EDUCATING TOMORROW'S SCIENCE TEACHERS

STEM ACT Conference Report

A report on a working conference on
Alternative Certification for Science Teachers
held May 5-7, 2006 in Arlington, VA.

Morton M. Sternheim, Allan Feldman, Joseph B. Berger, and Yijie Zhao
University of Massachusetts Amherst

February, 2008

EDUCATING TOMORROW'S SCIENCE TEACHERS

STEM ACT Conference Report

A report on a working conference on
Alternative Certification for Science Teachers
held May 5-7, 2006 in Arlington, VA.

Morton M. Sternheim, Allan Feldman, Joseph B. Berger, and Yijie Zhao
University of Massachusetts Amherst

This document reports on the findings of an NSF-funded conference (STEM ACT) on the alternative certification of science teachers. The conference explored the issues that have arisen in science education as a result of the proliferation of alternative certification programs in the United States, and to identify the research that needs to be done to reconcile the rapid growth of these programs with the demands that national standards and state curriculum frameworks put on science teacher quality. Alternative certification for science teachers has become a tapestry woven of various strands - political and professional, ideological and academic. Given the complexity of issues, the continued growth, and the on-going investment of public resources associated with alternative certification, a comprehensive, in-depth and systematic descriptive analysis is needed to help evaluate the ways in which alternative teacher certification does or does not address teacher supply and demand, and science teacher quality. Therefore, one purpose of the STEM ACT conference was to identify key features and issues relating to alternative teacher certification as the basis for suggesting a more systematic approach to the study of alternative teacher certification efforts.

The STEM ACT conference was held in early May 2006 in Arlington, VA. It was a working conference in which 65 participants presented and discussed 42 papers. Most of the papers are available on-line on the conference website. The conference was organized along three themes:

1. An overview of the existing <u>policy</u> on alternative certification of secondary (middle and high school) science teachers in the US, including key assumptions and questions.
2. A synthesis of existing <u>research</u> about the needs, methods, and outcomes of alternative certification for science teachers.
3. An in-depth look at existing <u>practice</u> through the examination of particular cases of alternative programs for science teacher preparation.

On the last day of the conference participants were grouped into writing committees to begin the preparation of white papers on each theme. The findings of the conference are presented in this document.

This report was supported by National Science Foundation award 0514620. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. There are four reports in all: Executive Summary, Policy, Research, and Practice.

Copies of the reports are available at www.stemtec.org/act/WhitePapers.htm. Print copies are also available on request at no charge while supplies last. Contact STEM Ed, 229 Hasbrouck Lab, University of Massachusetts, Amherst, MA 01003, or hq@umassk12.net.

TABLE OF CONTENTS

A National Science Foundation funded conference entitled, "Science, Technology, Engineering and Math – Alternative Certification for Teachers" (STEM-ACT) was held in May, 2006 in Arlington, VA. The conference was designed to facilitate a significant exchange of information, which was then synthesized to produce white papers on the three threads of the conference, i.e., policy, practice, and research. This summary presents the highlights of the three white papers.

One goal of the conference was to identify key issues related to the alternative certification (AC) of science teachers to support a more systematic study of AC efforts. A second goal was related to the extensive research programs on science teaching and learning that have been funded for 30 years by NSF and other agencies (see for example, Lederman & Abell (2007)). We now know a great deal about the teaching and learning of science in schools. What is not known, however, is how to incorporate this knowledge into AC programs. Therefore, a guiding question of the conference was, *"What do we know and what more do we need to learn about how to incorporate the results of research on science teaching and learning into alternative certification programs?"*

On day one, all attendees presented their research and served as respondents to other presenters. Papers were available ahead of time (see http://stemtec.org/act) so that respondents could prepare thoughtful comments. In the morning of day two, small groups identified the major ideas and in the afternoon writing teams began the preparation of three white papers. This article provides an overview of the papers, beginning by addressing the questions:

- *"What are the policy issues in the alternative certification of science teachers?"*
- *"What is alternative certification and what does it look like?"*
- *"What research needs to be done?"*

Policy issues for the alternative certification of science teachers

Policy makers rely on studies that provide contradictory data about teacher supply and demand and the efficacy of alternative and traditional teacher education programs. Therefore, an important goal of the policy group was to frame the problems that alternative certification addresses. They found that there are deficits in the quantity and quality of science teachers. Therefore, teacher certification public policy is concerned with addressing incentives and standards to ensure that there are enough qualified teachers. And, there must be enough quantity before quality can be addressed.

.The policy group found that several factors affect the demand for science teachers, including the number of classes that need to be staffed, teacher retention rates, and retirements. Demand also depends on student demographics, and on the funds available.

Dominating the supply of new science teachers is the limited number of people who receive training in the sciences, and their multiple career opportunities. The conference found that it is necessary to pay attention to both salary and working conditions to attract qualified people. The quality of the science teacher employed in a school will depend on the total compensation package (i.e., salaries, benefits, working conditions, and intrinsic rewards).

To balance supply and demand, districts can make several tradeoffs:

- There can be a quantity-quality tradeoff. A district can choose to employ fewer teachers but maintain high quality standards (e.g., increase class sizes and/or offer fewer courses but of higher quality) or it can sacrifice quality by employing as many teachers as possible regardless of quality.
- The district can sacrifice quality in science teaching to promote quality in other subject areas.
- The district can find that it needs to sacrifice both quantity and quality just to stay solvent.

Science is costly to teach; laboratories require extra resources. High quality science teachers may cost more because of their short supply. The attractiveness of teaching relative to other occupations available may be lower for individuals trained in the sciences than for those trained in other fields, such as English. Attracting a high quality science teacher may require a relatively costlier compensation package.

The district can find that it needs to sacrifice both quantity and quality just to stay solvent.

The cost of high quality science teaching and the relatively low incentive to produce it combine to exacerbate the shortage of good science teachers, particularly in schools with highly constrained resources. Hard-to-staff schools are doubly challenged, needing to funnel scarce resources into the areas upon which their survival depends most heavily *and* being less likely to attract high quality science teachers than schools with more desirable working conditions.

The policy group found that the main motivation for AC for science teachers is to increase supply by speeding up licensure by reducing impediments. This raises questions because of the group's other findings. First, do traditional certification programs produce a significant restriction on the rate of production of new science teachers, and if so, how? Second, how many people knowledgeable in the sciences are available to be science teachers? That number may be more critical than the certification process. Third, can policy makers shape science teaching so that it is competitive as a career with the other options available?

What is alternative certification and what does it look like?

The term alternative certification is ambiguous. Many programs considered AC are housed in institutions of higher education and lead to both licensure and a degree. Some call only undergraduate programs "traditional," and label all other teacher education programs as alternative. In addition, there is as much variation within programs as there is between programs. For example, Marjorie Wechsler reported on a large-scale study that found large variations among AC programs in the characteristics of participants (e.g., their education

"there is no agreement about the definition of alternative certification and there is some confusion as well about what constitutes traditional certification"

backgrounds), previous careers and classroom experience; and in the components of the AC programs, including participant experiences with coursework, mentoring and supervision, and the context of their school placements (Wechsler, Humphrey & Hough, 2006).

There are large variations in program structure among those programs labeled as alternative, the differences in candidate backgrounds within and among programs, and the wide range in the school contexts in which candidates were placed, both within and among programs. This led the conference to concur with the statement that "there is no agreement about the definition of alternative certification and there is some confusion as well about what constitutes traditional certification" (Zeichner & Conklin, 2005, p. 656; Zeichner, 2006). Rather than trying to compare traditional and alternative programs, one should consider a continuum of teacher preparation and support programs designed to serve the varied needs of schools and of pre-service and in-service science teachers. All effective teacher education programs, as argued in the practice white paper, should:

- include solid partnerships involving the state licensing authority, institutions of higher education and local school districts in the preparation process of AC science teachers,
- select and recruit of the candidates for admission that match the design of the particular program,
- have responsive program design and delivery, and
- train teacher mentors in ways that addresses the specific needs of science teachers.

Any list such as this requires a means of evaluating whether programs have these qualities and whether they have the desired effect. The evaluation of science teacher certification programs has two dimensions: teacher knowledge and teacher skills. Clearly science teachers need to know science. However, how do certification programs to ensure this? How do they determine the candidates' knowledge and how do they augment it when necessary? Science teachers also need knowledge of educational foundations and strategies. How do programs ensure this, and more importantly, how well versed are the candidates in the theories and practices that have emerged as a result of research on science teaching and learning, including research in areas such as culture, language, ethnicity, and gender? Candidates also must have the skills needed to create environments in which students learn. To evaluate this, programs need to look both at what their candidates do in classrooms, and what the candidates' students learn.

...much of what is believed about the quality of teacher certification programs, in general, is not supported by evidence.

As the practice white paper notes, much of what is believed about the quality of teacher certification programs, in general, is not supported by evidence. It also notes that both supporters and critics of AC base their opinions on a very thin research foundation. Therefore, further research is needed.

A research agenda for science teacher education

The wide variety among alternative and traditional programs means that little can be learned with comparative studies. However, the research group was able to identify three "divides" in teacher education that can be highlighted for research purposes:

- The divide that separates programs that have as their primary purpose teacher licensure from those that have as their primary purpose the education of teachers;
- The divide that separates science teacher education from the education of other teachers; and
- The divide that separates preservice and in-service teacher education.

The first divide distinguishes between the programs that exist solely to help candidates meet the state minimum requirements, while the latter help teacher candidates to develop the knowledge, skills, judgment and wisdom for teaching. The challenge is to design programs that have the benefits associated with credentialing programs yet prepare teachers to be effective science educators.

The second divide highlights the knowledge and skills that are particular to the teaching of science. It also focuses on the difference between the content knowledge of school science and the content knowledge of the academic disciplines as practiced by scientists and presented to college students (Hill & Ball, 2004; Stengel, 1997). The third divide, between preservice and in-service teacher education, has blurred as more and more novice teachers are already employed as teachers as they do their initial teacher education. Hence we see the distinction between novice and expert as being more fruitful than that between pre- and in-service.

These divides suggest that we need insight into

- what kinds of learning opportunities support diverse learners' science engagement and understanding,
- what science teachers need to learn in order to provide such opportunities for their students, and
- what kinds of experiences teachers need to learn what they need.

That is, if we want science teacher education to be research-based, then we need to have evidence that what, and how, we teach teachers benefits their students in meaningful ways. The research white paper argues that this research agenda requires mutually reinforcing activity on three fronts – conceptual, methodological, and empirical (see Figure 1).

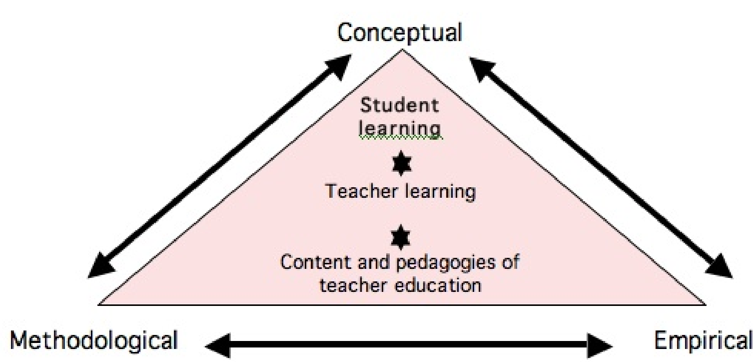

Figure 1: Conceptual, methodological, and empirical fronts of research on science teacher learning.

If teacher education programs are to have the qualities identified in the practice white paper, then there is a need for conceptual clarity about what and how science teachers must learn. Ongoing discussions about defining, and refining, research interests in useful ways for science teacher education would be a helpful step towards greater conceptual congruence. Rigorous research not only requires conceptual clarity but methodological support as well. In particular, there is a strong need for robust tools for measuring teacher change over time. Finally, we need to develop empirical warrants for our science teacher education practices. Without them, we cannot assume that our vision of science education reform "works" unless there is evidence necessary to back up claims.

The research white paper concludes with a list of questions proposed by STEM-ACT research participants. They include.

- What science content and in what form do science teachers need to know?
- How do we bridge traditional separations of preservice and in-service teacher education to create a professional continuum of science teacher education that includes the induction phase?
- How do diverse teachers acquire the beliefs, knowledge and skills across a variety of educational settings and opportunities?
- Who are the science teacher candidates? How do age, race, ethnicity, and gender; prior experience; science knowledge; and context and societal influences relate to candidates' learning to be science teachers?
- How do we transform credentialing programs into research-informed educational programs?

Conclusion

There were several expected outcomes of the STEM-ACT conference. One was that it would explore what is known about the alternative preparation of science teachers and identify the agenda for future research. The second was that by bringing together experts in science education, teacher education, and educational policy with educational administrators and policy makers it would help to shape the dialog on alternative and traditional certification programs. In addition, by asking salient questions about the alternative certification of **science** teachers, the conference would change the unit of analysis from all **teachers** to **teachers of science**. This in turn would open up for inquiry the importance of the large body of research on the teaching and learning of science on the preparation of science teachers, and insert it into policy discussions about how best to incorporate this knowledge into the training and certification of science teachers. The third was that it would impact the development, implementation and evaluation of AC programs for science teachers that would help meet the national demand for more science teachers who know and can use the knowledge generated through science education research. With the publication and dissemination of the white papers, the hoped for national conversation can begin to shape the research and development of science teacher certification programs.

References

Hill, H. C., & Ball, D. L. (2004). Learning mathematics for teaching: Results from California's Mathematics Professional Development Institutes. *Journal for research in mathematics education, 35*(5), 330-351.

Lederman, N. G., & Abell, S. (Eds.). (2007). *Handbook of Research on Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Stengel, B. S. (1997). "Academic discipline" and "school subject": contestable curricular concepts. *Journal of curriculum studies, 29*(5), 585-602.

Wechsler, M. E., Humphrey, D. C., & Hough, H. J. (2006, May 5-7). *Characteristics of effective alternative teacher certification programs.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Zeichner, K. M., & Conklin, H. G. (2005). Teacher education programs. In M. Cochran-Smith & K. M. Zeichner (Eds.), *Studying teacher education: The report of the AERA panel on research and teacher education* (pp. 645-735). Mahwah, NJ: Lawrence Erlbaum Associates.

Zeichner, K. (May 2006). *What do we know about the characteristics of good teacher education programs?* Keynote at the STEM ACT Conference, Arlington, VA. PowerPoint available at: http://www.stemtec.org/act/

EDUCATING TOMORROW'S SCIENCE TEACHERS

STEM ACT Conference Report: Policy Section

Joseph Berger	*University of Massachusetts Amherst*
Yijie Zhao	*University of Massachusetts Amherst*
Ted Britton	*WestEd*
Cassie Guarino	*RAND*
Jennifer Jackson	*University of North Texas*
Michael Marder	*University of Texas at Austin*

STEM ACT Conference Report

Policy Section

Introduction

The University of Massachusetts (UMass) STEM Education Institute and the UMass School of Education hosted a National Science Foundation funded conference called STEM ACT in Arlington, VA on May 5-7, 2006. The focus was on what we know and what we need to know about alternative certification programs for science teachers. By limiting the discussion to science teachers, we could explore the issues that are specific to this subject area. The goal was to frame a research agenda while providing useful advice in the form of relatively short "white papers" to the academic research, policy maker, and provider communities; the second of these is the audience addressed in this document. The Appendix lists the papers presented in the policy thread.

Alternative teacher certification has become one of the most significant contemporary educational policy issues across America and a favored policy response of the U.S. Department of Education to the dual demands of improving teacher quality and increasing teacher supply. The U.S. Secretary of Education's Third Annual Report on Teacher Quality (U.S. Department of Education, 2005) promotes alternative certification, and the federal No Child Left Behind Act includes participants in alternative certification programs in its definition of "highly qualified" teachers. The importance placed on alternative certification by policy-makers is evidenced by the fact that substantial increases in investment in alternative certification programs have occurred even when overall educational expenditures at the state and federal levels have been declining (Guarino, Stantibanez, Daley & Brewer, 2004). Nevertheless, the rapid growth of alternative certification has not been systematic and has generated a great deal of debate about what exactly is alternative teacher certification and how effective the various types of teacher training programs are in providing greater quantities and higher quality teachers for America's classrooms (Dixon & Ishler, 1992; Feistritzer & Chester, 2002; Huling-Austin, 1986; Roth, 1986). Much of the existing literature on alternative certification programs is in the policy domain and has looked broadly at teachers and teacher education, without a subject matter focus. This is problematic because one of the main issues currently being debated is the importance of subject matter knowledge and literacy skills compared to pedagogical and pedagogical content knowledge (Allen, 2003; Darling- Hammond & Youngs, 2002). Therefore, the purpose of this paper is to explore policy issues related to alternative certification for *science* teachers.

The focus on science teachers is particularly significant given the ever increasing importance of science in daily life throughout our society and the world, the intensification of global competition in science, and deepening concerns about the ability of the United States to produce highly skilled scientists. These points drive the recent report entitled "Rising Above the Gathering Storm" (2005), in which it is noted (p. 5):

> In a world where advanced knowledge is widespread and low-cost labor is readily available, U.S. advantages in the marketplace and in science and technology have begun to erode. A comprehensive and coordinated federal effort is urgently needed to bolster U.S. competitiveness and pre-eminence in these areas.

This congressionally requested report made four recommendations, including: "[a]nnually recruit[ing] 100,000 science and mathematics teachers …, thereby educating 10 million minds." (p. 5). Clearly, science teacher supply and demand is a timely topic of great importance, not only within education, but for American society as a whole.

A survey of urban school districts indicated that 95% of responding urban school districts had an immediate demand for high school science and mathematics teachers. Eighty percent reported a need for middle school science and mathematics teachers (Urban Teacher Collaborative, 2000). Lawrenz, Appleton, Bequette, Ooms, & Wassenberg (2006) note that recent studies (Ingersoll, 1999; 2003) show that 56% of secondary students in physical science are being taught by teachers without a major or minor in physical science, and 27% of students in mathematics are being taught by teachers lacking even a minor in mathematics. Furthermore, the authors cite that students in high-poverty schools are 77% more likely to be taught by an out-of-field teacher. Clearly, fields such as science and math require high levels of attention as we strive to improve the teaching corps in American schools.

