series of meetings to bring the cohort together to process their experience during student teaching—a feature that present in other cohort programs—and instead send weekly email reflections to the program coordinator.

The coursework is similarly heavy in the UrbanRes program, and although it is mostly integrated into the school day, the work they are charged with completing is roughly equivalent to two 3-credit courses. UrbanRes students are expected to hand classes back over to mentor teachers during the weekly class time or when other residency activities require their absence. One consequence of the district partnership in the UrbanRes program is that mentors are allotted an extra preparation period (i.e. one less class to tech) in order to spend time with the resident on planning, feedback, and other teacher learning activities, thus relieving some of the time pressures that often plague student teaching.

The AltRoute, SciCert, and NormState programs all require a 3-credit course to be taken in the evening during full-time teaching. The SciCert class is focused primarily on preparing teachers for the Advanced Placement chemistry or physics curriculum, but the NormState, AltRoute, and the UrbanRes classes are more seminar-based courses that offer an opportunity for class topics to emerge directly from the struggles and experiences of the candidates.

RschOne does not require any coursework to be taken during the student teaching semester. In fact this practice is discouraged on an institutional level because it is seen to remove focus from full-time student teaching and inhibit opportunities for candidates to engage in extracurricular activities at their sites. RschOne students do however, meet monthly to talk about their experiences student teaching within the supportive structure of the cohort.

For many students in their full-time teaching semester, holding down even a part-time job outside of teaching is extraordinarily difficult because of these time pressures. Of course, one goal of earning certification is to ultimately gain employment as a science teacher. What it means to the candidates to actually “finish” in these various programs can thus be debated, as the UrbanRes residents receive a stipend and tuition-waiver, and the AltRoute and SciCert teachers benefit from their paid employment. Conversely, students in the RschOne, STEMprep, and NormState programs all pay full-time tuition, and receive no paycheck for their efforts.

**Discussion**

In describing science teacher education programs, it is helpful to think in terms of the parameters of the different components described above. Significant differences between
programs—such as the presence of a third science methods course, the requirement of pre-admission fieldwork, or the negotiation an extra prep period for cooperating teachers—are masked in public discourse about science teacher preparation. Yet it is highly likely that these differences impact how candidates learn to teach science.

Looking across the six programs described here, it seems clear that anyone designing or modifying a science teacher education program must make decisions grounded in both values and available resources, and pragmatic constraints. To aid in this process, I present a series of questions that address a number of aspects of program structure influenced by these choices:

- What are the entry requirements? Who is the target population of prospective teachers?
- What is the program duration? Are summer semesters involved?
- Who is involved in the program? What do different actors such as tenure-track faculty, clinical specialists, and district personnel bring to the task of learning to teach?
- What coursework will be required, and where and how will it be delivered? Will the improvement of candidates’ content knowledge be within the purview of the program?
- What is the nature of the methods coursework? Will it be generalized to many disciplines or tightly focused on a single subject area? Will it include pedagogical content knowledge from practitioners?
- What is the purpose of the fieldwork? How much control will the program have over placement? What different fieldwork experiences are necessary to meet a particular program’s vision?
- Who are the cooperating teachers? Are they compensated in money, time, or both? What are the necessary qualities of cooperating teachers?
- What sort of supervision will candidates receive? What are the structures in place for candidates to receive feedback on their teaching?
- What will the program’s orientation to student diversity, social justice, and teachers as agents of change be? To what degree will STEM teachers certified in the program be prepared to teach English language learners and students with special needs?
- What commitments are made to partner districts? How much power do partner districts have within the program?
- Are students paid a stipend or a salary? Do they pay tuition? Will they need additional employment during the program?
- What is the appropriate amount of work required in the program? Is there sufficient time? Will there be additional program requirements during the full-time teaching semester? To what extent are candidates also expected to be involved in after-school activities at their sites?
- If the program is characterized as preparing STEM teachers, rather than just teachers of science or mathematics, what program elements are present that offer opportunities for candidates to make connections across science, technology, engineering, and mathematics?
- How does a program fit into other institutional and governmental structures? What decisions need to be made in terms of accreditation (e.g. NCATE)?

