EFFECTIVE STEM TEACHER PREPARATION, INDUCTION, AND PROFESSIONAL DEVELOPMENT

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April 2011

Offering a high quality education to all U.S. students and building the educational system to support their teachers are topics of much concern and investment, passion and critique. Teacher quality is at the core of those ardent discussions, with calls for the reform and critical review of teacher preparation, induction, and professional development programs. There is no lack of activity in response to these calls. There are over 1200 teacher education programs at universities, another 130 “alternative routes,” and at least as many induction programs. Every one of the over-15,000 school districts in the U.S. has multiple professional development programs sponsored by school districts, foundations, federal grants, universities, informal institutions, and other agencies.

WHAT DO WE KNOW ABOUT EFFECTIVE STEM TEACHER PREPARATION, INDUCTION, AND PROFESSIONAL DEVELOPMENT?

The charge was to review and summarize literature that would answer the following questions about the effects of high quality STEM teacher preparation, induction, and development and the factors that moderate the impact of such programs:

- What features have research shown are key to effective STEM teacher preparation, induction, and development? What are the models or key characteristics of teacher preparation, induction, and development that produce quality STEM teachers?
- What is the current state of STEM teacher preparation, induction, and development? Why is there such a range in the quality of these programs/activities? What are the issues that make improving the system difficult?
- What mechanisms or support structures moderate the impact of quality teacher preparation, induction, and development?

Considerable energy has gone into summarizing the literature on professional development and teacher preparation (e.g., Cochran-Smith & Zeichner, 2005; National Research Council (NRC), 2010; Wilson, Floden, & Ferrini-Mundy, 2001). My approach to this task was to review those reviews, and then was to examine the literature that has emerged since 2000, focusing specifically on research conducted on STEM teachers. I limited the search to the most highly respected generalist journals (e.g., *American Journal of Education, Teachers College Record, Educational Researcher, Harvard Educational Review, JREE*, and the *American Educational Research Journal*), the leading STEM education journals (e.g., *Science Education, the Journal of Research in Science Teaching, JRME, Journal of Research on Technology in Education, Educational*

Technology), and the leading teacher education journals (*Teaching and Teacher Education, Journal of Teacher Education*). Given the time frame for the paper, I do not comprehensively summarize that literature here, although it will be comprehensively summarized in a publishable literature review that will come out of this project. Here I present major points that are relevant to each question, illustrating the points with relevant research.

FEATURES OF EFFECTIVE STEM TEACHER PREPARATION, INDUCTION, AND PROFESSIONAL DEVELOPMENT

What features have research shown are key to effective STEM teacher preparation, induction, and development? What are the models or key characteristics of teacher preparation, induction, and development that produce quality STEM teachers?

Before summarizing the literature, several points are relevant. First, "effective" STEM teacher development is implicitly or explicitly anchored in a normative view of effective STEM education. That is, practitioners and scholars are interested in teacher support systems that lead teachers to teach in the ways that research and policy suggests they "should" teach. That is, visions of good STEM teaching are tangled up in all scholarship about good teacher preparation, induction, and professional development. Thus, when reading the research, one must consider the tacit or explicit assumptions about good teaching. Because much STEM teaching does not align with normative views of how teachers "should" teach, much of the literature aims to shed light on how to prepare teachers (at all stages in their careers) to teach in what many authors call "reform-oriented" ways. Very little of the research on teacher development anchors the research in student outcomes like achievement or engagement. Rather, the question is often: Did this program prepare people to teach in "reform-oriented" ways?

Second, there is a great deal of research that uses professional development, induction, or teacher preparation as *platforms* for answering. For instance, there is considerable interest in the issue of teacher identity in science teacher preparation. The logic goes something like this: If teachers are to become good, they need to identify themselves with science, and think of themselves as confident knowers and doers of science. This logic might lead a researcher to investigate the identities of participants in a teacher preparation program that is designed to help enhance teachers' identities. The results typically focus on claims about teacher identity more than on claims about high quality teacher preparation. In this sense, teacher development is entailed in the research, but the research is not necessarily designed or reported to focus on what makes a teacher development program effective. For the purposes of this review, I focused solely on research that had has its primary focus questions concerning program/course effectiveness.

STEM TEACHER PREPARATION

In the past 20 years, multiple policy, professional association, and expert panel documents offer guidance about the ranges of knowledge and skills teachers need and, therefore, the learning opportunities new teachers need to be offered in their initial preparation (e.g., Darling Hammond & Bransford, 2005; Levine, 2006; NCATE, 2010; NRC, 2000). However, three major reviews of research on teacher preparation in general have all drawn the same unsatisfying conclusion that we know very little about effective teacher preparation based on empirical research (Cochran-Smith & Zeichner, 2005; NRC, 2009; Wilson, Floden, & Ferrini-Mundy, 2001). The NRC Teacher Preparation Panel (2010) concluded, for example, that "The relevant body of work on what instructional opportunities are most valuable for mathematics teachers is growing but thus far is largely descriptive, and it has not identified causal relationships between specific aspects of preparation programs and measures of prospective teachers' subsequent effectiveness" (p. 117). The report drew similar conclusions about the preparation of science teachers.

But saying that we know very little is both frustrating and unhelpful in some ways, since many programs have worked hard on the problem of teacher preparation and we need to launch future work on the wisdom accumulated by effective programs. So what are some features of effective programs? Based on the research of the Pathways Project in New York City, the National Academy of Education (2010) argued that these features are associated with more effective teacher preparation:

- More courses required for entry or exit in their chosen content area (i.e., math or reading);
- A required capstone project (for example a portfolio of work done in classrooms with students or a research paper);
- Careful oversight of the student teaching experiences;
- A focus on providing candidates with practical coursework to learn specific practices;
- The amount of opportunity for candidates to learn about the local district curriculum; and,
- Having student teaching experience, and the congruence between the context of student teaching in terms of grade level and subject area and later teaching assignment. (p. 3)

The content preparation of new teachers continues to be a central focus of research on teacher preparation. For instance, Lee and Krapfl (2002) conducted semi-structured interviews with nine graduates of a teacher education program that included a Basic Science Minor that had been specifically designed to improve prospective elementary teachers' knowledge and familiarity with science concepts, processes, models, and investigations. The minor consisted of seven courses taken across four years that involved: activity based life science, activity based physical science, investigations in life science, earth science, and physical science, and integrated activities in mathematics and science, and experiences in elementary school science.