Given this policy context, this paper focuses on identifying key policy issues and strategies related to better understanding and improving the alternative certification of science teachers. The paper starts with the definition and scope of alternative certification in general, and then addresses current contextual issues related to the supply and demand of science teachers respectively. The paper concludes that alternative certification policy makers need to be better informed of empirical evidence based on systematic documentation so as to address more effectively the issues relating to both teacher supply and demand.

It is also clear that much more research is needed on teacher preparation programs of all kinds to better define policy issues. Conference keynote speaker Ken Zeichner stressed the difficulty of conducting meaningful work in this field, and concluded that most of the existing literature focused on surface characteristics and not deeper issues (Zeichner, 2006).

1. Defining the Nature and Scope of Alternative Certification

"Traditional" teacher certification refers to public school teaching credentials acquired by completing a state-approved program at an institution of higher education. "Alternative" teacher certification may be generally defined as any significant departure from the regular/traditional undergraduate route through teacher education programs in universities and colleges (Oliver & McKibbin, 1985, Mitchell 2006).

Blurring of the lines between alternative and traditional routes seems likely to increase.

Based on a state-by-state analysis of alternative certification programs, Feistritzer and Chester summarize the definition of the term "alternative teacher certification" as follows:

> [The term] historically has been used to refer to every avenue to becoming licensed to teach, from emergency certification to very sophisticated and well-designed programs that address the professional preparation needs of the growing population of individuals who already have at least a bachelor's degree and considerable life experience and want to become teachers (Feistritzer & Chester, 2002, p. 3).

Alternative certification programs typically offer qualified teacher candidates a streamlined preparation program that places them in the classroom as the teacher of record more quickly than traditional university-based programs. Furthermore, while traditional programs are generally structured around coursework and a culminating student teaching experience, many university programs are increasingly integrating coursework and student teaching. This blurring of the lines between alternative and traditional routes seems likely to increase.

A review of literature shows that there is a myriad of alternative teacher certification programs across the states with variations regarding program objectives, duration, content, training approaches, characteristics of teacher candidates, and certainly program effectiveness. For example, some alternative programs are traditional teacher education programs in a different package delivered at night for working adults; others are college-based programs for teachers hired with emergency certificates to complete a certain amount of coursework; still others are "fast-track" programs providing accelerated entry for prospective teachers to move through the basic curriculum and quickly begin classroom teaching (Feistritzer & Chester, 2002; Huling-Austin, 1986).

There are various forms of alternative teacher certification programs at national, state, and local levels, although prospective teachers have to meet the specific certification requirements of the particular state. National programs focus on preparing particular types of candidates for teaching, such as recent, high-achieving college graduates (e.g., Teach for America) or retiring military personnel (Troops to Teachers). State programs, such as the Massachusetts Institute for New Teachers (MINT), typically focus on statewide shortages as well as building a diverse pool of candidates. District-run programs tend to focus on specific shortages, often in urban areas (e.g., Los Angeles Unified School District's alternate route).

There are also alternative teacher certification programs designed for substantially different populations of candidates from those of traditional teacher preparation programs (Huling-Austin, 1986). Examples include career switchers (e.g., the teacher education program at Bank Street College of Education), paraprofessionals becoming teachers (e.g., programs for paraprofessionals in SREB states), and new college graduates entering teaching after graduation (e.g., Attracting Excellence to Teaching in Massachusetts). Most of these programs are designed for candidates who already have a bachelor's degree and are employed as teachers while earning a regular teaching license by completing the program. It is claimed that alternative teacher certification programs serve candidates "who will most likely be placed in teaching positions that are difficult-to-staff for any of a variety of reasons" (Huling-Austin, 1986, p. 52).

Debates about the meaning and definition of alternative certification are not merely over semantics; they reflect competing ideological beliefs, pedagogical implications, and political agendas.

Although Feistritzer and Chester (2002) contributed a comprehensive working definition, the term "alternative certification" itself is inherently problematic. Roth (1986) distinguishes between "alternate" and "alternative" route programs, with the former defined as a program for an individual with a bachelor's degree *"only if fully certified personnel are not available",* while the latter indicates a "*choice*" that a school district makes of "hiring an individual who is fully certified or hiring an individual without teacher preparation" (p. 1). While Roth's semantic distinction has policy implications, Dixon and Ishler (1992) delve into the differentiation between "alternative routes to certification" and "alternatives to certification" and the underlying beliefs about the role of pedagogy in teacher education. They posit that "alternative routes to certification" recognizes the need of providing non-traditional educational opportunities for culturally diverse students to be pedagogically prepared, while "alternatives to certification" indicates that teaching is an innate ability and pedagogy is just classroom survival tools (Zhao, 2005).

Debates about the meaning and definition of alternative certification are not merely over semantics; they reflect competing ideological beliefs, pedagogical implications, and political agendas. As Hawley (1990) stated, alternative certification is "evidence of the relative political strength of the opponents and proponents of the art and craft view of teaching and the intensity which these parties bring to the debate" (p. 5). What should be added to this comment or made more explicit is that alternative teacher certification is also evidence of where the opponents and proponents stand in the context of a multicultural, unevenly distributed student population, with diverse needs and wants, that a generic engineering process of teacher preparation is not able to meet (Zhao, 2005). In his review of current and future trends in alternative certification, Fenstermacher concludes with a prescient observation:

> Given that both traditional teacher education and alternative certification have some distance to travel in meeting the profound ends of teacher education, there may be value in ceasing to think of them as oppositional to one another. Perhaps the best course of action lies in blending these ideas, wherein in the benefits of being close to practice are maintained, but so are the advantages of reflective and critical approaches to pedagogy. This blending of the best from both approaches to teacher preparation would require new models of teacher education. The invention and implementation of such models may be one of the lasting benefits of alternative certification's challenge to traditional teacher education (Fenstermacher, 1990, p. 182).

As discussed above, the complexity of the alternative teacher certification phenomenon is far beyond the structural characteristics of the programs, such as duration, participants, training approaches, and programs goals, and reveals the fact that "alternative certification" carries different meaning to different people.

Apart from the debates regarding the definitions and legitimacy of alternative teacher certification, many have suggested that the increase of alternative certification has occurred in order to increase the supply of qualified teachers to meet projected demands for teachers (e.g., Hayes, 2006; Hussar & Gerald, 1998; Shen, 1997). The goal has been not only to increase the numbers of new entrants into the teaching profession, particularly in hard to staff subjects and schools, but also to develop new teachers that are more likely to remain in their chosen profession and at the schools in which they were initially hired (Guarino et al., 2004). Thus, alternative teacher certification is an issue with many sides centering upon the supply and demand of high quality teachers.

Some proponents of alternative certification programs have argued that they are likely to attract a more diverse population. However, in at least one study, it was found that these programs have the same difficulty attracting significant numbers of women and people of color into STEM teaching. Women who do choose STEM teaching careers are more likely to be found in biology than in any other specialization. People of color continue to be underrepresented in STEM specializations, except Asian-Americans who comprise a greater proportion of math teachers than would be otherwise expected (Chin, 2006).

A question facing AC programs is evaluating the content knowledge of its candidates. One way to assess this is with the state teacher tests. However, in a study of AC candidates at the University of North Texas, the level of the candidate's content area coursework, grade point average, and the time elapsed since the last upper-level content area course were not statistically significant predictors of success on the Texas Examinations. One reason for this is the mismatch between college science course contents and the material tested by the exams. A further concern is the failure of the tests to provide any measure of pedagogical content knowledge (Harrell, 2006).

Much of the controversy around alternative certification is about the effectiveness of such programs in producing teachers who can improve student performance. This has been addressed in a large scale study in New York City of participants in two selective AC programs, Teaching Fellows and Teach for America, and graduates of conventional teacher education programs. It finds that in some instances the Fellows and TFA members produce higher student achievement gains than the temporary license teachers they replace, but more typically, alternate route teachers are no worse than these teachers in their classroom results. When compared to teacher education graduates, the AC teachers often provide smaller gains in student achievement, at least initially. Many of these differences are not large in magnitude, typically about 2 to 5 percent of a standard deviation, and the variation in effectiveness within pathways is far greater than the average differences between pathways (Boyd, 2006).

It should be noted that the issues relating to alternative certification are not solely an American concern. Similar questions are being addressed, for example, in Canada (Vázquez-Abad, 2006) and in Australia (Harrison, 2006).

… teacher shortages are distributed unevenly depending on localities and specialties…

2. The Supply Side of (Alternative) Teacher Certification

A "qualified" teacher in the United States typically is defined as an individual who holds a bachelor's degree in education. The label can also refer to someone "who has gone through a college education program approved by the state department of education which has the authority to then confer a license to teach" (Feistritzer & Chester, 2002, p. 10). Based on the latter definition, only a third of fully qualified teachers nationwide are actually teaching the following year. Meanwhile, some 20 percent of all new hires leave the profession within three years, and in urban districts, nearly 50 percent of new teachers leave the profession within the first five years (National Education Association, 2002, 2003). Seventy-five percent of current teachers have a bachelor's degree in education, and the rest have a bachelor's degree in a field other than education (Feistritzer & Chester, 2002).

The projected shortage of qualified teachers is based on student enrollment increases, increased retirements of teachers, teacher attrition, and class size reduction (Feistritzer & Chester, 2002). However, researchers agree that severe nationwide shortages of teachers exist today in specific subjects and in regions that are considered less desirable for working and living. Therefore, teacher shortages are viewed in part as an issue of distribution rather than production (e.g., Darling-Hammond, 1999, 2000a, 2000b, 2000c; Darling-Hammond & Sykes, 2003; McDiarmid, Larson, & Hill, 2002, Ingersoll, 2001, 2003; Feistritzer & Chester, 2002). In other words, teacher supply/shortage is a context-specific issue. Teacher shortages are distributed unevenly and depend on geographic and subject areas (www.recruitingteachers.org). It is particularly acute in urban and rural communities. It is also acute for high-need subject areas such as mathematics and science, English as a second language, bilingual education, and special education, as well as for teachers of color and male teachers in some subject areas. There is some overlap of geography and subject as well. "In 1993-1994 only 8% of public school teachers in wealthier schools taught without a major or minor in their main academic assignment — compared with fully a third of teachers in high-poverty schools" (Darling-Hammond & Sykes, 2003, p. 17). Hard-to-staff schools actually experience shortages even in specialties with a surplus of licensed teachers, such as English (McDiarmid, et al., 2002).

Based on data drawn from the two most recent cycles of the Teacher Followup Survey (1994-95 and 2000-01), Ingersoll (2003) unpacked the teacher shortage and used the term "teacher turnover", which includes both teacher attrition and teacher migration. Teacher attrition refers to teachers leaving the profession altogether (the leavers); teacher migration refers to teachers transferring or moving to different teaching jobs in other schools (the movers). Studies on teacher shortage usually focus on teacher attrition assuming that teacher migration does not affect overall teacher supply. Nevertheless, it is a serious problem for certain types of schools to find qualified teachers. Thus both teacher attrition and teacher migration are the contributing factors to uneven distribution of teachers, and they are the major reasons for increased demand for teachers, rather than student enrollment and teacher retirement, which only accounts for 13% of total turnover, and 25% of leavers (Ingersoll, 2003, p. 3). The math/science teacher shortage serves as an example.

Although more new teachers are produced than needed, there is a shortage of mathematics and science teachers (Darling-Hammond & Sykes, 2003; Ingersoll, 2003). The turnover rate for math/science teachers is higher than that for teachers in a number of other fields, but the reasons why they depart from their teaching jobs, according to Ingersoll (2003), do not greatly differ from other teachers. "A large proportion indicate they depart for personal reasons (34% of migration and 44% of attrition). A large proportion also report they depart either because they are dissatisfied with their jobs or to seek better jobs or other career opportunities (40% of math/science teachers and 29% of all teachers)" (p.6). For every kind of community, reasons for both teacher migration and attrition include low salaries, student discipline problems, little support for new teachers, and little faculty input into school decision making. Schools with these characteristics tend to lose teachers to schools without these problems (Ingersoll, 2003). There are certain factors that policy changes cannot impact, such as teacher departure because of personal reasons, but how can alternative teacher certification address problems such as low salaries and inadequate new teacher school support which exist in schools with high turnover?

The key policy issues regarding the supply of alternatively trained science teachers revolve around the question: *What factors influence the attractiveness of science and math teaching to potential workforce entrants?* Policy-makers need to consider how a range of variables influences the supply of teachers. More specifically, in line with the purpose of this paper, policy-makers need to be aware of the factors associated with ensuring that the millions of dollars being invested in alternative certification are efficiently and effectively increasing the teacher supply, particularly in high need areas such as science. Moreover, given the diverse range of programs that fall under the rubric of alternative certification, policy-makers should consider which types of programmatic features are related to different categories of factors that are likely to influence supply.

A synthesis of much of the literature cited above suggests the supply of teachers is dependent upon four broad categories of variables:

- Training
- Licensure Testing Requirements
- Income & Compensation
- Working Conditions

Each of these categories can be conceptualized as representing different points in the supply pipeline – traditional and alternative – through which the supply of teachers is produced throughout the country. Training is typically the first segment of that pipeline as prospective teachers are trained and socialized as preparation for entering the professional role. Licensure testing requirements follow training, as an assessment of how well prepared potential teachers are as a result of the training. Income and compensation are key factors in both recruitment and retention, while working conditions have been shown to be a key influence on teacher retention (Guarino et al., 2004). It is worth noting that there is little empirical evidence on the influence of these factors on science teacher supply.

Each of these factors can be broken down into sub-categories that should be taken into consideration by policy-makers as they make decisions about the issues that must be addressed to promote an increased supply of science teachers. Within the category of "Training", issues such as pre-requisites (e.g. content knowledge, previous experience, contextual congruence), length (number of courses, years, etc.), cost (including foregone earnings and opportunity costs), difficulty of requirements and value or quality (perceived benefit in relation to cost) are all potentially important sources of influence. Similarly, licensure testing requirements vary in terms of cost (exams, applications, etc.) and level of difficulty (which tends to vary greatly by state). Income/compensation can be quite complex. Various aspects of income compensation include entry salary, future earnings, salary increments gained through experience, salary increments gained through career advancement opportunities (e.g. master teacher, head of department, etc.) and retirement. The list of potentially influential working conditions is quite long and includes:

- Number of Preps
- Supplies and Equipment
- Curriculum Resources
- Student Behavior
- Parental/Community Support
- Balance of Autonomy and Collegiality
- Administrative Support
- Mentoring, Induction Programs (etc.)
- Class Size
- Schedule Flexibility
- Intrinsic Rewards
- Professional Prestige
- Community-to-community and state-to-state differentials

"The sheer size of the teaching force combined with the relatively high annual turnover of the teaching occupation means that there are relatively large flows in, through, and out of schools each year"

Teaching represents 4% of the entire nationwide civilian workforce, and has a relatively higher turnover rate than other occupations. "The sheer size of the teaching force combined with the relatively high annual turnover of the teaching occupation means that there are relatively large flows in, through, and out of schools each year" (Ingersoll, 2003, p. 3). The instability of staffing, which does not apply to all schools and districts, not only causes problems for school administration, but also affects student learning. Teacher turnover, the driving force for demand for new teachers, indicates that generic teacher recruitment policies and strategies alone, in certain schools and districts, will not solve their school staffing problems without the issue of teacher retention adequately addressed in a context-sensitive way. Thus the conclusion seems to be that the core of the problem is not exclusively teacher supply/shortage, but includes the other side of the coin – teacher demand.

3. The Demand Side of (Alternative) Teacher Certification

Teacher shortages occur in a labor market when demand is greater than supply. This can be the result of either increases in demand or decreases in supply or both. The extent to which the demand for teachers is either unmet or exceeded generally determines the motivation for changes in policy. Guarino et al. (2004) have developed a conceptual framework that is helpful for thinking about the policy context of alternative certification of science teachers as a particular type of labor market. Their conceptual framework defines the demand for teachers as "the number of teaching positions offered at a given level of overall compensation" and the supply of teachers "as the number of qualified individuals willing to teach at a given level of overall compensation" (p. 174). The authors further note that overall compensation includes not just salaries and benefits, but also other types of intrinsic rewards such as working conditions and personal satisfaction. Therefore, the types of compensation "packages" available in any school or district will determine how many teachers can be employed and how many qualified teachers will be willing to be employed in each setting. When elaborating on teacher turnover as a context-specific phenomenon, Ingersoll (2003) noted that schools across the country with significantly lower levels of teacher turnover bear the reverse characteristics of those that tend to lose teachers. That is, schools with good support from the school administration for new teachers, such as induction and mentoring programs, with higher salaries, fewer student discipline problems, and enhanced faculty input into school decision-making, have higher teacher retention rate.

This part of the report is intended to explore why and where these strategies and conditions for teacher recruitment and retention are not a reality. Sources of influence on science teacher demand include:

- Accountability Systems
- Resource Allocation
- Screening and Selection
- Career-changer Bias
- Retention

Accountability systems are the flip side of license testing requirements; except, rather than focusing on the standards set for individual teachers to meet, the focus is on the ways in which teachers and schools can demonstrate that they are providing quality education for students. Particularly for science teachers, the difficulty of entry standards and the rigidity of subject-specific certification requirements are potentially significant policies that may dampen incentive in order to ensure quality.

Resource allocation also influences teacher demand. At the macro-level, the funding available through federal and state support plays an essential role in defining the demand for teachers at district and school levels. Local property values also affect demand, since in most cases that determines the ability of communities to support their schools. The choices made by district and school leaders about how best to spend resources – for example, on recruitment and retention, and the number of science and math teaching positions – are some of the most powerful sources of influence on teacher demand.

Screening and selection overlap with the first two categories. The resources allocated to screening and selection processes are important to consider. Also, it is likely that higher entry standards will reduce the quantity of available teachers.