Connecting these questions to other goals that arise in broadening the view from science teacher education to STEM teacher education are just as important. The questions primarily concern the certification process, but a strong case has been made throughout the STEM teacher
education literature that it is equally important to attend to the process of teacher induction during the first crucial years of teaching (Davis, Petish, & Smithey, 2006; Ingersoll & Strong, 2011; Luft et al., 2011).

**Conclusion and Implications**

Looking across the models of science teacher education portrayed in this paper, it is clear that science teacher education is anything but uniform across different contexts and programs. These findings may serve to establish markers for understanding science teacher preparation program effects, and also point to ways in which the field of science teacher education might productively respond to the shifting terrain of teacher education policy on state and national levels (Cochran-Smith & Fries, 2005). A program of research that seeks to identify crucial elements of discipline-specific methods coursework might productively inform efforts to strengthen the preparation of individuals in both traditional and alternative routes to certification in STEM fields, as well as guide the professional development of science teachers currently in the classroom.

One challenge for STEM teacher education researchers is to understand what effects these and other pathways into teaching ultimately have on student learning. Research on teacher education suggests that the content of the program and particular candidate experiences may be the more important focus for study (Zeichner, 2006, 2010) compared with simply comparing course titles and program durations. Yet the public discourse concerning science teacher preparation often makes little distinction between the various pathways that individuals follow to become certified, and it seems likely that even seemingly minor differences between programs may have large effects.

One ongoing program of research in teacher education anticipates the establishment of lengthy empirical lines of causality from teacher preparation programs to the academic achievement of students (Gitomer, 2009; Rothstein, 2009; Sanders & Horn, 1998). The promise that such research holds for science teacher education depends upon being able to identify effective program components and structures from various teacher pathways. A valuable first step in studying such STEM teacher certification effects entails being able to describe these pathways adequately and make distinctions between the components that we as a field believe make a difference in student learning, and are thus worthy of further research.

**References**


Counts, G. S. (1932). Dare the school to build a new social order? New York,: The John Day Company.


Larkin, D. B. (2010). Learning the pedagogical implications of student diversity: The lived experiences of preservice teachers learning to teach secondary science in diverse