The researchers found that the Basic Science Minor graduates professed a preference for "hands-on" teaching that emphasized student engagement over a text driven approach to science teaching. Several elementary teachers who were interviewed felt that they left the program with more science content knowledge and confidence in their ability to teach science than their fellow teachers from other programs. The graduates who had taught middle school reported that they did not feel they had acquired sufficient content knowledge. However, graduates did not all report being able to teach in ways they learned to in the program: time, lack of materials, and management issues were all reported as obstacles to teaching a more hands-on approach to science.

Tatto and Senk (2011) report on a major cross-national study of teacher education, the IEA Teacher Education and Development Study in Mathematics (TEDS-M) that documented the practices and policies of 17 countries in the mathematical preparation of teachers. In particular, they report on the study's results concerning future teachers' opportunities for learning school and tertiary mathematics and the links between OTL and teachers' mathematics content knowledge (MCK).

TEDS-M surveyed 15,163 future primary teachers, over 9389 future secondary teachers, and 4837 teacher educators. Questionnaires included questions about opportunities to learn; beliefs about mathematics, teaching, and learning, mathematics content knowledge (MCK), and mathematics pedagogical content knowledge (MPCK). Elementary teachers, across countries and programs, report high coverage of numbers and measurement; but the coverage of geometry varied considerably. "In general," the authors report, "as the education of primary teachers shifts toward the higher grades and becomes more specialized, an emphasis on the areas of functions, data, calculus, and structure becomes more prominent" (p. 127). For secondary teachers, there was high coverage of certain topics, including measurement, number, and geometry across programs and across countries. But there were noticeable differences for other topics, including probability, functions, calculus, and structures (p. 127). The researchers found that future elementary and secondary school teachers in high-achieving countries had more opportunities to learn tertiary level mathematics (geometry, continuity and functions) and school-level mathematics (functions, calculus, probability and statistics, and structure) than elementary teachers in other countries.

Reporting out on the same study, Blomeke, Suhl, and Kaiser (2011) examined the relationship between future teachers' mean achievement on a test of their MCK and MPCK and their background characteristics, including their gender, language, and their choices of teacher education programs they attended. Overall, future elementary school teachers in Taiwan had the best scores in the assessments of their MCK (500 points above the international mean); U.S. elementary school teachers were slightly above the international mean, and roughly equivalent to teachers in Germany and Norway. In terms of MPCK, elementary U.S. future teachers were significantly higher than the international mean, and approximately the same as Norway. Only two countries had higher means on MPCK (Singapore and Taiwan). Ten countries showed significant differences in MCK between men and women (in favor of males); only four countries showed significant differences in MPCK. In the U.S., German, and Thailand, there were significant differences in MCK and MPCK for teachers whose first language aligned with the language of instruction. All other countries appear to be better at avoiding such differential language effects (p. 162). "General ability seemed to be an important predictor of achievement in teacher education" (p. 166), the authors conclude. The higher the future teachers reported their general achievement, the higher their MCK and MPCK scores.

The researchers suggest that the U.S. elementary teacher preparation programs might want to increase opportunities to learn mathematics content knowledge and to be more selective in terms of bringing in students with higher general ability. This conclusion resonates with the NRC Panel's (2010) argument that one important dimension of teacher preparation programs to do more research on is program selectivity.

The lack of a core curriculum for teacher preparation has made university-based programs vulnerable to both criticism and competition; it is perhaps the field's Achilles' heel. In response, some teacher education researchers have begun focusing on core practices, and that field based work in teacher preparation needs to be focused on progressively more focused and developed work on developing those practices (Ball & Forzani, 2009; Franke & Chan, 2007; Grossman, Compton, Igra, Ronfeldt, Shahan, & Williamson, 2009; Grossman, Hammerness, & McDonald, 2009; Hatch & Grossman, 2009; Lampert & Graziani, 2009; NAE, 2010). Windschitl, et al. (2010) nominate the following criteria for such practices. They:

- are used frequently when teaching
- help to improve the learning and achievement of *all* students
- support student work that is central to the discipline of the subject matter
- apply to different approaches in teaching the subject matter and to different topics in the subject matter
- are conceptually accessible to learners of teaching
- can be articulated and taught
- can be practiced by beginners in their university and field-based settings
- can be revisited in increasingly sophisticated and integrated acts of teaching
- should be few in number to reflect priorities of equitable and effective teaching, and to allow significant time for novices to develop beginning instantiations of each of these practices.
- should play a recognizable role in a larger coherent system of instruction which explicitly supports student learning goals.

So, for example, the authors suggest that teaching model-based inquiry in science requires that novice teachers master four core practices: constructing the big idea, eliciting students' ideas to adapt instruction, (3) helping students make sense of material activity, and (4) pressing students for evidence-based explanation (Windschitl et al., 2010). In mathematics, a core practice might involve leading a discussion of a mathematical solution proposed by a student.