These strategies and conditions indicate a policy "trade off" for alternative certification, in which one type of emphasis (e.g. alternative certification as an incentive to attract individuals who might not otherwise pursue teaching as a career) may be negated or curtailed by another initiative (e.g., higher standards to ensure higher quality teachers by eliminating those who are, or appear to be, less qualified). In other words, incentive policies represent attempts to increase the quantity of teachers necessary to meet demand. Policies of standards are designed to increase the quality of teachers, but may have a negative effect on quantity.

This “incentives vs. standards” dilemma is not atypical in the paradoxical world of public policy. It is likely that alternative certification also creates tensions around short-term versus long-term effects. Incentive policies may generate larger pools of entering teachers in the short-term, but may also create a long-term retention problem once the allure of initial incentives is replaced by the realities of teaching in under-resourced public schools. Conversely, standards may eliminate candidates early in the pipeline, but may promote better retention by promoting higher levels of preparation. These are empirical questions for policy analysts that should be addressed in future studies. Examination of such questions and paradoxes is particularly important in a policy environment in which limited resources have been (and will be) available to serve multiple and sometimes competing needs within the American education system.

In addition to the sources of influence listed above, a less obvious one is the context for career-changers. This is particularly germane to alternative certification policy as districts and schools make choices about the use of such policies to recruit career-changers and there is documentation that many career-changers face in-school biases against them (Churchill, Berger, Brooks, Effrat, Griffin, Magouirk-Colbert, McDermott, Sharick & Shaheen, 2002).

Collectively, all of these sources of influence can affect retention: in the profession, in the school, and in high need districts. While retirement plays a role, Ingersoll (2003) and others have demonstrated that competition for talent within the education systems and competing opportunities outside of education contribute greatly to teacher turnover; particularly in high need districts and for individuals with science backgrounds who are likely to have attractive career opportunities outside of teaching.

Conclusion

Alternative certification has arisen as a policy response to concerns about supply and demand imbalances in the teacher labor market; this is particularly true for science teachers. Yet, there is little empirical research documenting the specific effects of potential sources of influence on individuals’ decisions to join this labor market as science teachers, nor has there been much data systematically gathered about the ways in which demand for science teachers is constructed at national, state and local levels. A better research base to inform policy-makers is clearly needed. This is particularly true at a time when the need for science teachers is so great and at a time when greater amounts of resources are being devoted to alternative teacher certification. Moreover, the diversity of alternative certification programs has been demonstrated to attract a wider variety of individuals (e.g. career changers) into the profession. However, it is not clear which, if any, of these programs are more attractive for science teachers and which, if any, of these programs prepare science teachers well enough to increase the likelihood that they will be well grounded in content-specific knowledge and persist as science teachers. These are important questions that policy-makers should be seeking answers to through research as we strive to improve the practice of teaching science through more and better qualified teachers.

References

Allen, M. (2003). *Eight questions on teacher preparation: What does the research say?* ED 479 051

Boyd, D., Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (May 2006). *How changes in entry requirements alter the teacher workforce and affect student achievement*. Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Churchill, A., Berger, J., Brooks, C., Effrat, A., Griffin, L., Magouirk-Colbert, M., McDermott, K., Sharick, R., & Shaheen, A. (2002). *Interim Report: The Massachusetts Institute for New Teachers and Master Teacher/NBPTS Programs*. Amherst, MA: Center for Education Policy.

Darling-Hammond, L. (1999). S*olving the dilemmas of teacher supply, demand, and standards.* New York: National Commission on Teaching and America's Future.

Darling-Hammond, L. (2000a). How teacher education matters. *Journal of Teacher Education*, *51*(3), 166-173.

Darling-Hammond, L. (2000b). Reforming teacher preparation and licensing: Debating the evidence. *Teachers College Record*, *102*(1), 28-56.

Darling-Hammond, L. (2000c). Teacher quality and student achievement: A review of state policy evidence. *Education Policy Analysis Archives, 8*(1). [Online]. Available: http://epaa.asu.edu/epaa /v8n1.

Darling-Hammond, L., & Sykes, G. (2003). *Wanted: A national teacher supply policy for education: The right way to meet the "highly qualified teacher" challenge.* [Online]. Available: http://epss.asu.edu/epaa/v11n33.

Darling-Hammond, L., & Youngs, P. (2002). "Defining 'Highly Qualified Teachers': What Does 'Scientifically-based' Research Actually Tell Us?" *Educational Researcher, 31*(9), 13–25.

Dixon, P., & Ishler, R. E. (1992). Acceptable approaches to alternative certification. *Teacher Education and Practice, 8*(1), 29-35.

Chin, E. (May 2006). *Characteristics of science and math teachers prepared through alternative certification programs in California.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Feistritzer, C. E., & Chester, D. T. (2002). *Alternative Teacher Certification: A State by State Analysis 2002*. National Center for Education Information.

Fenstermacher, G. (1990). “The Place of Alternative Certification in the Education of Teachers.” *Peabody Journal of Education*, *67*(3),155–185.

Guarino, C. M., Santibañez, L., Daley, G. A., & Brewer, D. (2004). *A review of the research literature on teacher recruitment and retention* (TR-164-EDU). Santa Monica, CA: RAND.

Harrell, P. E., & Jackson, J. K. (May 2006). *Teacher knowledge myths: An examination of the relationship between the Texas examinations of educator standards and formal content area coursework, grade point average and age of coursework.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Harrison, A. G. (May 2006). *Recruiting and educating science teachers in Australia.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Hawley, W. D. (1990). The theory and practice of alternative certification: Implications for the improvement of teaching. *Peabody Journal of Education,67*(3), 3-34.

Hayes, J. L. (2006, May 5-7). An inquiry into best practices for preparing and retaining alternative certification candidates in the sciences. Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Huling-Austin, L. (1986). Factors to consider in alternative certification programs: What can be learned from teacher induction research? *Action in Teacher Education, 8*(2), 51-58.

Hussar, W. J., & Gerald, D. E. (1998). *Projections of Education Statistics to 2008*. Washington, D.C.: National Center for Education Statistics, Office of Educational Research and Improvement, U.S. Dept. of Education.

Ingersoll, R. M. (2001). *A Different Approach to Solving the Teacher Shortage Problem.* Seattle: Center for the Study of Teaching and Policy.

Ingersoll, R. M. (2003). Is there a shortage among mathematics and science teachers? *Science Educator, 12*(1), 1-9.

Lawrenz, F., Appleton, J. J., Bequette, M. B., Ooms, A., & Wassenberg, D. (May 2006). Tripartite synthesis of research and data on recruitment and retention of STEM teachers. Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

McDiarmid, G. W., Larson, E., & Hill A. (2002). Retaining Quality Teachers for Alaska. ED 474 247.

Mitchell, A. (May 2006). *The National Council for Accreditation of Teacher Education and Alternative Programs: An Unexpected Convergence.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

National Academies (2005). *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: National Academies Press.

National Education Association. (2002, 2003). *Great public schools for every child*. [Online]. Available: www.nea.org.

Oliver, B., & McKibbin, M. (1985). Teacher Trainees: Alternative Credentialing. *California Journal of Teacher Education*, *36*(3), 20-23.

Roth, R. A. (1986). Alternate and alternative certification: Purposes, assumptions, implications. *Action in Teacher Education, 8*(2), 1-6.

Shen, J. 1997. "Has the Alternative Certification Policy Materialized Its Promise? A Comparison between Traditionally- and Alternatively-certified Teachers in Public Schools." *Educational Evaluation and Policy Analysis*, 19(*3*), 276–283.

The Urban Teacher Collaborative. (2000). *The urban teacher challenge: Teacher demand and supply in the Great City Schools.* A study by The Urban Teacher Collaborative: Council of the Great City Schools, Recruiting New Teachers, Inc. and Council of the Great City Colleges of Education. Washington, DC: Council of the Great City Schools. [Online]. Available: http://www.cgcs.org/reports/2000/RNT-0101.pdf

U. S. Department of Education. (2005). *The Secretary's fourth annual report on teacher quality: A highly qualified teacher in every classroom*. Office of Postsecondary Education. Washington, DC.

Vázquez-Abad, J., & Charland, J. (May 2006). *Preparing science teachers for Québec's high-school at Université de Montréal.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Zeichner, K. (May 2006). *What do we know about the characteristics of good teacher education programs?* Keynote at the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Zhao, Y. (April, 2005). *Alternative Teacher Certification for Science Teachers*: *Policy and Context.* Paper presented at the National Association for Research in Science Teaching annual international conference in Dallas, Texas.

Zumwalt, K. (1991). Alternate Routes to Teaching: Three Alternative Approaches. *Journal of Teacher Education, 42*(*2*), 83–92.

TOMORROW'S SCIENCE TEACHERS

STEM ACT Conference Report: Practice Section

Morton M. Sternheim	*University of Massachusetts Amherst*
Yijie Zhao	*University of Massachusetts Amherst*
Barbara Austin	*New Mexico Institute of Mining & Technology*
Wendy Frazier	*George Mason University*
Anita Greenwood	*University of Massachusetts Lowell*
Judith Hayes	*Wichita State University*
Charmaine Hickey	*University of Massachusetts Lowell*
Kathy Shea	*University of Massachusetts Lowell*

STEM ACT Conference Report

Practice section

Introduction

The University of Massachusetts (UMass) STEM Education Institute and the UMass School of Education hosted a National Science Foundation funded conference called STEM ACT in Arlington, VA on May 5-7, 2006. The focus was on what we know and what we need to know about alternative certification programs for science teachers. By limiting the discussion to science teachers, we could explore the issues that are specific to this subject area. The goal was to frame a research agenda while providing useful advice in the form of relatively short "white papers" to the academic research, policy maker, and provider communities; the last of these is the audience addressed in this document.

This white paper starts with a summary of issues presented at the conference with reference to practice in alternative certification for science teachers. This is followed by what we know so far about effective alternative certification programs, and what we still need to know through future rigorous research on alternative certification for science teachers. This paper also provides guidelines for assessment of alternative certification programs for science teachers.

A list of all the papers presented in the practice thread appears in the Appendix.

1. Summary of issues presented

The presenters at the conference discussed extensively issues related to 1) the definition of alternative certification (AC) programs, 2) the partnership characteristic of AC programs, and 3) AC teacher training practices. All these issues relate to AC teacher preparation in general and to AC science teacher preparation in particular. They are discussed respectively in the following sections.

1.1 Definition of alternative certification

One theme that came up repeatedly in the conference is that "alternative certification" is, at best, a poorly defined concept. To some, AC programs refer to those designed to respond to teacher shortages by putting career-changers and others into classrooms more quickly than "traditional" teacher education programs. Others use this designation for anything other than a four year undergraduate certification program. Antoinette Mitchell, of the National Council for Accreditation of Teacher Education (NCATE) (2006, p. 1) states:

> These programs range from 5th year programs for students without education backgrounds, to programs especially designed for career-switchers, to programs designed for specific sectors of the community such as military personnel and para-professionals.

The participants at the conference acknowledge that the "range" of the AC programs in existence is in response to the diverse training needs of prospective teachers. For example, Hayes (2006, p.9) posits:

> There's been a dramatic shift in the profile of people studying to be teachers through alternative routes. There are greater numbers of older, life-experienced people wanting to enter the teacher profession when compared with traditional preparation models. A higher percentage of these mid-career switchers are male

and/or are minorities interested in teaching in high-demand areas of the country in positions generally not sought by young, white females coming out of traditional schools of education.

... every alternative route to teacher certification is, in fact, a collaboration among the state licensing authority, institutions of higher education and local school districts.

Hence, the consensus at the conference was that there needs to be a continuum of teacher preparation and support programs to serve the varied needs of schools and of pre-service and in-service science teachers. Although there are concerns about sacrificing teacher preparation quality for meeting the science teacher demand, Mitchell (2006) notes that NCATE holds alternative certification programs to the same standards required of all programs in NCATE-accredited institutions as a way of making institutions programs accountable for the quality of their programs and for the quality of the educators they prepare.

Despite the proliferation of various AC programs to meet the challenge of science teacher shortages, partnership of AC programs, as a unifying organizational feature, was an issue addressed at the conference.

1.2 Partnership characteristic of AC programs

Alternative certification programs exist in a range of circumstances with various designs, admission criteria, program duration, amount of supervision, type of license or certification, course preparation, field experience and support. However, in spite of these differences, a unifying thread among alternative delivery models is that every alternative route to teacher certification is, in fact, a collaboration among the state licensing authority, institutions of higher education and local school districts.

There are primary and ancillary participants in a partnership for AC teacher preparation. Primary participants include the hiring school district or districts and the agent responsible for recommendation for certification. This recommending agent may be a university, a service center, or a district working directly with the state. Ancillary partners may include special interest groups such as industry or corporations, as with the Raytheon Teaching Fellows program (Hayes, 2006); military, as with Troops to Teachers; or organizations such as the National Science Foundation (NSF) or Department of Education (DOE) that provide grant funding with prescribed outcomes. With the increased demand for teachers to satisfy specific needs, innovation and collaboration have led to the development of creative partnerships.

Most of the AC programs presented at the conference are built upon solid partnerships as an integral support component in the preparation process. Indeed, research indicates that teacher candidates working in alternative licensure programs with strong district – university partnerships perform better and stay in the profession longer (retrieved from http://www.teach-now.org/overview.cfm). Thus, the establishment of strong partnerships seems to be a critical element of an effective alternative program. After all, a partnership provides the structure for science teacher preparation. The training process of prospective teachers determines not only the quality of AC programs but also the retention of the teachers trained.

1.3 AC teacher training practices

The variety of AC programs is associated with the plethora of AC teacher training practices that were presented at the conference. From selection and recruiting of AC teacher candidates, to meeting their diverse needs through AC course design, to providing mentoring support during the training process and/or as part of new AC teacher induction, a wide range of approaches have been adopted to attain the goals of the respective AC science teacher training programs.

1.3.1 Selection and Recruiting

Selecting and recruiting candidates for AC programs varies greatly, reflecting the diversity of these programs. Most programs require at least a bachelor's degree, and have some sort of screening process, which may include components such as tests, interviews,

evidence of content mastery, or a brief demonstration lesson. Many programs presented at the conference are highly selective, as is the case for the New York City Teaching Fellows Program (Boyd, Grossman, Lankford, Loeb & Wyckoff, 2005) and for the Wichita Area Teachers in Transition and Raytheon Teaching Fellows (Hayes, 2006). Humphrey, Wechsler and Hough (2006) have observed that "most alternative certification programs bet on education background, work experience, previous classroom experience, or some combination of the three" (p.4). There are, however, programs with relatively little selectivity. An example is the George Mason University effort to support provisionally licensed teachers already in Washington, D.C. area classrooms. (Sterling, Frazier, Logerwell & Kitsantas, 2006).

Recruiting practices also vary widely, depending on the character of the program. For instance, the large Texas A&M system (Harper & Edwards, 2006) reports that "recruitment practices which seem to be the most effective are scholarships, attending and hosting career fairs and recruiting in graduate programs" (p. 3).

At the University of Texas, which has a program designed for undergraduates, Marder notes (2006, p.5),

> **All students** in the College of Natural Sciences are **recruited** to join UTeach; they receive a letter about it upon admission, hear about it during orientation, and receive additional invitations during mailings each year, from presentations before students groups, and from newspaper and television reports.

Teach for America sends representatives to large numbers of campuses, focusing on students from selective institutions and selecting only a small fraction of the applicants. The NYC Teaching Fellows program targets mid-career professionals as well as recent college graduates. The Troops to Teachers program provides information and support to retiring military personnel, with offices in 32 states.

All of the teachers need practical knowledge about navigating the current school environment such as information about legal and ethical responsibilities, teaching to diverse populations, inclusion issues, and classroom management.

There was the consensus among the participants at the conference that selecting and recruiting the right candidates for admission to a particular program is important for the program's success, because "investing resources in candidates unlikely to succeed is a lose-lose situation for programs and districts" (Hayes, 2006, p.10). After the selection and recruitment of teacher candidates based on different selection criteria of different programs (Humphrey, Wechsler & Hough, 2006), the delivery of AC programs is another step to achieve a win-win situation for both the program partners and the teacher candidates themselves.

1.3.2 Responsiveness to AC participants' needs

The presenters at the 2006 STEM-ACT conference identified four types of students who participate in alternative certification.

- Group I candidates are undergraduate students attending a traditional university in which there is no traditional certification program, for example, at the University of Texas at Austin (Marder, 2006) and at New Mexico Tech (Austin, 2006).
- Group II candidates are recent graduates who have decided to become teachers.
- Group III candidates who seek alternative licensure are working professionals who decide to switch careers or retired military personnel.
- Group IV candidates are teaching out-of-field and need to take one or more courses in order to become highly qualified for their current appointment.

Candidates in each of these groups have different sets of needs and may have their needs met through different avenues. These needs can be grouped into five main categories.

Need 1: Practical teaching knowledge. All of the teachers need practical knowledge about navigating the current school environment such as information about legal and ethical responsibilities, teaching to diverse populations, inclusion issues, and classroom management. Groups I, II, and III participants have this need met through some form of coursework. Additional avenues for meeting this need for groups II and III are through induction programs that are associated with the alternative certification program or through identifying mentor teachers in the school system who are paid to work with these teachers. No mention was made of meeting this need for group IV teachers, perhaps because it is assumed these teachers received this knowledge from their initial certification or induction program.

Need 2: Content knowledge. Federal law mandates that teachers must have sufficient content knowledge as the major provision of being highly qualified. Content knowledge needs are not usually a consideration in design of AC programs for groups I, II, and III. Only Group IV primarily needs preparation in content knowledge.

Need 3: Pedagogical content knowledge. Best practices in the field of science and math education indicate that teachers not only need to understand math or science but teach in a manner that is consistent with what is known about how people learn math or science, and is based on significant insights from recent educational research. All four groups of teachers require instruction on content-specific pedagogical practices, and all the AC programs reported that they address this need through subject specific methods courses. Laboratory safety was cited as a priority issue that is specific to science teachers. They must be comfortable dealing with biological materials or chemicals, or they will do little or no hands on laboratory work with their students.

Need 4: Income during program. Many teacher candidates have specific needs with regard to financial support and the method and timing of course delivery. Based on presentations given by teachers trained through AC programs, fulfilling these needs is critical in determining whether members of groups II and III enter the field of teaching.