<table>
<thead>
<tr>
<th>Program</th>
<th>RsrchOne</th>
<th>NormState</th>
<th>AltRoute</th>
<th>STEMprep</th>
<th>UrbanRes</th>
<th>SciCert</th>
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*Coursework may be counted toward a graduate degree programs at the partner university.*
<table>
<thead>
<tr>
<th>Program</th>
<th>RsrchOne</th>
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<th>SciCert</th>
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<tbody>
<tr>
<td>Cohort?</td>
<td>Dual-cohort (secondary &amp; science)</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<td>Stipend and Tuition Remission</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
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<tr>
<td>Cooperating district coordination</td>
<td>Cooperating teachers must be credentialed through university supervision course.</td>
<td>Student teachers are placed in partner schools that are part of university network for educational renewal</td>
<td>None.</td>
<td>University commitment to large urban host district for part of fieldwork. Informal network for majority of student teaching.</td>
<td>District was a partner in writing the USDOE grant. Principals commit to induction program, 1 period release for mentor teachers. Strong commitment to hire graduates.</td>
<td>Proof of district adoption of the SciCert curriculum, with required equipment and materials (e.g. interactive white board).</td>
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<tr>
<td>Field placement</td>
<td>Central Coordinating office of the college in which the teacher preparation programs are located.</td>
<td>Central Coordinating office of the college in which the teacher preparation programs are located.</td>
<td>Candidates are responsible for securing paid teaching positions before beginning the second phase of the program</td>
<td>STEMprep program head personally directs placements</td>
<td>Mentor teachers (cooperating teachers) are selected through a search process, consisting of multiple site visits and commitments by mentors to participate in UrbanRes programs</td>
<td>Candidates are already in teaching positions, but there must be an opportunity for them to teach physics/chemistry after the initial coursework.</td>
</tr>
<tr>
<td>Program</td>
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<tr>
<td>Methods</td>
<td>Two science methods courses during semester 2 and 3. Taught by faculty or graduate students in science education</td>
<td>One science methods course prior to full-time student teaching. Taught by adjunct faculty with a graduate degree.</td>
<td>One general methods course (not science specific). Taught by adjunct faculty with a graduate degree.</td>
<td>Three science methods courses prior to full-time teaching. Taught by program coordinator or clinical science education faculty with a graduate degree.</td>
<td>Science methods is integrated into on-site coursework by science education faculty.</td>
<td>3 chemistry or physics-specific methods courses using the same SciCert curriculum that candidates are expected to use. Content and pedagogy are integrated. Taught by program coordinator or instructor with a graduate degree.</td>
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<tr>
<td>Fieldwork</td>
<td>Supervisors are graduate students with secondary science teaching experience. 3-4 site visits/observations per semester.</td>
<td>During observation semester: 1 site visit from university faculty/staff (MS or Ph.D. but not necessarily science)</td>
<td>30 weeks of mentoring support from school-based experienced mentor teacher (may or may not be in a science discipline).</td>
<td>Middle School practicum: Informal observations by university instructor. At least one lesson video recorded and observed by program coordinator.</td>
<td>Ongoing support from mentor teacher, core faculty, and district partners throughout the year.</td>
<td>Part of the district commitment to the SciCert program is to allocate at least 1 period a week to Professional learning communities for peer support.</td>
</tr>
<tr>
<td>Supervision</td>
<td>During full time student teaching: 3 formal observations each from a university content area mentor, an education mentor, and cooperating teacher (9 total)</td>
<td>During full time student teaching: Three observations by program coordinator or clinical science education faculty with a graduate degree.</td>
<td>Full time student teaching: Three observations by program coordinator or clinical science education faculty with a graduate degree.</td>
<td>Full time student teaching: Three observations by program coordinator or clinical science education faculty with a graduate degree.</td>
<td>Fall: Each resident has at least 4 Reformed Teaching Observation Protocol (RTOP) observations from core faculty.</td>
<td>Unspecified number of visits each semester by SciCert professor to the physics/chemistry class being taught.</td>
</tr>
<tr>
<td>Program</td>
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<tr>
<td>Fieldwork experiences</td>
<td>Year 1: 40 hours practicum in middle school placement and 40 hours practicum in a high school placement. 20 of these hours are in an inclusive classroom. These are mostly observational or one-on-one interactions with students. Limited full class teaching opportunities. Year 2: Two full semesters (half-day in fall, then full day in spring) following school district calendars. One middle and one high school placement.</td>
<td>30 hours in an urban school prior to program admission that includes teacher shadowing, meeting attendance, and service to the school (undergraduate only). Year 1: no fieldwork, coursework only. Year 2: Placement in either a middle or high school classroom. First semester, 60 hours of mostly observational or one-on-one interactions with students. Second semester is full time student teaching in the same class. Follows university calendar.</td>
<td>4 hours of classroom observation prior to admission (part of initial 24 hours of coursework). Stage 1: 15 hours of classroom observation. Stage 2: Full-time teaching employment (min. 15 hrs./week)</td>
<td>50 hours of practicum in urban middle school classroom. • 8 hours initial observation. • Co-teaching in groups of four. • ~10 hours as lead teacher • Various amounts of collaborative planning outside of classroom hours within co-teaching groups. Full day student teaching in a high school. Teaching semester follows the school district calendar. Visits to exemplary science teachers’ classrooms in 3rd methods course.</td>
<td>Six-week summer internship experience with partner district students. Clinical-apprenticeship model with residents in mentor teacher’s classroom for a full year. Coursework taught on-site in the schools, instructional rounds to classrooms in and out of district.</td>
<td>During the final two course clusters, teachers must teach a section of chemistry or algebra-based physics in their schools, which is coordinated evening coursework on teaching either AP Physics (B) or AP Chemistry.</td>
</tr>
</tbody>
</table>