Teacher educators in mathematics and science are currently exploring the possibility of organizing teacher preparation around the mastery of such practices. Ball and Forzani (2009) argue that this means moving away from an orientation that asks, "What do teachers need to know?" and toward one that asks, "What do they need to do?" This entails identifying the core practices, unpacking – or as Grossman and her colleagues argue “decomposing” them, and creating settings – ranging from virtual to actual – in which new teachers would gradually learn to master those practices (Lampert, 2006; Ball & Forzani, 2009). The National Academy of Education (2010) recommended that the federal government invest in more research to assess the viability of this approach to the improvement of teacher preparation.

In sum, there is considerable guidance and opinion about what teachers should learn in early preparation; less is known empirically. There is also considerable skepticism about the effects of “traditional” teacher preparation, that skepticism – combined with significant investment in “alternative” programs has led to the creation of a new teacher preparation system which includes a much broader array of models, platforms, and “vendors” of teacher preparation. This includes, but is not limited to university-based programs like UTeach, Teach for America, and urban residencies. These “new” programs are quickly picked up by some as innovations and seen as “good” largely due to the fact that they are different; subsequently, there is a press to replicate them nationwide. Unfortunately, very little empirical evidence is gathered to support the assumption that they are effective, nor is there a data collection system in place and research agenda that allows us to learn which of these programs is effective. Complicating things further, the lack of good metrics for making decisions about program effectiveness still hampers our ability to learn from this considerable experimentation (NAE, 2010; Wilson, Floden, & Ferrini-Mundy, 2001)

STEM INDUCTION PROGRAMS

Currently, more than three-fourths of beginning teachers are involved in some kind of formal induction, or new teacher support, program (American Association of State Colleges and Universities, 2006). Much of the writing on induction is part description, part advocacy. Impassioned calls for early career support abound, as do descriptions of programs or standards for such programs. These descriptions provide evidence that the kinds of induction programs available to new teachers are quite diverse. Teacher induction programs may include components such as mentoring, workshops, coaching, or support groups; can vary in the duration, level of intensity, and content of support offered; and may differ based on the purpose, participants, and support providers involved (Arends & Rigazio-DiGilio, 2000; Feiman-Nemser, Schwille, Carver, & Yusko, 1999; Fideler & Haselkorn, 1999; Smith & Ingersoll, 2004). For example, Odell (1986) used observational data to determine that novice teachers in one induction program received various types of support to address their needs; this support involved assistance with resources/materials, school/district procedural information, instruction, emotional needs, classroom management, organizing the classroom environment, and demonstration teaching, although teachers needed more support in the first two categories. Clearly, the types of induction available are as varied as the teachers who participate in these programs.

However, research on what teachers learn from these programs lags behind their proliferation and benefits to students remain largely unexamined (Lopez, Lash, Shaffner, Shields, & Wagner, 2004; Wang, Odell, & Schwille, 2008). Impassioned advocacy for induction programs also tends to obscure the lack of empirical evidence for the critical features of these programs. In exceptional cases where induction research has moved beyond description and advocacy to examine program effects, the majority of this research explores the impact of induction on the retention of beginning teachers or on teachers' attitudes (Fulton, Yoon, & Lee, 2005; Kelly, 2004; Serpell & Bozeman, 1999; Smith & Ingersoll, 2004; Strong, 2005). Overall, findings have been positive: teachers participating in induction programs are less likely to leave the teaching profession (at least initially) and are more likely to be satisfied with their jobs, to have positive attitudes towards their school communities and curricula, and to be committed to their teaching. In most cases, this research has examined each induction program as a whole and failed to look at features *within* particular programs. As such, the question of why particular features might matter more so than others remains unanswered. As Lopez et al. (2004) conclude: "Existing studies on induction…do not answer the question of which components of induction have the strongest potential to improve the effectiveness and retention of beginning teachers" (p. 33). Desimone (2009) makes a similar argument about research on professional development.

A notable exception is Smith and Ingersoll's (2004) findings that novice teachers who participated in induction programs that involved working with a mentor from their same field, collaborating with same-subject teachers, and participating in other teacher networks were more likely to stay in the profession and less likely to leave their current teaching positions. More recently, induction research has turned to examining the effects of various structural components, most often mentoring relationships and workshop participation. However, this approach treats each program component as a one-dimensional unit, failing to capture important differences *within* any one program component, and this is troubling, especially considering that research on mentoring practices demonstrates the wide variance in new teacher/mentor experiences, even within a single school or district (Achinstein & Barrett, 2004; Yusko & Feiman-Nemser, 2008).

Despite these efforts, the research remains thin in terms of knowing whether induction actually leads to higher quality teaching and in determining which program characteristics are associated with better or worse induction. A more comprehensive, nuanced examination is needed—both of how various components effect changes in critical outcomes (i.e., teacher knowledge and practice, and student achievement) and of important differences within induction program components. Recent research on how teachers learn from professional development suggests a more promising approach than that used to study the effects of teacher induction—documenting *what* teachers have the opportunity to learn, *how much time* they spend in these learning opportunities, and *relevance* to their own teaching situations (Blank, de las Alas, & Smith, 2008; Cohen & Hill, 1998; Penuel, Fishman, Yamaguchi, & Gallagher, 2007).

Another feature of both induction programs and research on induction is that it is rarely subject-specific. That is, many induction programs focus on generic help to new teachers, and not on supporting teachers as they learn to teach specific subjects. Thus, the research base for understanding effective teacher induction in STEM disciplines is particularly sparse (Adams & Krockover, 1997; Sanford, 1988). And as Sanford (1998) noted, the problems faced in the induction phase for teachers across those disciplines might be qualitatively different, and so know little about the different kinds of supports that teachers in different STEM disciplines would need during induction.

Some recent research is attempting to fill this gap in the literature. Luft, Roehrig, and Patterson (2003) set out to understand the impact of different induction programs on beginning secondary science teachers. The researchers used a mixed methodology, and took place in two stages. During the pilot, five secondary science teachers participated in a university-based, science-specific induction program; the other five received formal and/or informal support from a school district induction program. In the second phase, 18 middle and secondary school new teachers were placed in three groups: six were part of the university-based, science-specific support program (Alternative Support for Induction Science Teachers, ASIST), six were in general support programs, and 6 had no access to any induction program. Data consisted of observations, interviews and collected documents.