Need 5: Non-traditional course delivery. Programs designed for groups II, III, and IV consist almost entirely of non-traditional course delivery, such as a summer immersion component prior to placement of candidates, multiple summers of course work, evening courses, and online, self-paced course delivery.

Although both the types of candidates and their educational needs can be categorized and summarized fairly succinctly, a shared understanding among the conference participants is that there is no easily identified one-to-one correspondence between candidate and needs. Therefore, a challenge to AC program designers is characterizing the potential population of teacher candidates with regard to their needs, and designing the program that is responsive to these needs. A related issue to meeting teacher candidate needs is mentoring support from the school district as an AC program partner.

1.3.3 Mentoring support

In addition to mentoring support provided to AC teacher candidates while they are in training (e.g., Gagne, 2006), it is also becoming a key component of new teacher induction (Feiman-Nemser, 1996), depending on the design of the AC programs. Given that most AC teacher candidates, i.e., Groups II, III and IV candidates, and new AC teachers generally lack education course work and need assistance not only with general pedagogy, but with content and science specific pedagogical content knowledge, the presenters (e.g., Britton, 2006; Greenwood, Shea & Hickey, 2006) at the conference agreed that mentors involved in AC programs need differentiated training from those on traditional certification programs so that the mentors are able to address the subject specific needs of these individuals on AC programs. Differentiated mentoring training is also important for AC science teacher professional socialization when they start to work as full-time teachers, taking into account that some AC teachers are career changers. They are “novices in a new and entirely different position”, despite their “previous career experience” (Mayotte, 2003, p. 691) which will often have included teaching in some context other than K12 schools. There is research evidence that career changers’ prior career experiences influence their conceptions and expectations of mentoring. When there is consistency between mentor and mentee in the conception of the mentor’s role, the mentoring relationship is productive (Koballa, Bradbury, Deaton & Glynn, 2006).

In addition to the traditional one year mentoring support, there has been some experience with providing mentoring as part of AC teacher on-going professional development spanning several years (e.g., Hayes, 2006). Such a structure reportedly not only enhances new teachers’ perceived self-efficacy, but also provides a continuum of professional development for all participants (Hayes, 2006).

> *He (Zeichner) cautioned against oversimplified views of excellence, specifically against attempting to connect the surface features of teacher education programs (e.g., their length) to various teacher and student outcomes without accounting for the characteristics that candidates bring to their preparation.*

An overview of the conference presentations on practices in alternative science teacher training indicates that an AC program is a synergetic endeavor to meet the demand for qualified science teachers involving the hiring school district, the agent responsible for recommendation for certification, and some special interest groups. The process of AC teacher training, from selection and recruitment to program delivery and mentoring support, has implications for the quality of the AC programs as well as the cost-effectiveness of the alternative routes to teacher licensure. With reference to the presentations at the conference and existing literature on AC programs, the following section presents what we know so far about the characteristics of effective alternative science teacher certification programs, thus providing insights into what we still need to know.

2. What we know: Characteristics of effective alternative science teacher certification programs

As noted above, keynote speaker Ken Zeichner (Zeichner, 2006) stressed the limitations of the existing research on teacher preparation programs of all kinds, noting that "teaching and teacher education are inherently complex and are not reducible to simple prescriptions for practice". He cautioned against oversimplified views of excellence, specifically against:

> Attempting to connect the surface features of teacher education programs (e.g., their length) to various teacher and student outcomes without accounting for the characteristics that candidates bring to their preparation. …. Attempting to define the characteristics of good teacher education programs by the mere presence or absence of certain program elements without addressing how these elements are defined and used and for what purposes.

In 2006, 48 states and the District of Columbia reported to the National Center for Educational Information (NCEI) that they were implementing alternative routes to teacher certification, with the most rapid growth occurring since 2000 (retrieved from http://www.teach-now.org/overview.cfm). As alternative routes have gained in prominence, there has been increased interest in academic research to ascertain the best practices of alternative science teacher certification, or the effective program components that contribute to the supply and retention of successful AC science teachers.

With reference to the presentations at the conference and existing literature (e.g., Berry, 2004; Duhon-Haynes, Augustus, Duhon-Sells, Duhon-Ross and Mitchell, 1996; Feistritzer & Chester, 2000; Littleton and Larmer, 1998; Lutz and Hutton, 1989; McKibbon and Ray, 1994; NCATE, 2002; Wilson, Floden and Ferrini-Mundy, 2001), common themes that emerge as effective alternative certification program characteristics include seven dimensions: 1) needs-based design of the program; 2) high entrance standards; 3) intensive training focusing on professional expertise; 4) on-site support during training; 5) frequent program evaluation; 6) high exit standards; and 7) ongoing support of graduates after the program. They are elaborated on as follows.

1) Needs-based design:

- The program is designed specifically to meet the needs of particular regions, e.g., urban and rural areas, and/or subject areas, such as math and science.
- The program is tailored to meet the specific needs of the participants, e.g., taking into account the educational backgrounds and learning styles of older teacher candidates.

2) High entrance standards:

- The teacher candidates are screened through a comprehensive process to ensure that high quality candidates are accepted to the program, such as passing tests, interviews, and demonstrated mastery of content.
- Candidates with appropriate science or science-related backgrounds are recruited.

3) Intensive training in professional expertise:

- The program content includes instructional strategies, classroom management, curriculum, student assessment and how to work with the specific age group and diverse student population.

- The program provides the teacher candidates with sufficient subject conten pedagogical knowledge and skill training, and pedagogical content knowledge.
- The program provides multicultural and special education curricula and experiences related to developing and increasing candidate abilities to work with students, families, and communities from different racial/ethnic and socio-economic backgrounds, as well as with students with exceptionalities.

4) Field-based training

- An organized and comprehensive system of support is available from experienced, trained mentors once the candidate begins working in a school.
- Prospective teachers go through their training in cohorts at school so that they have sufficient peer support.
- Teacher candidates have the opportunity of guided practice in lesson planning and teaching prior to taking full responsibility as a teacher.

5) Frequent and substantial evaluation: A system is in place for continuous monitoring, evaluation, and feedback of individual and group performance to allow for program adjustment and improvement.

- All teacher candidates receive frequent and substantial formal and informal evaluation of their teaching from well-trained mentors and faculty with strong science education backgrounds;
- Faculty receives continual formal and informal evaluation of their instruction from the teacher candidates.

6) High exit standards tied to state standards for teaching: At the end of the program, teacher candidates demonstrate that they have mastered the knowledge, skills, and dispositions identified in state standards and can have a positive impact on P-12 student learning.

7) Ongoing support of graduates after the program.

- There is a structured, well-supervised induction period when the novice receives observation and assistance in the classroom by an experienced teacher.
- Ongoing professional development and reflection is supported and provided by the school and/or the university through seminars and workshops.

In the case of collaboration of colleges, which historically have been responsible for training teachers, with school districts on alternative certification programs, coordination of the schools and the colleges is needed to support candidates.

- Colleges, schools and the teacher candidates have constant communication to ensure that teaching theory and practice are effectively integrated to address classroom and pedagogical issues.
- School districts provide the teacher candidates in alternative certification programs with a supportive school environment to help them with effective transition to teaching.

- The program prepares individuals for specific positions in specific schools, and should place participants in those positions early in the training.

An AC program encompassing all these components may be an ideal, but these benchmarks provide a frame of reference for an effective AC program. These components are not meant to be an oversimplified checklist to measure the excellence of an AC program, but rather, to serve as research directions for in-depth inquiry into the implementation and efficacy of these elements to achieve excellence in AC teacher preparation.

3. What we need to know: Research agenda

It is clear from the presentations that research on alternative certification programs to date is very weak. Keynote speaker Kenneth Zeichner, from the University of Wisconsin-Madison, opened the conference with an excellent, critical overview of the relevant teacher education research. He notes that much of what is believed about teacher education program excellence in general cannot currently be supported by the evidence. It is oversimplified to judge the quality of an AC program by a simple criterion such as its length without, for example, taking into account the characteristics of the participants. Another example is that everyone agrees that mentoring of new teachers is important, but in practice the quality and extent of the mentoring offered varies enormously. Humphrey, Wechsler and Hough (2006) similarly note, “Ironically, both the endorsement and criticism of alternative certification are based on a very thin research base” (p. 4).

Based on the review of research on practice of AC science teacher training, future research needs to focus on the following areas.

- Given that “different programs have different selection criteria” (Humphrey, Wechsler & Hough, 2006, p. 8), we need to test the assumptions about the most desirable qualities of an effective teacher, and about which qualities are generic and which are specific to science teachers.
- Given that the strong interaction among AC program partners has impact on recruiting, selection and initial placement and the training processes (Daly, 2006; Harper & Edwards, 2006), we need to know the impact of such collaborative innovations on AC teacher retention.
- Research shows that field-based experiences through alternative certification routes have the potential to: 1) engage interns in the exploration of different instructional methods; 2) increase intern self-efficacy; 3) connect university coursework to classroom decision making (Bullough, Young, Erickson, Birrell, Clark, Egan, Berrie, Hales & Smith, 2002); and 4) create the “transformative pathway” (Abell, 2006) for teacher candidates to interact with veteran teachers for understanding and experiencing the teaching profession. What we need to know is through what structural, organizational, and systemic elements in the partnerships AC candidates benefit most from the field-based experiences.
- In the area of mentor training, we need to know
    - The type of assistance that is most needed by first year, alternative certification science teachers.
    - The type of mentor training that enables mentors to effectively develop the pedagogical content knowledge in alternative certification science teachers.
- Regarding mentoring relationships that best support AC science teachers, we need to know

  - The process of selection of mentors in order to ensure that productive partnerships with AC science teachers develop.
  - The expectations for mentoring that are held by both mentors and mentees.
  - The types of partnerships between mentors and mentees that most effectively develop AC science teachers' classroom skills.
  - The support of the partnerships from the school systems with release time or other means of facilitating meetings.
- In order to examine the efficacy of AC induction programs, we need to know
  - The structure of long-term professional development programs and the role of mentoring in these programs.
  - The benefits to the AC teachers who are participating in mentoring programs as a part of long-term professional development.
- Research indicates that AC science teacher training efficacy appears to be a function of the interaction between the program as implemented, the school context, and individuals' backgrounds (Humphrey & Wechsler, 2005). What we need to know is how the interaction influences novice AC teachers' performance with reference to student achievement, and their retention not only in the teaching profession but also in hard-to-staff schools.
- For comparative studies of certification programs, Humphrey and Wechsler (2005) theorize that rather than comparing different AC programs "a better unit of analysis would be a subgroup of individuals from different programs with similar backgrounds and experience, who work in the same or similar school settings"(p. 30).

The quality of an AC science teacher is a direct reflection of the quality of the AC program that he/she went through. The following section recommends guidelines for assessment of AC programs through the evaluation of the AC science teachers' mastery of teacher knowledge and their skill performance.

4. Guidelines for assessment of AC programs for science teachers

Though variation exists among routes to licensure according to state regulations and the alternative pathways that teachers can utilize to become certified, guidelines must be established to assess the alternative certification programs existing today. Included here are guidelines for states, school districts, and higher education institutions to use in order to determine the effectiveness of their alternative certification programs and for programs to use to better prepare its science teachers. The guidelines address both teacher knowledge and teacher skill performance.

4.1 Teacher Knowledge

Teacher knowledge includes teacher content knowledge and teacher knowledge of educational foundations and strategies.

Content knowledge

The STEM areas are a growing body of content knowledge. This requires a periodic examination of the content that science teachers are required to know. Science teacher preparation is particularly precarious since there are distinct, yet related, disciplines within science that no one teacher can truly be expected to master completely. While several states, such as Texas, offer "composite science" certification so that teachers are certified to teach in all science content areas, such encompassing certificates in science should be used with caution. A teacher with a degree in the life sciences may not be equipped to teach the physical sciences, and vice-versa. In order to assess the extent to which alternative certification programs effectively prepare teachers who have the appropriate content knowledge set, some guiding questions are:

- To what extent do the alternative certification program's requirements for content knowledge meet local, state, and national guidelines for content?
- What evidence does the program provide regarding the teacher's working knowledge of the range of content that they will possibly teach?
- To what extent does the program identify deficiencies in content knowledge and require content preparation to meet deficiencies?
- To what extent does the program include instruction in the range of content that the teacher will likely teach?
- To what extent does the program extend teachers' knowledge beyond the range of content they will likely teach?

Educational foundations and strategies

Being a good teacher is more than knowing content (Darling-Hammond, 1999, 2000, 2002, 2003). Included in alternative certification programs are usually training in educational foundations and strategies. While an individual in an alternative certification program may have a degree in their certification area and have practiced as a professional in that area, further preparation is still needed, such as opportunities for teachers to experience first-hand the environment in which they will be working prior to their employment. Once the teacher is employed full-time, training in effective teaching strategies should continue with the support of a mentor teacher in the same content area and grade level, and mentors should receive adequate training in research-based strategies in order to meet the changing needs of the teachers (Evertson & Smithy, 2000; Hawkey, 1998). Thus, assessment of alternative certification programs must include an assessment of the training that mentors receive as well. In order to assess the extent to which alternative certification programs effectively prepare teachers who possess an appropriate knowledge of appropriate educational foundations and strategies, some guiding questions are:

- To what extent do the alternative certification program's requirements for knowledge of educational foundations and strategies meet local, state, and national guidelines for beginning teachers?
- What evidence does the program provide indicating that the teacher has a working knowledge of educational foundations and strategies necessary for the range of grade levels they will possibly teach?
- To what extent does the program identify deficiencies in this area and require preparation to meet deficiencies?

- To what extent does the program include preparation in the range of educational foundations and strategies necessary for the grade levels that the teacher will possibly teach?
- What field experiences are provided so that teachers have the opportunity to become familiar with the school environment, observe effective teaching, and interact with students within their particular certification area and for the range of grade levels they will possibly teach?
- What evidence is there indicating that each mentor has expertise in their assigned teacher's content area and grade level?
- What type of training does each mentor receive in research-based mentoring strategies?

4.2 Teacher skill performance assessment

In addition to assessing the extent to which alternative certification programs prepare teachers in terms of their content knowledge and their knowledge of educational foundations and strategies, programs must be held accountable for ensuring that the graduates are capable of using effective teaching practices through direct observation both during and after the program and with reference to student outcomes.

Direct observation

In order to assess the extent to which alternative certification programs effectively prepare teachers who are able to demonstrate effective teaching practices, some guiding questions are:

- To what extent do the alternative certification program's requirements for teacher performance meet local, state, and national guidelines for beginning teachers?
- What evidence does the program have indicating that the teacher is capable of employing the teaching skills necessary for the range of grade levels they will possibly teach?
- What deficiencies does the program identify in this area prior to the full-time employment of the teacher and require preparation to meet the deficiencies?
- What opportunities does the program provide for teachers to demonstrate effective teaching practices during their training for the range of grade levels that the teacher will possibly teach?
- What field experiences are provided prior to their employment as a full-time teacher so that teachers have the opportunity to demonstrate effective teaching practices within their particular certification area and for the range of grade levels they will possibly teach?
- What specific feedback do teachers receive on their teaching once hired as full-time teachers?
- What deficiencies does the program identify in this area that require remediation and sustained support to meet the deficiencies?
- What are the evaluation results of the teachers by multiple individuals over multiple observation visits that include both planned and unplanned observations?

Student outcomes

Another means of determining the extent to which teachers are able to utilize effective teaching practices is their influence on student performance as measured by students' course grades and standardized test scores. Research indicates that better prepared teachers have a more positive impact on student performance as compared to less prepared teachers (Darling-Hammond, 1999, 2000, 2003; Marzano, 2003; Reeves, 2002; Sanders, 1998).

Alternatively licensed teachers should have students performing at comparable levels to the students of traditionally prepared teachers with similar school placements, teaching assignments, students, and years of experience. Due to the potential subjective nature of students' course grades (Adelman, 1983; Bracey, 1994; Marzano, 2000; USDOE, 1994), student performance on standardized tests should be weighted heavily in this comparison. In order to assess the extent to which alternative certification programs effectively prepare teachers who utilize effective teaching practices, some guiding questions are:

- To what extent do the alternative certification program's requirements for teacher performance, as measured by student outcomes, meet local, state, and national guidelines for the students of beginning teachers?
- To what extent does the alternative certification program have access to, and make use of, student data to ensure that the teacher is capable of employing the teaching skills necessary for their particular teaching assignment?

Conclusion

Alternative teacher certification (AC) is a complex phenomenon. It has a significant impact on how teachers are educated and brought into the profession (Feistritzer & Chester, 2002), and it has become a catalyst for debates centering upon interpretations of teacher shortages, on the definition of "highly qualified" teachers, and on the nature of teaching and teacher education. However, research on the effect of alternative teacher certification programs is "limited" and research findings are very often "mixed" (Wilson, Floden & Ferrini-Mundy, 2002, p. 198) because of flaws in AC research (Hawley, 1990; Zeichner, 2006). The presentations at the conference help to define what we know about current effective practices of AC programs in preparing science teachers and to clarify what we still need to know through future research in this area.

References

Abell, S. A., Arbaugh, F., Chval, K., Friedricshen, P., Annin, J., & Volkmann, M. (May 2006). *Research on alternative certification: Where do we go from here?* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Adelman, C. (1983). *Devaluation, diffusion, and the college connection: A study of high school transcripts 1964-1998.* (ERIC Document Reproduction Service No. ED 228 244).

Austin, B. (May 2006). *Alternative licensure at New Mexico Tech.* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Berry, R. Q. (2004). Transition to teaching: An alternative certification program through a partnership between a public school district and a public university. *The Journal of Mathematics and Science: Collaborative Explorations*, *7*, 149-165.

Boyd, D., Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (2005). *How changes in entry requirements alter the teacher workforce and affect student achievement*. Available at: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=870605

Bracey, G. (1994). Grade inflation. *Phi Delta Kappan, 4*, 328-329.