During the pilot study, the researchers found that the beginning teachers who participated in the university-based, science-specific program enacted more extended inquiry lessons than did their peers in the other group. The beginning teachers in the general and no formal support groups reported more frustration with their instruction and a lack of support; their espoused beliefs about instruction also shifted more toward didactic instruction. In the second phase of the research, the Contrasting Landscapes Study, all of the participants used a variety of methods and materials while teaching; the beginning teachers in ASIST tended to use laboratories and student work groups more often, and the teachers in general or no induction tended to use seat work more often. Although ASIST emphasized the need to use more inquiry-based investigations, the beginning teachers in ASIST tended to use more traditional laboratories than did their general and no induction peers. ASIST participants also used more instructional and technology-based materials and more equipment in their laboratories.

The researchers also noted that while the ASIST teachers discussed problems in their schools (e.g., how hard it was to do laboratory work in their schools), the ASIST teachers nonetheless managed to do those laboratories (the teachers with less or no support did not). They attributed their ability to focus on science content and on inquiry-oriented instruction to their induction program. Beginning teachers in the general induction program tended to emphasize covering the content ad getting through the curriculum, teachers with no induction support were isolated and struggled. They tended to have more management problems and to teach in much more traditional ways.

Wilson and her colleagues have documented the learning opportunities for new teachers in the Exploratorium Beginning Teacher Induction Program (BTIP), a multifaceted program for middle and high school science teachers that uses varied approaches to develop teacher knowledge and practice. Key elements include: 1) workshops, 2) coaching, 3) mentoring, 4) summer institute, and 5) access to a host of curriculum resources. Teachers with three or fewer years of science teaching experience participate in the program over the course of two school years; participants experience varied pathways into science teaching. Some have graduate or undergraduate degrees from teacher education programs; others have intern credentials and are completing education coursework while teaching full-time. A good number of participants have degrees in science; others have had a prior career as a scientist or engineer and some have little or no training in a science discipline or field.

During the school year, BTIP participants attend content workshops and new teacher pedagogy workshops. The science content workshops focus on enhancing teachers' content knowledge related to different science topics, such as weather, viruses, or energy, while the new teacher pedagogy workshops focus on key issues related to teaching, learning, and classroom management. Each teacher is assigned a coach and a mentor who work with the teacher throughout both school years to develop his/her teaching practice and knowledge. BTIP participants also have access to a wide variety of resources—a plethora of teaching materials, an online listserv to communicate with a host of experienced and knowledgeable science teachers and scientists, the Exploratorium museum exhibits, and a workshop to make mini-exhibits for their classrooms. During the summer after the first school year, teachers attend a four-week Exploratorium summer institute, which is also attended by experienced teachers who are part of the Teacher Institute. The main purpose of the summer institute is to develop teachers' content knowledge related to specific science topics. During the four week summer workshop, teachers investigate and discuss scientific phenomena; the TI staff members help the teachers develop their understanding of these scientific concepts through hands-on and minds-on learning experiences. After this intensive summer experience, participants spend a second academic year attending workshops of their choosing, working with coaches and/or mentors when they see fit, and accessing any resources available to them through the BTIP. After two years, the novice teachers "graduate" and become part of the Exploratorium "family," which provides them with access to these resources and workshops for the duration of their professional careers.

The researchers studies three different cohorts of BTIP teachers over five years: the 2006 cohort (year one: n=32; year two: n=19), the 2007 cohort (year one: n=25; year two: n=20), and the 2008 cohort (year one: n=24; year two: n=17). Accounting for missing data and attrition from the program, sufficient data were available to complete the analyses for 79 teachers during year one and 56 teachers during year two of the program. In order to examine links between PD, teacher learning and practice, and student learning/ engagement, researchers used data collected from questionnaires, interviews, and observations to develop a method for representing each teacher's induction along three dimensions: (1) proximity to the classroom (that is, how closely tied an induction activity was to teachers' classroom experiences), (2) content of induction sessions (for example, whether the focus was on classroom management, how to teach about electricity, or finding cheap materials), and (3) intensity/duration of participation.

Findings showed that teachers exhibited characteristic patterns in the learning opportunities they accessed from the TIP (Mikeska, Rozelle, Galosy, & Wilson, 2009). For example, some teachers received support that focused almost exclusively on science pedagogy and content and was more theoretical and detached from their own teaching practice. Others received support that helped them address teaching issues of a more general nature, such as how to work with diverse students or how to handle classroom management problems, in lieu of an intense focus on science pedagogy. Sometimes the support was concentrated on helping a teacher address particular problems or dilemmas that stem from his/her own teaching practice. Further analyses showed that the way teachers accessed TIP could be predicted with reasonable accuracy by examining the quality of the teacher preparation they received prior to teaching and the challenge of their school context. For example, poorly prepared teachers who taught in high needs schools overwhelmingly accessed the program in ways that favored more individualized support in classroom management and work-life issues at the expense of more science-related support.

The researchers also compared a variety of outcome measures related to teacher knowledge and practice and student learning/engagement. (Mikeska, Galosy, Rozelle, Green, & Wilson, 2011). They developed multiple constructs to describe teaching practice (e.g., active learning, investigative classroom culture, student engagement, etc.), calculated change scores from topic-specific assessments that teachers completed before and after each school year, and calculated effect sizes for each teacher from students' assessments given at the beginning and end of instruction. Current findings suggest that science-related support provided by the TIP does improve teachers' scores on teacher knowledge assessments, especially in the first year of the program. As well, novice teachers who received more topic-specific PD were more likely to demonstrate the ability to foster content learning and to use a higher proportion of student-centered instructional strategies than those teachers with less topic-specific PD. Moreover, these teachers also saw greater gains in student achievement. In this way, this study linked the effects of PD to teacher knowledge, teaching practice, and student learning.

Across these two studies, there is some modest evidence that a subject-specific focus in induction leads to novice teachers spending more teaching science, and less time focused on some management issues. One might speculate that this would lead to higher student engagement and achievement, but such evidence is yet to be offered by research.

In sum, there continues to be considerable enthusiasm (as reflected in state policies) for early career teacher support. But very little empirical evidence can be located to determine what makes a program effective. Outcome measures tend to assess retention, very little research measures subject-specific aspects of teacher knowledge or instruction, or student achievement in STEM areas.

PROFESSIONAL DEVELOPMENT

There appears to be some consensus among researchers regarding characteristics of high quality professional development (Garet, Porter, Desimone, Burman, & Yoon, 2001; Guskey, 2003b; Hawley & Valli, 1999; Wei, Darling-Hammond, Andree, Richardson, & Orphanos, 2009), especially of effective science professional development (Supovitz & Turner, 2000). In particular, both the National Staff Development Council (2001) and the National Science Education Standards (National Research Council, 1996) have published professional development guidelines for teachers. The vision across both organizations includes the importance of PD that focuses on subject matter, draws upon teachers' current practices and experiences, and is intensive and sustained – all characteristics relevant to our current study. However, empirical evidence supporting these professional development characteristics is not always consistent, and other factors pertaining to teachers and schools also appear to play a noteworthy role in each characteristic's importance (Guskey, 2003a).

One widely-promoted notion is the critical importance of professional which focuses on developing teachers' capabilities and knowledge to teach content and subject matter. High quality PD—at any stage of development—focuses, in part, on developing teachers' knowledge of and ability to teach subject matter (Cohen & Hill, 1998; Wilson & Berne, 1999). Another characteristic prioritizes the extent to which the professional development addresses relevant problems and issues teachers are currently facing in their classrooms. Effective professional development needs to be structured around the "concrete tasks of teaching, assessment, observation, and reflection" (Darling-Hammond & McLaughlin, 1995, p. 598), thus attending to teachers' classroom work and the problems they encounter in their school settings. Lastly, in order to be effective, teachers must spend sufficient time engaged in the program's activities and learning experiences. Effective professional must go beyond the traditional, one-day workshop model and, instead, provide multiple, sustained opportunities across a substantial timeframe in order to make a difference (Cohen & Hill, 2001; Garet, et al., 2001).

These characteristics, which were initially gleaned from a variety of difference kinds of policy and research documents have been summarized (e.g., Blank, de las Alas, & Smith, 2008) and tested more recently in large-scale research. We have yet to reach a point where we can be confident that there is substantial evidence to support each "best practice."

Garet, Porter, Desimone, Birman, and Yoon (2001) examined the effects of various features of professional development on mathematics and science teachers' self-reported learning. Using data from a national evaluation of the Eisenhower Professional Development Program, the researchers examined the relationship between features of professional development ranging from structure of activities, duration of activities, the degree to which professional development activities involves the collective participation of teachers/principals from the same school, grade, or department, the degree to which a professional development activity had a content focus, whether it involved active learning on the part of the teacher participants, and whether activities provided coherence of teachers' pd. Outcomes were measured through teacher self-reports of increases in their knowledge and skill and changes in their teaching.

The researchers found that activity types influenced duration: activities associated with teaching in reform-minded ways took more time; the researchers also found a modest positive effect of activity that was about reform-minded instruction of enhanced teachers knowledge and skill. Time and contact hours had a positive effect on opportunities for active learning, and longer activities tended to promote coherence, as well as having a modest positive effect on PD having a content focus. Teachers reported that professional development with a content focus and coherence had a positive effect on an increase in their knowledge and skills; active learning also had a positive effect on knowledge and skill but at a more modest level. Finally, teachers reported that increase in their knowledge and skills were associated with positive changes in their instructional practice.

Roschelle, Schechtman, Tatar, Hegedus, Hopkins, Empson, Knudsen, and Gallagher (2010) report on a series of studies involving scaling up SimCalc, a technology-based approach to advanced mathematics. The project included tightly integrating SimCalc software, curriculum, and professional development so that teachers and students alike would experience an "aligned intervention" (p. 835). SimCalc is characterized by a commitment to having students make sense of conceptually rich mathematics through computer animations that engage student in making and analyzing graphs. The curricular activities are intended to connect students' experiences to their mathematical understanding of rate and proportionality.

The researchers implemented two randomized experiments over two years: seventh and eight grade. The intervention's logic involved providing teachers with replacement units that integrated technology and curriculum. Teachers' professional development was also part of the intervention and was designed to enhance teachers' mathematical content knowledge, ability to understand and use the curriculum materials, and plan how to use those materials in meaningful ways with their students. Teachers attended a 3-day summer workshop about the SimCalc replacement units. Outcomes were measured by project-developed assessment items.

The researchers found that, across the studies, students who had the SimCalc intervention learned more than the control students who experienced the "business-as-usual" curriculum; effect sizes were large and significant. The SimCalc teachers reported placing greater emphasis on advanced mathematics, and they did not report neglecting basic topics. SimCalc teachers reported using high-demand tasks more often (p. 871)

In a study with a similar logic, Borman, Gamoran, and Bowdon (2008) tested experimentally the impact of a content and inquiry rich teacher development intervention on elementary students' science learning. System-Wide Change for all Learners and Educators (SCALE), a partnership between scientists, teachers, and science educators, provides 4th and 5th grade teachers with professional development in the summer and coaching and mentoring while they are using curriculum (immersion) units that involve doing classroom science inquiry. Schools were randomly assigned; teachers in the experimental schools received professional development and the immersion units. Control schools used the immersion units without the professional development.