Britton, E. (May 2006). *Subject-Specific Induction for Beginning Science Teachers.* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Bullough, R. V. Jr., Young, J., Erickson, L., Birrell, J. R., Clark, D. C., Egan, M. W., Berrie, C. F., Hales, V., & Smith, G. (2002). Rethinking field experience: Partnership teaching versus single-placement teaching. *Journal of Teacher Education, 53*(1), 68-80.

Darling-Hammond, L. (1999). Teacher quality and student achievement: A review of state policy evidence. University of Washington: Center for the Study of Teaching and Policy. Available at: http://depts.washington.edu/ctpmail/PDFs/LDH_1999.pdf.

Darling-Hammond, L. (2000). Teacher quality and student achievement: A review of state policy evidence. *Educational Policy Analysis Archives*, *8*(1). Available at: http://epaa.asu.edu/epaa/v8n1.

Darling-Hammond, L. (2002). Learning to teach for social justice. In L. Darling-Hammond, J. French, and S.P. Garcia-Lopez (Eds.), *Learning To Teach For Social Justice* (pp. 1-8). New York: Teachers College Press.

Darling-Hammond, L. (2003). Keeping good teachers: Why it matters, what leaders can do. *Educational Leadership, 60(*8), 6-13.

Duhon-Haynes, G., Augustus, M., Duhon-Sells, R., Duhon-Ross, A., & Mitchell, J. (1996). *Post-baccalaureate teacher certification programs: Strategies for enhancement, improvement, and peaceful co-existence with traditional teacher certification programs.* East Lansing, MI: National Center for Research on Teacher Learning. ED 404 334.

Evertson, C. & Smithy, M. (2000). Mentoring effects on protégés' classroom practice: An experimental field study. *Journal of Educational Research, 93*, 294-304

Feiman-Nemser, S. (1996). *Teacher Mentoring: A Critical Review, Teaching and Teacher Education,* AACTE, Washington DC. (ERIC Document Reproduction Service NO. ED 397060)

Feistritzer, C. E., & Chester, D. T. (2000). *Alternative teacher certification: A state-by-state analysis 2000.* Washington, DC: National Center for Education Information.

Feistritzer, C. E., & Chester, D. T. (2002). *Alternative Teacher Certification: A State by State Analysis 2002*. National Center for Education Information.

Gagne, K. D. (May 2006). 180 Days in Springfield: Cultivating school-university partnerships to enhance urban teaching. Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Greenwood, A., Shea, K., & Hickey, C. (May 2006). Instructional support to alternative route novice stem teachers: Two Studies. Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Harper, I., & Edwards, M. M. (May 2006). Pact & Peer: On-line mentoring for the ACP science intern. Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Hawkey, K. (1998). Mentor pedagogy and student teacher professional development: A study of two mentoring relationships. *Teaching and Teacher Education, 14, 657-670.*

Hawley, W. D. (1990). The theory and practice of alternative certification: Implications for the improvement of teaching. *Peabody Journal of Education,67*(3), 3-34.

Hayes, J. L. (May 2006). An inquiry into best practices for preparing and retaining alternative certification candidates in the sciences. Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Humphrey, D. C., & Wechsler, M. E. (2005). Insights into Alternative Certification: Initial Findings from a National Study. *Teachers College Record*, ID Number 12145.

Humphrey, D. C., Wechsler, M. E., & Hough, H. J. (2006). Characteristics of Effective Alternative Teacher Certification Programs. *Teachers College Record, 110* (4).

Koballa, T. R. Jr., Bradbury, L. U., Deaton, C. M., & Glynn, S. M. (May 2006). *Conceptions of Mentoring and Mentoring Practice in Alternative Secondary Science Teacher Education.* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Littleton, M. & Larmer, B. (1998). Alternative education: Reflection on the past and implications for the future. *Teacher Education and Practice*, 14(1), 1-9.

Lutz, F. & Hutton, J. (1989). Alternative teacher certification: Its policy implications for classroom and personnel practice. *Educational Evaluation and Policy Analysis*, 11, 237-254.

Marder, M. (May 2006). *UTeach.* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

Marzano, R.J. (2000). *Transforming classroom grading*. Alexandria, VA: Association for Supervision and Curriculum Development.

Marzano, R.J. (2003). *What works in schools: Translating research into action*. Alexandria, VA: Association for Supervision and Curriculum Development.

Mayotte, G. A. (2003). Stepping Stones to Success: Previously Developed Career Competencies and their Benefits to Career Switchers Transitioning to Teaching. *Teaching & Teacher Education, 19*(7), *681-695.*

McKibbon, M. & Ray, L. (1994, Winter). A guide for alternative certification improvement. *The Educational Forum*, 58, 201-208.

Mitchell, A. (May 2006). *The National Council for Accreditation of Teacher Education and Alternative Programs: An Unexpected Convergence.* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

National Council for Accreditation of Teacher Education. (2002). *Professional standards for the accreditation of schools, colleges, and departments of education 2002 Edition.* Washington, DC: Author.

Reeves, D.B. (2002). *Making standards work: How to implement standards-based performance assessments in the classroom, school, and district (3rd ed.).* Denver, CO: Advanced Learning Press.

Sanders, W.L. (1998). Value-added assessment: A method for measuring the effects of the system, school and teacher on the rate of student academic progress. Available at: http://www.aasa.org/publications/saarticledetail.cfm?ItemNumber=4627&snItemNumber=950&tnItemNumber=951

Sterling, D. R., Frazier, W. M., Logerwell, M. G., & Kitsantas, A. (May 2006). *New science teachers' support network: How can we help provisionally licensed teachers succeed?* Proceedings of the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

U.S. Department of Education, Office of Educational Research and Improvement (1994). *What do student grades mean? Differences across schools.* (Office of Research Report 94-3401). Washington, DC: Office of Educational Research and Improvement.

Wilson, S. M., Floden, R. E., & Ferrini-Mundy, J. (2001). *Teacher Preparation Research: Current Knowledge, Gaps, and Recommendations*, (R-01-3), Center for the Study of Teaching and Policy, University of Washington, Seattle.

Wilson, S. M., Floden, R. E., & Ferrini-Mundy, J. (2002). Teacher Preparation Research: An insider's view from the outside. Journal of Teacher Education, 53(3). 190-204.

Zeichner, K. (May 2006). What do we know about the characteristics of good teacher education programs? Keynote at the STEM ACT Conference, Arlington, VA. Available at: http://www.stemtec.org/act/

EDUCATING TOMORROW'S SCIENCE TEACHERS

STEM ACT Conference Report: Research Section

Authors

Allan Feldman	*University of Massachusetts Amherst*
Jodie Galosy	*Michigan State University*
Carole Mitchener	*University of Illinois Chicago*

Writing committee

Abdulkadir Demir	*University of Missouri, Columbia*
Allan Feldman	*University of Massachusetts Amherst*
Jodie Galosy	*Michigan State University*
Richard Iuli	*SUNY Empire State College*
Carole Mitchener	*University of Illinois Chicago*
Hsing Chi Wang	*University of Calgary*
Bruce Herbert	*Texas A&M University*

STEM ACT Conference Repor
Research Section

Introduction

The major theme of the STEM ACT conference was to respond to the question, "What do we know and what more do we need to learn about how to incorporate the results of more than 30 years of research on science teaching and learning into alternative certification programs?" However, a review of studies that have compared alternative with traditional programs led us to the conclusion that given the wide variety in the structures of alternative and traditional programs, and the wide variety in the knowledge, skills, and dispositions that candidates bring to the programs, there is little that can be learned through research that attempts to compare alternative and traditional programs. Hence, in this white paper we argue that what is needed, instead, are studies that identify and examine how teacher learning occurs in those experiences; what is learned; and how teachers put that learning to use. In other words, this white paper's primary purpose is to outline a research agenda for the initial preparation of science teachers, regardless of programs, which takes into account results of more than 30 years of research on science teaching and learning.

This white paper starts with issues related to defining alternative certification programs and research on such programs, which is followed by delineation of what we refer to as the "Reform Vision" of science teaching, and what and how science teachers would need to learn in order to construct reform vision classrooms. We conclude the paper with recommendations and questions for future research.

A list of all the papers presented in the research thread appears in the Appendix.

1. Defining Alternative Programs

One of the findings of the STEM ACT conference was that alternative certification is a wide-ranging term that fails to clearly delineate a unique set of programs. Many programs considered to be alternative programs are in fact housed in institutions of higher education and lead to both licensure and a degree. Others have chosen to call only undergraduate programs "traditional," and to place all other teacher education programs in the category of alternative. In addition, there is at least as much variation within programs as there is between programs. For example, Marjorie Wechsler, in a paper delivered at the STEM ACT Conference, reported on a large scale study of alternative certification programs done with her colleagues at SRI International. They found large variations among alternative certification programs in the characteristics of participants (e.g., their education backgrounds), previous careers and classroom experience; and in the components of the alternative certification programs, including participant experiences with coursework, mentoring and supervision, and the context of their school placements (Humphrey, Wechsler, & Hough, 2006).

Similarly, in another conference presentation Sandra Abell and her colleagues (2006) reported that the literature indicates wide variation in the design and purpose of alternative certification programs (Darling-Hammond, 1992; Feistritzer, 1998). In particular they noted that

"Scribner, Bickford, and Heinen (2004) found differences in program goals, structure, support in teaching field placements, and mentoring available to interns among the various alternative certification programs within the state of Missouri (Abell et al., 2006, p. 3)." Abell at al. concluded from this that, "Because of this variation in program design, the research results are difficult to interpret and inadequate for informing the design and implementation of alternative certification programs (2006, p. 3)." Moreover, in a study of new science teachers in "Bayline" school district, Jodie Galosy noted that "even within this one district and alternative certification program, considerable variability existed across teachers, their school contexts, and their learning opportunities" (Galosy, 2006, p. 2). Michelle Lee also found wide variations among candidates in the alternative programs that she studied and that the candidates' perceptions of the program varied widely in terms of structure and cohesiveness (Lee, Olson & Scribner, 2006).

… much of the literature on alternative certification programs is in the policy domain, such as issues about who enters teaching through an alternative certification route, where they teach, and how long they stay. These studies pay little attention to teacher learning, the goal of teacher education programs

Thus, the large variations in program structure among those programs labeled as alternative, the differences in candidate backgrounds within and among programs, and the wide range in the school contexts in which candidates were placed, both within and among programs, led us to concur with the statement that "there is no agreement about the definition of alternative certification and there is some confusion as well about what constitutes traditional certification" (Zeichner & Conklin, 2005, p. 656). Given that the meaning of alternative (or traditional) certification "is obscure and its forms of implementation are many" (Fenstermacher, 1990, p. 155), research that contrasts alternative with traditional programs has limited ability to inform science teacher education. We argue that we need studies focusing instead on the educational experiences programs provide, what teachers learn from these opportunities, and the implications for their students. We expand on these points in the following section of the paper.

2. Research on Alternative Programs

Alternative teacher certification has become a proliferating phenomenon in the United States in the past two decades. Nonetheless, much of the literature on alternative certification programs is in the policy domain, such as issues about who enters teaching through an alternative certification route, where they teach, and how long they stay. These studies pay little attention to teacher *learning*, the goal of teacher education programs. Moreover, policy studies tend to look broadly at teachers and teacher education in general, often without a subject matter focus. That is, little or no attention is paid to whether the teachers will teach at the elementary, middle or high school level; or what subject area they will teach. This was confirmed by a thorough search of the literature in which we found few references to studies of alternative certification programs for science teachers. This is problematic because subject matter knowledge is considered an essential component to pedagogical and pedagogical content knowledge (Allen, 2003; Darling-Hammond & Youngs, 2002; EOTP, 2002; USDOE, 2002).

While science-specific studies of teacher learning are needed, equally valuable but less often discussed (or researched), is the importance of science teachers' knowledge of research findings on science teaching and learning, and how to use those findings in their classrooms. This includes studies of students' everyday and scientific understanding of science concepts (e.g., Clement, 1982; Driver, Guesne & Tiberghien, 1985), conceptual change (Posner, Strike, Hewson & Gertzog, 1982), and scientific discourse in classrooms (e.g., Clement, 1982; Crawford & Kelly, 1997; Driver, Asoko, Leach, Mortimer & Scott, 1994; Posner, Strike, Hewson & Gertzog, 1982; Rosebery, Warren & Conant, 1992[1]). There have also been large research programs on the teaching of science. These have primarily been in the areas of inquiry (Layman, 1996); the science, technology and society (STS) approach (Yager & Tamir, 1993); and the assessment of learning (Atkin & Coffey, 2003; Black, Harrison & Lee, 2004). Other research programs that have informed science teacher preparation include those on the nature of science (Lederman, 1992; Solomon, Duveen & Scot, 1992) and women and underrepresented groups in science (Brickhouse, Lowery & Schultz, 2000; Rodriguez, 1998). While there is more research needed in these and other areas of science education, the field would benefit from examining the impact these studies have on teacher education, teachers, and their students.

Accordingly, we recommend rephrasing the guiding question to "What do we know and what more do we need to learn about science teacher education that takes into account the results of more than 30 years of research on science teaching and learning?" That is, what and how do varied educational opportunities (for example, learning about research findings) contribute to the beliefs, knowledge, and skills that science teachers develop and to their students' learning? Such a shift moves away from the overemphasis on policy and licensure toward content-rich teacher learning across a teacher development continuum.

3. The Terrain of Science Teacher Education

In the preceding section we argued that it is of little value to compare and contrast traditional and alternative programs for the purpose of research on science teacher education. However, in order to put boundaries on the scope of this white paper there is a need to locate it as best we can among the various contexts in which science teacher learning occurs. In doing so we begin by thinking about the field of science teacher education in terms of terrain, and then by focusing on one type of geographical feature – the divide. In research on science teacher education the divides that we are concerned with are those that separate science teacher education from the education of other teachers, those that separate preservice and inservice teacher education; and those that separate programs that have as their primary purpose teacher licensure from those that have as their primary purpose the education of teachers. We particularly like the metaphor of the geophysical divide because rather than a clear line, the divide is often a long ridge that separates watersheds. For example, when rain falls near the continental divide that separates the Colorado and Mississippi watersheds, it will either eventually flow into the Sea of Cortez or the Gulf of Mexico, depending on which side of the divide it falls on. However, because so little rain actually falls exactly on the "dividing line" its precise location is not important except to a small number of hydrologists. Instead what is important is whether the rain drops head toward the tributaries of the Colorado or to those of the Mississippi. In the same way we are not too concerned with surveying exactly the divide between our categories, but rather which side of the divide we examine.

[1] C.f., National Research Council (2005) for a summary of studies on student learning.

3.1 Divide between science teacher education and generic teacher education

The first divide that we examine is between programs that focus on the preparation of science teachers and those that are more generic. A major part of our argument in this white paper is that science teachers need to have knowledge and skills particular to the teaching of science and that these knowledge and skills go beyond those that can be learned and developed without paying attention to what it means to teach and learn science. In addition, there is the difference between the content knowledge of school science and that of the academic disciplines, between what is practiced by scientists and what is presented to college students (Hill & Ball, 2004; Stengel, 1997). This is further compounded by the fact that science is not itself monolithic. Each of the sciences has its own substantive and syntactic structures (Schwab, 1978) that determine what is known and the warrants for knowledge.

3.2 Divide between preservice and inservice teacher education

A second divide is between teacher education activities that occur before candidates are hired as teachers of record and those that occur after they enter the teacher workforce. The divide between preservice and inservice teacher education, especially in the early years of practice, has become more of a wide plateau than a mountain ridge as the models for initial science teacher education proliferate. Just as we found that it is not useful to distinguish between traditional and alternative teacher education programs for the purpose of research on science teacher learning, we believe that it is not fruitful to continue to try to maintain the distinction between preservice and inservice teacher education. Rather, it may be better to distinguish between novices and experts in studies, because the distinction has more to do with the level of knowledge and skills that they have, rather than where they are in their professional careers.

3.3 Divide between licensure programs/educational programs

The third divide that we examine is between programs that have as their primary purpose the *licensure* or *credentialing* of new teachers and those that have as their primary purpose the *education* of new teachers. In their extreme forms, the former exist solely to help candidates meet the minimum requirements of state licensing agencies, while the latter help teacher candidates to develop the knowledge, skills, judgment and wisdom for teaching. The advantages of the former are that they require minimal resources to run the programs, and keep the cost to the candidates low, especially in terms of income lost while otherwise enrolled in the program. They also quickly produce the teachers that are needed in high demand regions. What we are calling teacher education programs, on the other hand, require many more resources, because they recognize that time and effort are required to produce knowledgeable, skilled, and wise practitioners. A challenge in science teacher education is how to design programs that have the benefits associated with credentialing programs yet prepare teachers to be effective science educators. Much research on science teacher learning must be done to make sure that as programs are trimmed to increase productivity, they maintain the quality that keeps teacher learning at the center.

We now look more closely at science teacher education by delineating the “reform vision” for science education that guides most of the research in science teacher education. We then turn to the teacher beliefs, knowledge and skills that support the reform vision, and then to ways that teacher education can be embedded in practice.

4. Visionary Strides: What And How Science Teachers Need to Learn

What science teachers need to learn is inextricably linked with our vision of science education. In the following section, we consider contemporary visions for science education and their implications for teacher learning. We describe what educational reformers imagine, the implications for what science teachers — particularly those new to the profession — must learn, and the research progress, to date.

4.1 A reform vision of good science teaching

Over the past decade, the science education community has developed a vision for science classrooms where all children have opportunities to develop deep understanding of science and its practices. This vision imagines science classrooms as active and exciting places; where science is relevant and interesting to students' lives, awakens their curiosity about the world within and beyond their own experience, engages them in scientific inquiry, and deepens their commitments to responsible citizenship.

These hopes for what science education could be stand in sharp contrast to descriptions of science classrooms students typically encounter — often depicted as dull, boring places dominated by lecture, incomprehensible textbooks and worksheets, and punctuated with occasional laboratory procedures which — when followed precisely — yield pre-determined results. Moreover, all learners do not have equal opportunities to participate in and/or experience success in science, as evidenced by achievement gaps between some racial, ethnic, and economic groups (Lynch, 2000).