The analysis focused on student (N=6385) science achievement in 80 schools in LAUSD, and the 4th graders nested in those schools. Student achievement was measured with periodic, aligned science assessments administered by the school district. For the first year of analyses, the researchers found, that with regards to the assessment most closely associated with the immersion unit -- life science -- there was a statistically significant negative effect of participating in the experimental group, that is, of receiving the professional development. There were no significant effects for the other two assessment domains: earth and physical science. Additional analyses found that the intervention's effects did not depend on the percentage of ELL students in a class; but did find that the intervention had positive effectives for students of early career teachers. Larger negative effects were documented for students of teachers with more than three years of experience.

Hill (2011) surveyed a nationally representative sample of 1000 teachers in 2005 and 2006, measuring both their mathematical knowledge for teaching (MKT) and inquiring into their professional earning opportunities. Over 450 middle school teachers responded. MKT was measured using a teacher knowledge instrument, which focused on number and operations, a dominant focus of middle school mathematics. Learning opportunities included an assortment of typical opportunities teachers encountered, ranging from university-based mathematics or mathematics methods courses to Math Science Partnership (MSP) institutes or workshops to lesson study to professional development that focuses on newly-adopted textbooks.

Teachers reported spending more time in MSP workshops/institutes or in mathematics lesson study groups than other forms of professional development. The modal length of time spent in such settings for the respondents hovered around 8 or less hours, although 32% of respondents reported that they spent between 9-40 hours in a MSP workshop or a lesson study group. Hill examined the relationship between forms of professional development and gains (or losses) in teachers' MKT. Teachers in MSPs "lost" MKT, and had an average MKT change lower than teachers who reported participating in no professional development at all. For teachers in lesson study, new textbook workshops, and mathematics courses, knowledge growth was flat. In general, however, the teachers in the sample had a modest increase in their knowledge of number and operation items; mathematics methods coursework predicted these gains. Thus, the middle school teacher respondents, in general, increased their MKT over the year of the study, but this was not attributable to MSP workshops/institutes, textbook professional development, university-based mathematics courses, or lesson study.

Hill's overall assessment was that: "This paints a picture of a teacher population actively engaged in professional development, but engaged at only a minimal level of involvement, with potentially fragmented experiences" (p. 218). This seems largely accurate. States mandate professional development; ambitious teachers seek it out. School districts offer professional developed staffed by internal staff (curriculum directors, teachers-teaching-teachers) or through partnerships on funded projects through NSF and other organizations. Some of the professional development is mandatory; a great deal remains voluntary. Teachers are largely free to wander from opportunity to opportunity. Some might learn a great deal. It is equally true, however, that a teacher travelling across these programs could end up with holes or weaknesses in her understanding of relevant professional knowledge and an incoherent set of practices and unevenly developed skills. There are plenty of things she might never have an opportunity to learn. She might not learn how to work with students with autism, or

English language learners. She might repeatedly learn about scientific inquiry but know nothing about formative and summative assessments or how to use test data to alter her instruction. She might have learned a great deal about operations and fractions and next to nothing about geometry and calculus.

THE CURRENT STATE OF AFFAIRS

What is the current state of STEM teacher preparation, induction, and development? Why is there such a range in the quality of these programs/activities?

There is no central database that can be used to answer this question definitively. Information about teacher education, induction and professional development programs is not centrally collected, nor are data consistently collected about particular features that have been highlighted as important.[1] Shulman (2005) commented:

> There is so much variation among [teacher education] programs in visions of good teaching, standards for admission, rigor of subject matter preparation, what is taught and what is learned, character of supervised clinical experience, and quality of evaluation that compared to any other academic profession, the sense of chaos is inescapable. . . .Compared to any other learned profession such as law, engineering, medicine, nursing or the clergy, where curricula, standards and assessments are far more standardized across the nation, teacher education is nothing but multiple pathways. It should not surprise us that critics respond to the apparent cacophony of pathways and conclude that it doesn't matter how teachers are prepared. (p. 7)

Unfortunately, Shulman's argument holds for all forms of teacher development. This (non) system of professional learning opportunities is carnivalesque (Cohen & Spillane, 1992; Wilson, Rozelle, & Mikeksa, in press): crowded, noisy, incoherent, with both attractive and seedy options. Teachers wander from one option to another. They attend a teacher preparation program with one focus and curriculum, and then join an induction program with an entirely different focus and curriculum. Programs are selected on the basis of interest, convenience, or mandate. Considerable personal, public, state, and federal resources are poured into teacher development, but despite the investment, teachers seldom receive guidance about or the opportunity to select professional development that builds upon prior experience or support. Moreover, professional development providers have a difficult time building a coherent and comprehensive program of learning opportunities tailored to teachers' needs at various points in their careers. In sum, the system is incoherent, diffuse, and uncoordinated. The curriculum for teachers across these opportunities is flat, with no opportunity for building on

[1] For teacher preparation, AACTE does annual reports of its member institutions; NCATE and TEAC have information about their members; and Emily Feistritzer regularly updates information about alternative routes to teaching her annual Alternative Teacher Certification: A State-by-State Analysis reports. One might imagine being able to synthesize that information into a reasonable inventory of teacher preparation programs. There is no basis for doing something similar for teacher induction or professional development programs.

previous learning over time. Making matters worse, much professional development is fleeting: Programs lose funding, interventions and materials come and go, vendors change.

Because teachers are free to select much of their professional development *and* because school districts often patch together teacher learning opportunities with the resources available, participants in various teacher development programs enter with a wildly different array of experiences, knowledge, and skill. Due to funding and local leadership, some induction programs are homegrown, some provide every new teacher with Harry Wong materials, some hire the New Teacher Center to implement their model. Some new teachers find themselves participating in several induction programs at once; and almost every teacher encounters a range of disconnected professional development experiences – some mandated, some not – over the course of any given year.

This leads to problems: induction leaders and professional developers cannot count on what participating teachers have learned before; thus, most often leaders feel like they are starting from scratch. It also means that programs' curricula, when assessed overall, can seem "flat," that is, nothing builds on previous learning and development. All of this makes it challenging to track a program's effects.

Since research is most often done on the programs that are offered, it is not surprising that the knowledge base on teacher learning is equally carnivalesque and patchy. The National Academy of Education (NAE), National Research Council (NRC), and others have argued for a view of research that is more cumulative and coherent (e.g., Rand Mathematics Study Panel, 2003; NRC, 2002), yet this is nearly impossible in research on teacher learning and support given the system's incoherence. It is no wonder that most scholars who attempt to summarize what we "know" about teacher preparation, induction, or professional development conclude that the literature is too varied and uneven to draw any strong empirical claims (e.g., Cochran-Smith & Zeichner, 2005; NAE, 2009; Wilson, Floden, & Ferrini-Mundy, 2001).

Missing too is a central theory of how teachers learn. Dewey (1938) theorized about educative experience; Feiman-Nemser (2001) developed a list of core tasks of teaching to be mastered; some scholars frame the work of learning to teach as socialization (e.g., Hewson, Tabachnick, Zeichner, & Lemberger, 1999; Tabachnick & Zeichner, 1984); apprenticeship (Lortie, 2002); and entering learning communities (e.g., Shulman, 2004). Sociocultural and activity theory has been used to explain learning to teach (e.g., Feryok, 2009; Grossman, Smagorinsky, & Valencia, 1999; Grossman, Valencia, Evans, Thompson, Martin, & Place, 2000; Smagorinsky, Cook, & Johnson, 2003). Here too, then, we see a lack of coherence in the field of teacher support more generally.

MODERATING MECHANISMS AND SUPPORT STRUCTURES

What mechanisms or support structures moderate the impact of quality teacher preparation, induction, and development? What are the issues that make improving the system difficult?

Because teacher preparation, induction, and professional development are different enterprises, often involving different actors, I'll nominate factors that moderate quality that are specific to each, highlighting which ones run throughout the system. This is, by no means, a comprehensive list, but offers up a sense of the range of factors that shape quality preparation:

TEACHER PREPARATION[2]

√ State policies (concerning preparation teacher preparation structures and content; K-12 student curriculum)
√ University policies (concerning coursework, selectivity, admissions standards, credit hours, reward structures for faculty working in schools or teaching prospective teachers, etc.)
√ Cross-university commitment to teacher preparation (for content preparation)
√ Faculty quality and connectedness
√ Institutional capacity
√ Relationships with schools
√ Availability of high quality collaborating teachers to model appropriate instruction, and prepared mentor teachers
√ Principal leadership, teacher collaborative culture, resources in schools in which teachers learn
√ District and school policies for teacher assignment
√ Anchoring in core curriculum and/or texts that teachers will be expected to use

INDUCTION

√ State policies about induction, including funding allocations
√ Entering characteristics of new teachers
√ Lack of consistency of who is a "new teacher"
√ Availability of high quality and prepared mentor teachers
√ Principal leadership, teacher collaborative culture, resources in schools in which teachers learn

[2] For a relatively comprehensive view of the range of issues that are implicated in teacher preparation, see Science and Mathematics Teacher Imperative's *Framework for Describing and Analyzing Science and Mathematics Teacher Preparation and Development Programs.*

PROFESSIONAL DEVELOPMENT

√ Inconsistency and lack of predictability in terms of what teachers have learned prior to specific professional development
√ Lack of diagnostic information concerning what teachers need to learn: "Neither individual choice nor district/school mandates will suffice in the absence of diagnostic information on teachers' mathematical knowledge" (p. 230).
√ Lack of centralized funding or plans to use funding in coherent ways
√ Policies, practices, and resources that support long term, sustained, collective focus

WHAT ISSUES MAKE IMPROVING THE SYSTEM DIFFICULT?

The range of mediating factors is astonishing and includes everything from institutional capacity at all of the institutions that are involved in teacher development to state and local policies that shape what programs can/should do to material and social resources that are necessary to enable high quality teacher support. Here I discuss three features of the work of teacher development/support that profoundly effects what we can do.

First is the issue of sheer size. In university-based programs, staffing programs with qualified and skilled personnel is challenging. In some STEM disciplinary departments, there are only a few faculty who are invested in educating teachers, and there can be a generalized sense that teaching and teaching teachers in particular is not rewarded or valued. In large professional programs, many doctoral students and adjunct faculty are hired to teach courses, which also threatens quality. In teacher preparation programs and induction programs, identifying enough high quality mentor teachers whose classrooms are the appropriate places for new teachers to learn is extremely challenging.

Second is the issue of a common curriculum that teachers will be teaching. University based teacher preparation programs can teach prospective teachers the relevant state standards, but they cannot know what the curriculum is that a new teacher will be handed, nor what assessments they will need to be able to use and interpret. Professional development and induction leaders often deal with this challenge by identifying "big ideas" that transcend particular curricula: in science that might include the nature of science or scientific inquiry, or key concepts (like force and motion or natural selection) that seem foundational to scientific disciplines (like physics or biology). In mathematics, this might include fractions, patterns and functions, or reasoning and proof. It is a safe bet that most teachers will need to teach those topics at some point, and that enhancing their content and pedagogical content knowledge of those ideas would be beneficial. Unfortunately, because there is no differentiation of topic or the complexities of teaching that topic that govern curriculum, assessments, or teacher assignments, it is hit or miss whether teachers learn about these topics – and others.