4.2 What do science teachers need to learn to construct Reform Vision classrooms?

Visions are ideological; school classrooms are not. Studies point out the strenuous demands that instructional reforms, like those proposed for science, exact on experienced teachers, let

alone novices (Gamoran, Anderson, Quiroz, Secada, Williams & Ashmann, 2003; Kennedy, 1998; National Research Council, 2000). Ambitious visions for classroom science teaching and learning have profound implications for teacher learning — expectations for what teachers know and are able to do expand accordingly (c.f. NSTA, NSES, NBTS, INTASC). Science teaching becomes more complex and demands much from teachers, especially those at the beginning of their careers. The lists of beliefs, knowledge, and skills considered necessary are lengthy: deep understanding of science and scientific practices, pedagogical and pedagogical content expertise, knowledge of learners, and capacities for context-specific judgment and reasoning, to name a few. Consider, for instance, the range of beliefs, knowledge, and skills included within the research papers for this conference (see Table 1).

Science education research continues to pursue meaningful lines of discipline-specific inquiry — like those represented at the STEM ACT conference — with implications for science teacher preparation. For instance, we now have a much better grasp of how students develop conceptual understandings of a wide variety of science concepts (c.f., research studies on conceptual change). Other promising lines of work include, but are not limited to, teacher content knowledge, learners' views of science, and student assessment. However, we know little about the impact of incorporating this scholarship into early career science teacher education. That is, what are the implications for teachers and their students?

Consequently, empirical warrants for what good science teachers must know are emergent, at best. Progress requires long-term, coordinated commitments from the science education research community to investigate relationships between science teachers' professional development, their beliefs/knowledge/practices and what their students know and are able to do. This is the agenda for research on *any* program invested in science teacher *education*, regardless of designation (e.g., alternative, undergraduate, graduate, etc.). We now consider research progress on *what* science teachers need to learn.

Table 1. Teacher learning outcomes referenced in STEM ACT research papers

Paper/Poster lead authors	Beliefs/knowledge/skills/practices
Abell	Content knowledge for teaching (CKT) and Pedagogical content knowledge for teaching (PCK)
Demir	Inquiry-based teaching practices
Dern	Teacher beliefs about student-centered teaching practices
Galosy	Teachers' expectations for their students' science learning
Greenwood	Teacher efficacy — belief that they can have positive impacts on student learning
Lee	A range of science teaching practices (active learning, collaborative learning, connecting science with students' experience, addressing students' misconceptions and learning difficulties, assessment)
Mitchener	Inquiry-based teaching beliefs and practices
Sterling	Classroom management, planning, and instructional capacities

4.3 Teacher beliefs, knowledge, and skills that support the Reform Vision

In their review of research on professional development, Wilson and Berne (1999) suggest that getting at the "what" of good teaching entails both conceptual and empirical work. We see the vision for science teaching already discussed as the kind of conceptual work necessary. The thirty-year history of science education research provides some empirical footing. However, studies that examine the results of teacher education and especially research that links teacher and student learning are needed. Moreover, if we are to characterize and test models of teacher and student learning we need more robust conceptual and methodological tools for our work. We draw on the STEM ACT research presentations to offer some examples of the kind of research and tools we mean; discussing, in turn, teachers' content and pedagogical content knowledge, inquiry-based teaching, students' conceptual development, and the nature of science.

4.3.1 Science teacher content knowledge

The candidate's science background is the most shared focus across research papers presented at the STEM ACT conference. Galosy (2006) highlighted the critical importance of this knowledge as one of the personal resources that three STEM-degreed teacher candidates relied on to access and effectively use a variety of other available resources. Similarly, Mitchener (2006) argued that this STEM background played a significant role in beginning teachers successfully conducting action research projects during their second years to improve their teaching. Abell et al. (2006), Herbert (2006), and Wang (2006) all focused more specifically on the teacher candidate's content knowledge, and what and how the formal and informal aspects of this knowing becomes accessible to students.

The work of Britton and colleagues (2006) support a growing consensus that science teachers need a depth and breadth of content knowledge that college science courses alone are unlikely to provide.

The work of Britton and colleagues (2006) support a growing consensus that science teachers need a depth and breadth of content knowledge that college science courses alone are unlikely to provide. Their studies suggest content for science teaching is domain-specific in at least two ways – 1) to the particular science discipline and 2) to the work of teaching itself. It is clear that teachers need to know the science that they will teach – a major in biology will not provide the content knowledge needed to teach earth science. Moreover, drawing on the work of Ball and colleagues in mathematics (Hill & Ball, 2004), Abell et al. (2006) note that the content knowledge for teaching may be qualitatively different from that required for a career as a research scientist or engineer. Contrary to typical assumptions, then, teacher candidates with science majors or previous career experience in science-related fields may not necessarily have the right content knowledge for science teaching. In fact, Wang (2006) — citing Lederman and Gess-Newsome's work (1999)— implicates college-level science courses as major contributors to the fragmented and shallow "knowledge structures" evidenced by many secondary science teachers (pp. 13-14).

Yet, as Wang (2006) points out, studies investigating secondary science teacher content knowledge reveal little about what constitutes "good training in science" (p. 11) for science teaching. Previous studies of teacher content knowledge often are not domain-specific; using proxies, like number of science courses, for teacher content knowledge. Further, other commonly-used measures, like teacher or mentor reports of content confidence/competence have suspect validity. More robust measures for assessing domain-specific teacher content knowledge are needed; there are several NSF-funded works in progress to develop such measures (e.g., Abell et al., 2006; Kern, Roehrig & Luft, 2006).

More importantly, the idea that content knowledge for teaching is significantly different from the academic knowledge of the university (Hill & Ball, 2004; Stengel, 1997) suggests that teachers must continue to learn their subject within the context of their practice if they are to become experts. We believe that studying how teachers develop this expertise is a potentially fruitful and important area for research on science teacher learning.

4.3.2 Nature of science

Science education reform documents, such as the AAAS Benchmarks (AAAS, 1993) and the National Science Education Standards (National Research Council, 1996), frame science as both a body of knowledge and a process for developing that knowledge (often referred to as the "Nature of Science' or NOS). NOS experts contend science textbooks' treatment of "the scientific method" mislead teachers and students about scientific disciplinary practices. Consequently, if science teachers are to help students develop more realistic views about science, the teachers, themselves, will need to understand science as a discipline.

Attempts to measure NOS have a long and contested history (Lederman, Schwartz, Abd-El-Khalick & Bell, 2001; Munby, 1983). However, efforts to develop national science standards have contributed to a growing consensus about practices that characterize scientific work; and practices students (and their teachers) should have opportunities to understand and experience. In turn, these scientific practices form the basis for instruments intended to measure NOS. Research into NOS development in science teacher education has been facilitated by recent validation studies of NOS instruments (Lederman, et al., 2001).

While there is no single definition of NOS, reform documents emphasize some common characteristics of scientific work: "Scientific knowledge is: tentative (subject to change), empirical, theory-laden, partly the product of human inference, imagination, and creativity…and socially and culturally embedded" (Abd-El-Khalick, 2005, pp.16-17). Studies of pre-service teachers, to date, show most teacher candidates have limited understanding of NOS. Moreover, even when their views more closely represent those described above, the "translation of these views into instructional practices was, at best, limited and mediated by several factors" (Abd-El-Khalick, 2005, p.16). However, we know little about the impact that teachers' knowledge and beliefs have on their NOS understanding and classroom practice. STEM ACT Conference participants did not address NOS explicitly in their work. However, Greenwood and colleagues (2006) do note that given present efforts to attract STEM graduates to teaching, STEM training, work history, and especially experiences doing scientific research bears further study. In addition to the implications these prior experiences have for teacher preparation and support (as Greenwood et al., 2006, suggest), another interesting line of inquiry is how these prior experiences influence teacher learning about NOS and classroom instruction.

4.3.3 Science teacher pedagogical content knowledge

Research on science teacher pedagogical content knowledge (PCK) parallels content knowledge — we have fledgling understandings of what "it" is and thus, few valid measures of "its" assessment. In their literature review on the construct, Kern, Roehrig and Luft (2006) draw on Shulman's (1987) work and describe pedagogical content knowledge as "the capacity of a teacher to transform the content knowledge he/she possesses into forms that are pedagogically powerful and yet adaptive to the variations in ability and background represented by the students" (p. 7). Again, as with content knowledge, the challenge is translating this general description in context-specific terms. For instance, what does pedagogical content knowledge of a novice science teacher "look like" when teaching force and motion to a diverse group of seventh grade students? We suggest, then, that the field not only needs research that applies across contexts but also context-specific studies.

Not surprisingly, given what we yet have to learn about content knowledge for science teaching, researchers are grappling with how to examine PCK. Several STEM ACT research groups — led by Greenwood, Britton, Kern, and Abell — included PCK measurement in their work. We briefly describe each of their approaches to data collection and analyses.

Greenwood and colleagues (2006) evaluated the PCK of new science teachers with a survey questionnaire that they administered to the novice's mentors. There are twenty-seven items in the questionnaire's PCK scale that includes a range of criteria from laboratory safety to lesson planning to teacher enthusiasm. Although the PCK scale has high internal consistency (Cronbach's alpha = 0.952), the questionnaire has only been used, to date, to collect mentor teachers' perceptions of their mentees.

As part of their national study of induction programs, Britton's (2006) research team used a combination of several classroom observations and interviews to assess PCK development in the following areas:

- multiple ways of representing content
- constructing content- and student- appropriate tasks
- understanding specific content within the disciplinary and curricular contexts
- identifying students' prior knowledge
- understanding student errors and addressing student misconceptions
- assessing student understanding.

Kern and colleagues (2006) used some of the categories Britton's group identified in their investigation of beginning secondary science teachers' PCK. Kern conducted beginning and end-of-year semi-structured interviews and coded them with rubrics that were developed by Luft and colleagues (Lee, Puthoff, Luft & Roehrig, 2005). These measures delineate "three levels of proficiency within two broad categories of knowledge: student learning in science (use of students' prior knowledge, variations in students' approaches to learning and students' difficulties with specific science concepts) and knowledge of instructional strategies (level of inquiry and different representations of content)" (p. 13).

Abell's (2006) group also used Luft and colleagues' rubrics (cited above) to analyze PCK development in their study of early career secondary science teachers. In addition to interviews, Abell's data collection involved a series of lesson planning tasks — both hypothetical and within the teachers' classrooms — over time. In addition to knowledge of student learning and instructional strategies, Abell's group is developing PCK rubrics for other areas of interest, including assessment of student understanding.

Looking across this work on PCK, we see a consensus about what kinds of knowledge fall within the domain of PCK and the beginnings of some shared measures for guiding research. Both are important for a successful research agenda on early career science teachers and PCK. At the same time, STEM ACT participants also noted that most of this work relied on intensive data collection over time and development of case studies. Understandably, investigating PCK — content- and context-specific as it is — may well require case study designs. It also seems likely that investigating PCK development as a continuum necessitates longitudinal studies. We take up the implications of these research designs in our recommendations. We now consider several other lines of work that also inform research into early career science teacher development regarding their PCK, including teacher beliefs, scientific inquiry, students' conceptual understanding, and formative assessment

4.3.3.1 Teacher beliefs

Growth in science knowledge and science knowledge for teaching is not the only one way to think about growth in expertise (Feldman, 2002). There is also the sense of becoming and the changes in self-identity that occur in the transition from novice to expert that leads to the ability to say with confidence, "I am a science teacher." For instance, Greenwood and colleagues (2006) investigated the influence that various types of feedback from a college supervisor had on three early-career science teachers' self-efficacy and noted that more research in this area was needed. They found Bandura's (2001) self-efficacy scale a useful instrument and recommended further work into the relationship between specific mentoring and supervisory practices and teachers' sense of self-efficacy. While Greenwood et al's rationale for studying self-efficacy is its relationship to teacher retention (citing Glickman and Tamashiro's 1982 study), investigating the influence of teacher self-efficacy on teaching practices and student learning would be equally valuable.

However, although inquiry stands as a marker of reform pedagogy, it is a complex notion, neither uniformly understood nor easily translated into classroom practices.

Kern et al. (2006), Galosy (2006), and Mitchener (2006) also considered the role teachers' beliefs play in their expectations for students and teaching practices. As a whole, these studies and others reviewed by Clift and Brady (2005) concluded that prospective teachers entered teacher preparation with their own firmly held beliefs and values about science, teaching, and learning, much of which related to their own schooling. Like their future students, what they learned, in this case through teacher education, was mediated by these prior beliefs and values derived from prior life and education experiences. Given the important role that efficacy, identity, and teachers' beliefs about science, teaching and learning play in teacher education, attention to this area, especially with regard to professional development, classroom practices and student learning is needed. Such studies would strengthen our understanding of what kinds of educational opportunities help teachers develop beliefs consistent with effective science teaching.

4.3.3.2 Scientific inquiry

Scientific inquiry figures prominently in reform documents, such as the *National Science Education Standards* (National Research Council, 1996), and its follow-up, *Inquiry and the National Science Education Standards* (National Research Council, 2000). However, although inquiry stands as a marker of reform pedagogy, it is a complex notion, neither uniformly understood nor easily translated into classroom practices (National Research Council, 2000). Confusion about inquiry is exacerbated by its double meaning in the NSES — as a learning goal for students and as a teaching strategy or method. The 2000 document reminds us that "inquiry" is not just about teaching but also refers to understanding how the scientific community builds knowledge:

> When educators see or hear the word "inquiry," many think of a particular way of teaching and learning science. Although this is one important application for the word, inquiry in the Standards is far more fundamental. It encompasses not only an ability to engage in inquiry but an understanding of inquiry and of how inquiry results in scientific knowledge. (National Research Council, 2000, p. 13)

Clearly, if students are to learn what inquiry means, learn how to engage in inquiry, and learn through inquiry-based teaching methods, then teachers will need the knowledge and skills to make that happen.

Research reports at the STEM ACT conference noted the connection between teachers' understanding of inquiry and the opportunities they made available for their students. Teachers tended to have partial and fragmented views of inquiry; associating inquiry, for instance, with "hands-on" activities (Demir, 2006) or using inquiry and activity interchangeably in instructional goals and practice (Galosy, 2006). Teachers with limited understanding of inquiry tended not to espouse inquiry-related student learning goals (Demir & Abell, 2006; Galosy, 2006; Lee et al., 2006). However, more sophisticated knowledge of inquiry did not necessarily translate into classroom instruction. Even when teachers did appear to have more complete understandings of inquiry, their classroom practices did not necessarily reflect their knowledge — they were hesitant to incorporate inquiry-based teaching due to management concerns, perceived school priorities, and/or time for planning (Demir & Abel, 2006; Galosy, 2006; Lee et al., 2006).

What new teachers know about inquiry, then, appears to be an important factor in the opportunities students have to learn about, and from, inquiry. However, there are a number of other variables that may be equally influential in making inquiry-based experiences more prevalent in science classrooms. For instance, how might a decreased course load influence novice science teachers' willingness to pursue inquiry-based instructional methods and what are the implications for their students? Classroom research can provide the evidence necessary to ensure policies and programs that not only support early-career science teachers' knowledge of inquiry but pay equal attention to factors that impact the extent to which investment in teacher learning improves student learning.

4.3.3.3 Students' conceptual understanding

Knowledge of the conceptions that students bring to the science classroom – including what have been called "misconceptions" – is often included as an aspect of PCK (see the earlier discussion on PCK). Research into student conceptions in physical, earth, and biological systems has been quite extensive over the years.[2] Yet we know little about the effect that incorporating findings from this research into teacher preparation programs can have on teachers' instructional practices or student learning. In one study from the conference, Lee et al. (2006) found that first year teachers who were simultaneously taking teacher education courses were somewhat more likely to address students' conceptions in their lesson planning if their coursework also did so. However, the factors that influenced how new teachers made use of this line of research, and the learning opportunities they created for their students as a result, require further examination.

4.3.3.4 Formative assessment

One area in which teacher education has paid particular attention to student conceptions research is formative assessment. This line of work includes studies on teaching that begin with an assessment of student's prior knowledge, and proceed with the design and modification of one's teaching in light of that prior knowledge. It also includes studies that focus on the preparation of teachers to investigate students' ideas about key concepts within science, and to be able to discern alternative conceptions that students hold from their informal experiences with science. In addition, future teachers are taught to engage in ongoing assessments of student learning to diagnose what conceptions of science their students hold, and how their teaching changes those pre-existing and developing conceptions. Although past efforts have focused on the use of instruments such as concept maps and webs or the use of clinical interviews (Mintes, Wandersee & Novak, 2000), more recent studies are examining the use of formative assessment by teachers to inform their practice (Atkin & Coffey, 2003; Black, Harrison & Lee, 2004; Feldman & Capobianco, 2003).

In summary, given the demands of science education reform, the list of what teacher education must prepare science teachers to know and be able to do is extensive. While this is not surprising—after all, science teaching is complex and multi-faceted—it does present difficulties for setting a coherent, yet comprehensive, research agenda on the content science teacher education ought to include. While we have pointed to several key areas discussed during the STEM ACT conference, there are other essential issues we have missed or touched on lightly; most notably, supporting diverse learners' science understanding and engagement. All of these lines of inquiry into science teachers, beliefs, knowledge, skills, and practices seem equally important for understanding science teacher preparation. The task then does not seem to be about setting priorities that choose one aspect of teacher learning over another. Rather, the challenge is to ensure that the evidence we are accumulating demonstrates if, and how, these areas influence teacher and student learning. We look more closely at what such work requires in our

[2] For example, see the bibliography assembled by Reinders Duit (http://www.ipn.uni-kiel.de/aktuell/stcse/stcse.html) that contains over 7700 entries.

recommendations. First, however, we turn from the content of science teacher education to review what conference participants presented and discussed about its' pedagogies—*how* science teachers learn.

5. Science Teacher Education Embedded in Practice

The second divide that we highlighted was between preservice and inservice teacher education. We suggested that this distinction be set aside and instead that researchers examine the ways that teacher expertise grows in all settings. Given that the STEM ACT Conference focused on teacher education programs, it is not surprising that most of the research reported on practice-based teacher education, particularly induction programs and mentoring in the first few years of teaching (see Table 2).

As early as 1975, Lortie concluded that school socialization overpowers what is learned in university preparation. Almost twenty-five years later, Kennedy (1999) characterized teacher education as still struggling with what she called, "a problem of enactment": the continued difficulty of beginning teachers putting into practice what they learned in their pre-service education. Yet several factors appear to be making inroads in understanding the nature of this problem and working to counteract it. A structural change most commonly referenced in this regard is "induction and mentoring"—a colloquial phrase within the profession that highlights the importance of the first three years of teaching. Induction, along with its assumed complement, mentoring, has grown over the last thirty years to become commonplace, and often state legislated, in many public schools (American Federation of Teachers, 2001). Generally, induction and mentoring policies call for school-based support that may be delivered individually or in groups to beginning teachers to assist with their classroom teaching and socialization to school practices and policies. A school or local university, often in combination with schools, districts or other education agencies may administer an induction program. Therefore, mentors can be district/school professionals, university personnel, or both.

Table 2. Teacher education experiences referenced in STEM ACT research papers

Lead author	Pedagogy/pedagogical tools
Abell	Guided and independent internship models
Britton	Science-specific mentoring and field experiences
Demir	Inquiry-based experiences
Galosy	Mentoring, coaching, workshops, literacy strategies
Greenwood	Mentoring, field supervision
Mitchener	Action research
Sterling	Coursework, classroom coaching
Wang	Coursework, field experiences, inquiry-based instruction

Clift and Brody (2005) concluded that, in general, partnerships between universities and schools on professional development decreased the potential discrepancy between what beginning teachers learned during their formal education and got enacted through their practice in these beginning years. These types of partnerships and the nature of mentoring during this induction period was a major theme across many research papers presented at the STEM ACT conference. Given that some teacher preparation programs do not have formal student teaching experiences (e.g., teacher candidates hold full-time teaching positions while also attending teacher education programs), induction and mentoring practices often replace traditional notions of student teaching. Consequently, induction/mentoring support takes on heightened priority for these early-career science teachers.

However, similar to observations of alternative certification programs, induction and mentoring practices widely vary, both between and within programs. The beginning science teachers Galosy (2006) observed, for instance, had very different kinds of support available to them. For example, some had science-specific mentoring, coaching, and workshops; others had limited access to science-specific support. Further, Galosy found teachers who had context-specific assistance (e.g., matched to subject, grade-level, setting) tended to develop more ambitious goals for their students.

Britton's (2006) review of induction support emphasized science-specific content and pedagogical content knowledge. Britton's conference presentation highlighted the tendencies to oversimplify what such a mentoring approach entails and the complexities of putting it into practice. In general, he called attention to the need to balance general mentoring needs with subject-specific ones and attempted to demystify three common *oversimplifications* in studies of science-specific induction. These oversimplifications include:

1. Induction programs must only address general needs of first year teachers, or else they will not survive.
2. Credentialed science teachers and career-switchers from industry do not have any content needs.
3. First year teachers cannot cope with an induction program focused primarily on content.

Within this same vein, Galosy (2006) warns that while teacher educators often fear putting beginning teachers in a "sink or swim" situation, this fate can also occur when overwhelmed by too many competing support resources, as much as from a lack. Balancing support, then, also requires coordination between individuals and programs offering assistance; something Galosy found often did not happen in the district she studied.

Additional conference research papers also addressed mentoring practices. Greenwood et al. (2006) examined the types of interactions college supervisors had with new science teachers and noted the importance of matching interactions to individual teacher characteristics and needs. Koballa, Bradbury, Deaton & Glynn (2006) also considered teachers' needs by studying the kinds of mentoring beginning teachers prefer. Specifically, they explored whether the previous experiences of these teacher candidates and the immersion aspect of their teacher preparation would impact the type of mentoring beginning teachers preferred and needed. They found that there is no one accepted view of mentoring, and that new teachers and their mentors had at least three different conceptions of the mentoring relationship: mentoring as apprenticeship; mentoring as personal support; and mentoring as co-learning. They also found that prior life and professional experiences play an important role in the formation of conceptions of mentoring, and, therefore, also in the formation of the relationship that develops between mentor and mentee.

Looking more broadly at mentoring practices, Humphrey, Wechsler and Hough (2006) found effective programs "provide trained mentors who have the time and resources to plan lessons with candidates, share curricula, demonstrate lessons, and provide feedback after frequent classroom observations". Recommended structures that facilitate mentoring include partner pairings (Wang, 2006) and co-teaching (Tobin, 2006). Given the scarcity of inquiry-based pedagogy in most schools, continued research on methods like these where new teachers and mentors work out teaching practices together in the classroom, would benefit teacher education. Clearly, there is much to learn about how teacher expertise grows for both partners in the mentoring relationship, especially in terms of subject-specific knowledge and skills that are required for reform vision science teaching.

There are other contexts in which teacher learning occurs. The most common form is the inservice course or workshop, which for most part, have been shown to have little effect on teachers' practice (Bransford, Brown & Cocking, 1999). However, large-scale studies of science teacher professional development indicate that sustained, ongoing experiences (e.g., lesson study addressed below) hold more promise. Science teachers also have had the opportunity to participate in ongoing scientific research projects through programs such as the NSF's Research Experiences for Teachers. While there have been several studies done on science teachers' research experiences (Brown, Bolton, Chadwell & Melear, 2002; Feldman, Rogan-Klyve & Divoll, 2007; Westerlund, Schwartz, Lederman & Koke, 2001), there is still much to be learned about how and what teachers learn as a result of these experiences.

Finally, we turn to what may best be thought of as inquiry learning experiences for teachers such as lesson study and action research. While there has been some exploration of lesson study as a form of teacher education for math teachers (Curcio, 2002; Fernandez, 2002), there has been little research on its use by secondary science teachers. Researchers have attended more closely to science teachers' conducting action research. At the STEM ACT conference, Mitchener (2006) shared that after a first year of overwhelming challenges, second-year teachers introduced to action research were able to take advantage of this pedagogical tool in crafting a practice anchored in learning-based principles. Other research on action research by science teachers includes studies by Capobianco (2006), Feldman (1994, 1995, 1996), Feldman & Minstrell (2000), and Van Zee (1998). Roth (2007) reviews studies of action research in the most recent *Handbook of Research on Science Education* (Abell & Lederman, 2007). Additional inquiry into lesson study and action research with beginning science teachers that focused on teacher and student learning would enhance teacher educators' abilities to use these pedagogies strategically and effectively.

Similar to our remarks about the content of science teacher education, we see numerous pedagogical possibilities as well—varied mentoring/induction practices, workshops, research experiences, and inquiry-based opportunities to study classroom practice. We also acknowledge that this list is incomplete; for instance, we have not discussed technology as a tool for science teacher education. While policies treat induction and mentoring generically, STEM ACT conference participants (along with other science education researchers) take a more nuanced approach; delineating specific practices and examining whether, and how, teachers benefit from those practices. Again, the research agenda STEM ACT participants advocate is not about selecting one pedagogical approach over another, but keeping the focus on teacher learning and broadening implications to include student outcomes as well.

6. Recommendations

In the preceding sections of this paper, we drew on STEM ACT research presentations and discussions to consider the question: “What do we know and what more do we need to learn about science teacher education that takes into account the results of more than 30 years of research on science teaching and learning?” We noted the teacher beliefs, knowledge, skills, and practices needed to support contemporary visions of science education. Moreover, we pointed out the wide range of content and pedagogies researchers explore as they examine science teacher education that supports reform visions. However, we state the obvious when we say that translating research on science teaching and learning into a variety of science teacher education settings is arduous work. There are multiple strands necessary. We need insight into (1) what kinds of learning opportunities support diverse learners’ science engagement and understanding, (2) what science teachers need to learn in order to provide such opportunities for their students, and (3) what kinds of experiences teachers need to learn what they need. That is, if we want science teacher education to be research-based, then we need to have evidence that what and how we teach teachers benefits their students in meaningful ways.

While there have been ongoing research efforts in the three areas described above, there are also gaps, especially with regard to student learning. Moreover, these strands are often treated separately, rather than intertwined. In this section, we make recommendations for a research agenda that builds on existing research, keeps teacher and student learning central, and strengthens communication channels that support rigorous science teacher education research.

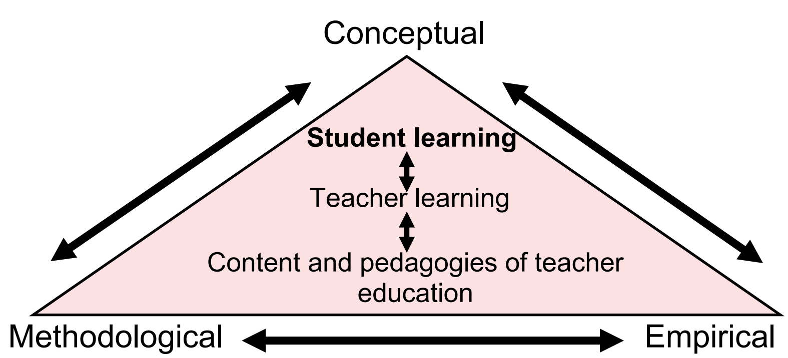

Figure 1. Research agenda for science teacher education

The work we have just described requires mutually reinforcing activity on three fronts – conceptual, methodological, and empirical (see Figure 1). We group our recommendations into these three broad categories, briefly describing each and including a few examples of some research questions generated during the STEM ACT research discussions.

One major conceptual issue that emerged from our discussions is the need for conceptual clarity (if not consensus) about what and how science teachers need to learn. We first noticed this with regard to alternative certification programs, but saw it in other places as well. Mentoring, inquiry and induction (just to name a few) are widely varied; researchers must be careful, for instance, about making broad claims about mentoring, without specifying the practices involved. Ongoing discussions about defining, and refining, research interests in useful ways for science teacher education would be a helpful step towards greater conceptual congruence.

Rigorous research not only requires conceptual clarity but methodological support as well. A research agenda focused on teacher and student learning requires robust tools for gauging change over time. Developing such measures demands substantial resources not available to many research teams. Investments in a pool of instruments to be shared across the science education research community regardless of program would facilitate cross-study comparisons. These shared measures would ideally include interview and classroom observation protocols, survey questionnaires, teacher assessments of content and pedagogical content knowledge, and student assessments.

The third focus for our recommendations relates to the need to develop empirical warrants for science teacher education practices with research that stretches across the teacher continuum and takes local contexts into account. For instance, there is an extensive line of research on students' science conceptions/ misconceptions/alternative conceptions. Several, more recent, studies of formative assessment examine how that information can assist teachers with their particular students' learning. We see here an example of an empirical chain that extends from science teacher education to student learning. However, this work means that as researchers, we must take a skeptical stance on what we hold dear. We cannot assume that our vision of science education reform "works" unless we have the evidence necessary to back it up.

We conclude our recommendations with a list of research questions proposed by STEM ACT research participants. This is not meant to be exhaustive; but to suggest potentially fruitful direction for ongoing science teacher education research.

7. Research Questions

- What science and in what form do science teachers need to know?
- How do we bridge traditional separations of preservice and inservice teacher education to create a professional continuum of science teacher education, which includes the induction phase?
- How do diverse teachers acquire the beliefs, knowledge and skills across a variety of educational settings and opportunities?
    - What *coursework* and *field experiences* lead to the development of knowledge and skills that help teachers, at various points in their professional development,

    bring reform visions into science classrooms (action research, institutional partnerships)?
  - What roles can *teacher collaboratives*—groups of science teachers learning together—play in the continued education and production of professional knowledge? (e.g. mentoring, communities of practice)
- Who are the science teacher candidates? How do the following relate to candidates learning to be science teachers?
  - Age, race, ethnicity, gender
  - Prior experience
  - Science knowledge
  - Context and societal influences
- How do we transform *credentialing* programs into research-informed *educational* programs?

Conclusion

Once the distinction between alternative and traditional programs is abandoned, we see that teacher education is a mix of coursework, fieldwork, and on-the-job learning experiences, each of which can vary in time and intensity. In this white paper we argue that what is needed, instead of comparisons of traditional and alternative certification programs, are studies that identify and examine how teacher learning occurs in those experiences; what is learned; and how teachers put that learning to use.

The research agenda outlined requires studies that cross the continuum of teacher learning experiences and that follow teachers longitudinally through their careers. In addition, studies are needed that examine the ways in which these experiences can be shaped to be part of teacher education programs that respond to the constraints and affordances of local situations. Research is also needed on subject matter and level specific teacher education and teacher learning that takes into account subject matter knowledge, pedagogical content knowledge, and content knowledge for teaching.

The research described is urgently needed to support science education reform. Amidst demands to improve science teaching, science teacher education is an essential reform tool. Consequently, our research in science teacher education needs to be as ambitious as our vision of science education reform. We cannot realize our potential without substantial investment in systematic conceptual, methodological, and empirical work.

References

AAAS. (1993). *Benchmarks for science literacy*. NY: Oxford University Press.

Abd-El-Khalick, F. (2005). Modeling Science Classrooms after Scientific Laboratories: Sketching Some Affordances and Constraints Drawn from Examining Underlying Assumptions. *NSF Inquiry Conference Proceedings*. Retrieved from http://www.ruf.rice./edu/~grandy/NSFConSched.html.

Abell, S., Arbaugh, F., Chval, K., Friedricshen, P., Lannin, J., & Volkmann, M. (2006, May 5-7). *Research on alternative certification: Where do we go from here?* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Abell, S., & Lederman, N. G. (Eds.). (2007). *Handbook of research on science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Allen, M. (2003). *Eight Questions on Teacher Preparation: What Does the Research Say? A Summary of the Findings*. Denver, CO: Education Commission of the States.

American Federation of Teachers. (2001). *Beginning teacher induction: The essential bridge* (No. Educational Issues Policy Brief, 13). Washinton DC: American Federation of Teachers.

Atkin, J. M., & Coffey, J. E. (Eds.). (2003). *Everyday assessment in the science classroom*. Arlington, VA: National Science Teachers Association.

Bandura, A. (2001). *Guide for Constructing Self-Efficacy Scales (Revised)*, Available from Frank Pajares, Emory University, 2001

Black, P., Harrison, C., & Lee, C. (2004). Working inside the black box: Assessment for learning in the classroom. *Phi Delta Kappan, 86*(1), 8-21.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (Eds.). (1999). *How people learn: brain, mind, experience, and school*. Washington, DC: National Academy Press.

Brickhouse, N. W., Lowery, P., & Schultz, K. (2000). What kind of girl does science? The construction of school science identities. *Journal of research in science teaching, 37*(5), 441-458.

Britton, E. (2006, May 5-7). *Subject-specific induction for beginning science teachers.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Brown, S. L., Bolton, K., Chadwell, N., & Melear, C. T. (2002, January 10-13, 2002). *Preservice Secondary Science Teacher Apprenticeship Experience with Scientists.* Paper presented at the Annual International Conference of the Association for the Education of Teachers in Science, Charlotte, NC.

Bruce E. H., Longnion, B., & Sconzo, G. (2006, May 5-7). *Bridging communities: The roles and impact of STEM faculty in building a professional learning community supporting intern teachers seeking alternative certification*. Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Capobianco, B. M. (2006). Science teachers' attempts at integrating feminist pedagogy through collaborative action research. *Journal of research in science teaching, 44*(1), 1-32.

Clement, J. (1982). Students' Preconceptions in Introductory Mechanics. *American Journal of Physics, 50*(1), 66-71.

Clift, R. T., & Brady, P. (2005). Research on methods courses and field experiences. In M. Cochran-Smith & K. M. Zeichner (Eds.), *Studying teacher education: The report of the AERA Panel on Research and Teacher Education* (pp. 309-424). Mahwah, NJ: Lawrence Erlbaum Associates.

Crawford, T., & Kelly, G. J. (1997). An Ethnographic Investigation of the Discourse Processes of School Science. *Science Education, 81*(5), 533-559.

Curcio, F. R. (2002). *A user's guide to Japanese lesson study: Ideas for improving mathematics teaching*. Reston, VA: National Council of Teachers of Mathematics.

Darling-Hammond, L. (1992). Teaching and knowledge: Policy issues posed by alternate certification of teachers. *Peabody Journal of Education, 67*(3), 123-154.

Darling-Hammond, L., & Youngs, P. (2002). Defining "Highly Qualified Teachers": What does "Scientifically-based research" actually tell us? *Educational Researcher, 31*(9), 13-25.

Demir, A. (2006, May 5-7). *Alternatively certified beginning science teachers' practice of inquiry-based instruction*. Poster presentation delivered at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Driver, R., Asoko, H., Leach, J., Mortimer, E., & Scott, P. (1994). Constructing scientific knowledge in the classroom. *Educational researcher, 23*(7), 5-12.

Driver, R., Guesne, F., & Tiberghien, A. (1985). *Children's Ideas in Science.* Open University Press.

EOTP. (2002). *A Quality Teacher in Every Classroom: Improving Teacher Quality and Enhancing the Profession*. Washington, DC: Executive Office of the President.

Feistritzer, C. E. (1998). Alternative teacher certification: An overview. Retrieved August 28, 2005, from http://www.ncei.com/Alt-Teacher-Cert.htm. Retrieved August 26, 2006, from http://www.ncei.com/Alt-Teacher-Cert.htm

Feldman, A. (1994). Erzberger's dilemma: Validity in action research and science teachers' need to know. *Science education, 78*(1), 83-101.

Feldman, A. (1995). The Institutionalization of Action Research: The California "100 Schools". In S. Noffke & R. Stevenson (Eds.), *Educational Action Research: Becoming Practically Critical* (pp. 180-196). NY: Teachers College Press.

Feldman, A. (1996). Enhancing the practice of physics teachers: Mechanisms for the generation and sharing of knowledge and understanding in collaborative action research. *Journal of Research in Science Teaching, 33*(5), 513-540.

Feldman, A. (2002). Multiple perspectives for the study of teaching: Knowledge, reason, social context and being. *Journal of research in science teaching, 39*(10), 1032-1055.

Feldman, A., & Capobianco, B. (2003, April 21-25). *Real-Time Formative Assessment: A Study of Teachers' Use of an Electronic Response System to Facilitate Serious Discussions about Physics Concepts.* Paper presented at the Annual Meeting of the American Educational Research Association, Chicago, IL.

Feldman, A., & Minstrell, J. (2000). Action research as a research methodology for the study of the teaching and learning of science. In E. Kelly & R. Lesh (Eds.), *Handbook of Research Design in Mathematics and Science Education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Feldman, A., Rogan-Klyve, A. M., & Divoll, K. A. (2007, April 15-18). *Translating Experience Into Practice: The Effect of Legitimate Peripheral Participation in Authentic Science on Classroom Practice.* Paper presented at the Annual Meeting of the National Association for Research in Science Teaching, New Orleans, LA.

Fenstermacher, G. (1990). The place of alternative certification in the education of teachers. *Peabody Journal of Education, 67*(3), 155-185.

Fernandez, C. (2002). Learning from the Japanese approaches to professional development: The case of lesson study. *Journal of teacher education, 53*(5), 393-405.

Galosy, J. (2006, May 5-7). *A case study of an urban district: resources and intern science teacher's curriculum goals.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Gamoran, A., Anderson, C. W., Quiroz, P. A., Secada, W. G., Williams, T., & Ashmann, S. (2003). *Transforming teaching in math and science: How schools and districts can support change*. New York: Teachers College Press.

Glickman, C. D., & Tamashiro, R. T. (1982). A Comparison of First-Year, Fifth-Year, and Former Teachers on Efficacy, Ego Development, and Problem Solving, *Psychology in Schools*, 19, *4*, 558-562

Greenwood, A., Shea, K., & Hickey, C. (2006, May 5-7). *The role of mentors and college supervisors in providing instructional support to alternative route novice STEM teachers: Two studies.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Hill, H. C., & Ball, D. L. (2004). Learning mathematics for teaching: Results from California's Mathematics Professional Development Institutes. *Journal for research in mathematics education, 35*(5), 330-351.

Humphrey, D. C., Wechsler, M. E., & Hough, H. J. (2006, May 5-7). *Characteristics of effective alternative teacher certification programs.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Kennedy, M. (1998, April). *The relevance of content in inservice teacher education*. Paper presented at the annual meeting of the American Educational Research Association, San Diego, CA.

Kennedy, M. (1999). The problem of evidence in teacher education. In R. Roth (Ed.), *The role of the university in the preparation of teachers* (pp. 87-107). Philadelphia: Falmer.

Kern, A. L., Roehrig, G. H., & Luft, J. A. (2006, May 5-7). *An examination of a science teacher intern program.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Koballa, T. R. Jr., Bradbury, L. U., Deaton, C. M., & Glynn, S. M. (2006, May 5-7). *Conceptions of mentoring and mentoring practice in alternative secondary science teacher education.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Layman, J. W. (1996). *Inquiry and learning: Realizing science standards in the classroom*. New York: The College Board.

Lederman, N. G. (1992). Students' and teachers' conceptions of the nature of science: A review of the research. *Journal of Research in Science Teaching*, 29(*4*), 331-359.

Lederman, N. G., & Gess-Newsom, J. (1999). Reconceptualizing secondary science teacher education. In J. Gess-Newsome & N. G. Lederman (Eds.), *PCK and science education* (pp. 199-213). Hingham, MA: Kluwer Academic Publishers.

Lederman, N. G., Schwartz, R. S., Abd-El-Khalick, F., & Bell, R. L. (2001). Pre-service teachers' understanding and teaching of the nature of science: An intervention study. *Canadian Journal of Science, Mathematics, and Technology Education, 1,* 135-160.

Lee, E., Puthoff, E., Luft, J. A., & Roehrig, G. H. (2005). *Capturing the Pedagogical Content Knowledge of beginning secondary science teachers: Year 1*. National Association for Research in Science Teaching.

Lee, M. H., Olson, T. A., & Scribner, J. P. (2006, May 5-7). *Exploring alternative teacher certification policy and practice through an examination of novice science teachers.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Lortie, D. (1975). *Schoolteacher. A Sociological Study* (Second ed.). Chicago: University of Chicago Press.

Lynch, S. J. (2000). *Equity and science education reform*. Mahwah, New Jersey: Lawrence Erlbaum Associates.

Mintes, J. J., Wandersee, J. H., & Novak, J. D. (Eds.). (2000). *Assessing science understanding: A human constructivist view*. San Diego: Academic Press.

Mitchener, *C.* (2006, May 5-7). *The importance of action research in the second year: learning to teach science through an alternative route.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Munby, H. (1983). Thirty studies involving the Scientific Attitude Inventory: What confidence can we have in this instrument? *Journal of Research in Science Teaching, 20*, 141-162.

National Research Council. (1996). *National science education standards*. Washington, DC: National Association Press.

National Research Council. (2000). *Inquiry and the National Science Education Standards* Washington, DC: National Association Press.

National Research Council. (2005). How students learn: Science in the classroom. Committee on How People learn, A Targeted Report for Teachers, M.S. Donovan and J.D. Bransford, Editors. Divisions of Behavioral and Social Sciences and Education. Washington, D.C.: The National Academies Press

Posner, G., Strike, K., Hewson, P., & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Science education, 66*(2), 211-227.

Rodriguez, A. J. (1998). Strategies for Counterresistance: Toward Sociotransformative Constructivism and Learning To Teach Science for Diversity and for Understanding. *Journal of Research in Science Teaching, 35*(6), 589-622.

Rosebery, A., B. Warren and F. Conant (1992). Appropriating scientific discourse: Findings from language minority classrooms. *The Journal of the Learning Sciences* 2: 61-94.

Roth, K. J. (2007). Science teachers as researchers. In S. Abell & N. G. Lederman (Eds.), *Handbook of research on science education*. Mahwah, NJ: Lawrence Erlbaum Associates.

Schwab, J. (1978). Education and the structure of the disciplines. In I. Westbury & N. Wilkof (Eds.), *Science, curriculum, and liberal education: Selected essays [of Joseph J. Schwab]* (pp. 229-272). Chicago: University of Chicago Press.

Scribner, J. P., Bickford, A., & Heinen, E. B. (2004, April). *Alternative teacher certification: A program theory analysis.* Paper presented at the Annual Meeting of the American Educational Research Association, San Diego, CA.

Solomon, J., Duveen, J., & Scot, L. (1992). Teaching about the nature of science through inquiry: Action research in the classroom. *Journal of Research in Science Teaching*, 29(*4*), 409-421.

Stengel, B. S. (1997). “Academic discipline” and “school subject”: contestable curricular concepts. *Journal of curriculum studies, 29*(5), 585-602.

Tobin, K. (2006). Learning to Teach Through Coteaching and Cogenerative Dialogue *Teaching Education, 17*(2), 133-142.

USDOE. (2002). *Meeting the highly qualified teacher challenge: The Secretary’s annual report on teacher quality*. Washington, DC: US Department of Education.

Van Zee, E. H. (1998). Fostering elementary teachers’ research on their science teaching practices. *Journal of Teacher Education, 49*(4), 245-254.

Wang, H. (2006, May 5-7). *Unfolding issues of secondary science teachers’ knowledge for an alternative certification program.* Paper presented at the Science, Technology, Engineering and Math - Alternative Certification for Teachers Conference, Arlington, VA.

Westerlund, J. F., Schwartz, R. S., Lederman, N. G., & Koke, J. R. (2001). *Teachers learning about the nature of science in authentic science contexts: Models of inquiry and* *reflection.* Paper presented at the National Association for Research in Science Teaching, St. Louis, MO.

Wilson, S. M., & Berne, J. (1999). Teacher learning and the acquisition of professional knowledge: An examination of research on contemporary professional development. In A. Iran-Nejad & P. D. Pearson (Eds.), *Review of Research in Education* (pp. 173-209). Washington, D.C.: American Educational Research Association.

Yager, R. E., & Tamir, P. (1993). STS Approach: Reasons, Intentions, Accomplishments, and Outcomes. *Science Education, 77*(6), 637-658.

Zeichner, K. M., & Conklin, H. G. (2005). Teacher education programs. In M. Cochran-Smith & K. M. Zeichner (Eds.), *Studying teacher education: The report of the AERA panel on research and teacher education* (pp. 645-735). Mahwah, NJ: Lawrence Erlbaum Associates.

Appendix: Policy Presentations

The practice and research presentations are listed in the respective reports. Abstracts and papers for most of these presentations are available at www.stemtec.org/act.

Keynote: *Ken Zeichner, University of Wisconsin-Madison*
Title: WHAT DO WE KNOW ABOUT THE CHARACTERISTICS OF GOOD TEACHER EDUCATION PROGRAMS?

Emily Feistritzer, National Center for Alternative Certification

Antoinette Mitchell, National Council for Accreditation of Teacher Education
Title: THE NATIONAL COUNCIL FOR ACCREDITATION OF TEACHER EDUCATION AND ALTERNATIVE PROGRAMS: AN UNEXPECTED CONVERGENCE

Cassandra Guarino, RAND
Title: TEACHER RECRUITMENT AND RETENTION: A REVIEW OF THE RECENT EMPIRICAL LITERATURE

Frances Lawrenz, James J. Appleton, Marjorie Bullitt Bequette, Ann Ooms and Deena Wassenberg, University of Minnesota
Title: TRIPARTITE SYNTHESIS OF RESEARCH AND DATA ON RECRUITMENT AND RETENTION OF STEM TEACHERS

Hamilton Lankford, University at Albany - SUNY
Title: HOW CHANGES IN ENTRY REQUIREMENTS ALTER THE TEACHER WORKFORCE AND AFFECT STUDENT ACHIEVEMENT

Elaine Chin, California Polytechnic State University
Title: CHARACTERISTICS OF SCIENCE AND MATH TEACHERS PREPARED THROUGH ALTERNATIVE CERTIFICATION PROGRAMS IN CALIFORNIA

Allan G. Harrison, Central Queensland University, Australia
Title: RECRUITING AND EDUCATING SCIENCE TEACHERS IN AUSTRALIA

Jesus Vázquez-Abad and Jean-Pierre Charland, Université de Montréal, Canada
Title: PREPARING SCIENCE TEACHERS FOR QUÉBEC'S HIGH-SCHOOL AT UNIVERSITÉ DE MONTRÉAL

Pamela Esprivalo Harrell, University of North Texas
Jennifer K. Jackson, Western Governors University
Title: TEACHER KNOWLEDGE MYTHS: AN EXAMINATION OF THE RELATIONSHIP BETWEEN THE TEXAS EXAMINATIONS OF EDUCATOR STANDARDS AND FORMAL CONTENT AREA COURSEWORK, GRADE POINT AVERAGE AND AGE OF COURSEWORK

Appendix: Practice Presentations

The research and policy presentations are listed in the respective reports. Abstracts and papers for most of these presentations are available at www.stemtec.org/act.

Keynote: *Ken Zeichner, University of Wisconsin-Madison*
Title: WHAT DO WE KNOW ABOUT THE CHARACTERISTICS OF GOOD TEACHER EDUCATION PROGRAMS?

Michael Marder, University of Texas at Austin
Title: UTEACH

Dan MacIsaac, (SUNY) Buffalo State College
Title: THE SUNY-BUFFALO STATE COLLEGE ALTERNATIVE CERTIFICATION PROGRAM FOR HS PHYSICS TEACHERS

Bruce E. Herbert, Texas A&M University
Bonnie Longnion, North Harris Montgomery Community College District
Guy Sconzo, Humble Independent School District
Title: BRIDGING COMMUNITIES: THE ROLES AND IMPACT OF STEM FACULTY IN BUILDING A PROFESSIONAL LEARNING COMMUNITY SUPPORTING INTERN TEACHERS SEEKING ALTERNATIVE CERTIFICATION

Posters

Barbara Austin, New Mexico Institute of Mining and Technology
Title: ALTERNATIVE LICENSURE AT NEW MEXICO TECH

Craig A. Berg, University of Wisconsin-Milwaukee
Michael P. Clough, Iowa State University
Title: "ALTERNATIVE" STILL REQUIRES REACHING YOUR DESTINATION: A VISUAL FRAMEWORK FOR TEACHER DECISION-MAKING

Kathleen D. Gagne, University of Massachusetts
Title: 180 Days IN SPRINGFIELD: CULTIVATING SCHOOL-UNIVERSITY PARTNERSHIPS TO ENHANCE URBAN TEACHING

John R. Gantz, Troops to Teachers
Title: TROOPS TO TEACHERS – A SOURCE OF QUALITY MATH AND SCIENCE TEACHERS

Judith L. Hayes, Wichita State University
Title: AN INQUIRY INTO BEST PRACTICES FOR PREPARING AND RETAINING ALTERNATIVE CERTIFICATION CANDIDATES IN THE SCIENCES

Grant L. Holley and John Penick, NC State University
Title: DO YOU HEAR WHAT I HEAR? BUILDING A MODEL BASED ON RESEARCH AND EXPERIENCE-NC STATE UNIVERSITY

Richard Iuli, Robin Voetterl and Tina Wagle, SUNY Empire State College
Title: SUNY EMPIRE STATE COLLEGE'S MAT PROGRAM: AN ALTERNATIVE ALTERNATIVE STEM TEACHER PREPARATION PATHWAY

Bobby Jeanpierre, University of Central Florida
Title: WHAT DOES IT TAKE TO BECOME A SUCCESSFUL URBAN MIDDLE-LEVEL SCIENCE TEACHER

Vicki H. Metzgar and Alene H. Harris, Vanderbilt University
Title: HELPING ALTERNATIVELY CERTIFIED SCIENCE TEACHERS MAXIMIZE THEIR TEACHING POTENTIAL THROUGH RESEARCH-BASED CLASSROOM MANAGEMENT STRATEGIES IN SCIENCE LABS

Chris Olszewski, SUNY-Buffalo State College
Title: THE ROAD LESS TRAVELLED: A PH.D. PHYSICIST BECOMES A HS PHYSICS TEACHER

William Veal, College of Charleston
Dorothy Mebane, University of North Carolina
Keri Randoph, Northwood High School,Chatham County, NC.
Title: ONLINE SCIENCE METHODS FOR LATERAL ENTRY SCIENCE TEACHERS

Appendix: Research Presentations

The practice and policy presentations are listed in the respective reports. Abstracts and papers for most of these presentations are available at www.stemtec.org/act.

Keynote: *Ken Zeichner, University of Wisconsin-Madison*
Title: WHAT DO WE KNOW ABOUT THE CHARACTERISTICS OF GOOD TEACHER EDUCATION PROGRAMS?

Anita Greenwood, Kathy Shea & Charmaine Hickey, *University of Massachusetts Lowell*
Title: THE ROLE OF MENTORS AND COLLEGE SUPERVISORS IN PROVIDING INSTRUCTIONAL SUPPORT TO ALTERNATIVE ROUTE NOVICE STEM TEACHERS: TWO STUDIES

Carole Mitchener, University of Illinois at Chicago
Title: THE IMPORTANCE OF ACTION RESEARCH IN THE SECOND YEAR: LEARNING TO TEACH SCIENCE THROUGH AN ALTERNATIVE ROUTE

Jodie A. Galosy, Michigan State University
Title: A CASE STUDY OF AN URBAN DISTRICT: RESOURCES AND INTERN SCIENCE TEACHER'S CURRICULUM GOALS

Edward Britton, WestEd
Title: SUBJECT-SPECIFIC INDUCTION FOR BEGINNING SCIENCE TEACHERS

Daniel C. Humphrey, Marjorie E. Wechsler and Heather J. Hough, SRI International
Title: CHARACTERISTICS OF EFFECTIVE ALTERNATIVE TEACHER CERTIFICATION PROGRAMS

Joan Prival, National Science Foundation
Title: ALTERNATIVE CERTIFICATION MODELS: NSF FUNDING PPORTUNITIES FOR RESEARCH AND DEVELOPMENT

HsingChi A. Wang, University of Calgary, Canada
Title: UNFOLDING ISSUES OF SECONDARY SCIENCE TEACHER'S NOWLEDGE FOR AN ALTERNATIVE CERTIFICATION PROGRAM

Thomas R. Koballa Jr., University of Georgia
Leslie Upson Bradbury, Appalachian State University
Cynthia Minchew Deaton, University of Georgia
Shawn M. Glynn, University of Georgia
Title: CONCEPTIONS OF MENTORING AND MENTORING PRACTICE IN ALTERNATIVE SECONDARY SCIENCE TEACHER EDUCATION

Sandra Abell, Fran Arbaugh, Kathryn Chval, Patricia Friedricshen, John Lannin and Mark Volkmann. University of Missouri-Columbia
Title: RESEARCH ON ALTERNATIVE CERTIFICATION: WHERE DO WE GO FROM HERE?

Michele H. Lee, Travis A. Olson and Jay P. Scribner, University of Missouri – Columbia
Title: EXPLORING ALTERNATIVE TEACHER CERTIFICATION POLICY AND PRACTICE THROUGH AN EXAMINATION OF NOVICE SCIENCE TEACHERS

Posters

Abdulkadir Demir, University of Missouri, Columbia
Title: ALTERNATIVELY CERTIFIED BEGINNING SCIENCE TEACHERS' PRACTICE OF INQUIRY-BASED INSTRUCTION

Anne L. Kern and Gillian H. Roehrig, University of Minnesota
Julie A. Luft, Arizona State University
Title: EXAMINATION OF A SCIENCE TEACHER INTERN PROGRAM

Judith R. McDonald, Charlotte Mecklenburg Schools, NC
Title: A STUDY OF SECOND CAREER LATERAL ENTRY SCIENCE TEACHERS: THE RELATIONSHIP BETWEEN THE NATURE OF SCIENCE AND THEIR CLASSROOM PRACTICES

Donna R. Sterling, Wendy M. Frazier, Mollianne G. Logerwell and Anastasia Kitsantas
George Mason University
Title: NEW SCIENCE TEACHERS' SUPPORT NETWORK: HOW CAN WE HELP PROVISIONALLY LICENSED TEACHERS SUCCEED?