Third is the related issue that there is no common curriculum for what teachers need to know, at what times in their careers. While most everyone acknowledges that beginning teachers will not know as much as their accomplished, more senior colleagues, little work has been done to articulate what reasonable expectations might look like for teachers across grade levels and/or disciplines. While states and INTASC have developed standards for beginning teachers, there is very little explicit guidance about what specifically those new teachers need to know. What about the cell might they understand? What is essential that they know about teaching fractions, and what might be postponed until they have had more experience? What basic knowledge do they need about their learners and communities? Where do we draw the line in terms of the depth or breadth of that knowledge? There is no well-articulated theory that differentiates beginning teachers from their experienced colleagues. Feiman-Nemser (1999) posits a continuum of teacher learning, but there exists little empirical that differentiates teacher knowledge and skill over a career. This leads to problems: teacher educators and professional developers cannot count on what their teachers have learned before. Many professional development programs include both experienced and inexperienced teachers, so professional developers feel as though they must start from scratch. Both because teachers are free to select much of their professional development, and because school districts patch together teacher learning opportunities with a mishmash of resources available (and do not have a district-wide plan of teacher development themselves), participants in various professional development programs – and even induction programs – enter with a wildly different array of experiences, knowledge, and skill. This also means that the curriculum of teacher education or induction or professional development or the three taken as a whole appears flat, very rarely building on what teachers have previously learned, nor ensuring complete coverage of any common curriculum.[3] After all, how could it given that anyone arriving at such a program has had an experience quite different from another?

It also leads to redundancy, where participating teachers complain of doing the same assignments over and over again, seeing the same films, doing the same science experiments or solving the same mathematics problems. Teachers' autonomy in selecting their own professional development exacerbates this, as do the limited and scattered resources teachers and school districts have for induction and professional development. The development of curriculum for teacher preparation, induction, and professional development is best understood as "parallel play," where staff conceptualize their curriculum independently from one another, but often drawing on similar resources which they pick up in professional networks of likeminded colleagues. Further, this lack of agreement, alignment, and linking of teacher preparation, induction, and professional development is enabled by the lack of a commitment to "cycles of continuous improvement" in the larger educational system (Sykes, Kennedy, & Bird, 2010). Without a larger system that is putting data into the system around a set of focused goals, teachers, teacher educators, and induction and professional development staff engage in a kind of parallel play that, not surprisingly, fails to get any traction on the improvement of teaching and schooling.

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[3] There are, of course, notable exceptions here: Marilyn Burns staged professional development through Math Solutions I, II, and III; Developing Mathematical Ideas developmental sequence for teachers and then teachers of teachers; or the Exploratorium's Teacher Institute. See http://www.mathsolutions.com/http://www2.edc.org/cdt/dmi/dmicur.html; and http://www.exploratorium.edu/teacher_institute/

Fourth is the role of context, or the nature of situated work. While much of the focus in discussions of teacher quality attends to the individual teacher, there is considerable evidence that teaching quality is also a product of school-level characteristics. In teacher preparation, the Holmes Group persuasively made the logical argument that prospective teachers need to learn in the classrooms of quality teachers; thus, what someone learns in a teacher education program is dependent on the quality of the school in which s/he learns, and the quality of the collaborating teachers and mentors with whom s/he works. In induction this is just as true. In a recent study, Johnson, Kraft, and Papay (2011) found that collegial relationships, principal leadership, and a school culture of mutual respect and trust, as well as commitment to student achievement – which the researchers consider components of a larger variable they call “the social context of teachers’ work” – were significantly related to teachers’ satisfaction and their commitment to staying in a school. Put another way, teachers can only learn to teach if they stay in a school; their willingness to stay depends on the quality of the social working environment. In professional development, the need for sustained, long term programs is largely due to the need for teachers to try things out in their classrooms, in real time, with real students, and to bring what they are learning back to the professional development program to reflect on and learn from.

Related to this contextual and situation nature of teacher development is the fact that teacher support programs often take place at the interstices of organizations: universities and the schools, museums and the schools, intermediate school districts and the schools. Partnerships across such organizations take time to develop and considerable social, political, financial and material resources to enable and sustain.

Other forces are also at play: State regulations govern much of the content of teacher preparation, but across states there can be enormous variation. Induction programs are an unfunded mandate in many states, and so school districts must find ways to offer support systems with few material and human resources to do so. Analysts have already demonstrated how funding for professional development is often decentralized in a school district, leading to a plethora of programs with little centripetal force to pull them together in a coherent way (Education Resource Strategies, 2004; Miles et al., 1999; Miles, et al., 2003).

Making some progress in remedying this lack of a coordinated system for teacher learning is hampered by one last unintended consequence. Since research is done on the programs offered, it is not surprising that the knowledge base on teacher learning is equally carnivalesque and patchy. The National Research Council (NRC, 2002), and others have argued for a view of research that is more cumulative and coherent (e.g., Rand Mathematics Study Panel, 2003), yet this is nearly impossible in research on teacher learning and support given the system’s incoherence. It is no wonder that most scholars who attempt to summarize what we “know” about teacher preparation, induction, or professional development conclude that the literature is too varied and uneven to draw any strong empirical claims (e.g., Cochran-Smith & Zeichner, 2005; NAE, 2009; Wilson, Floden, & Ferrini-Mundy, 2001).

REFERENCES

Achinstein, B., & Barrett, A. (2004). (Re)Framing classroom contexts: How new teachers and mentors view diverse learners and challenges of practice. *Teachers College Press, 106*, 716-746.

Adams & Krockover

Arends, R. I., & Rigazio-DiGilio, A. J. (2000). *Beginning teacher induction: Research and examples of contemporary practice*. Paper presented at the Annual Meeting of the Japan-United States Teacher Education Consortium.

Ball, D. B., & Forzani, F. M. (2009). The work of teaching and the challenge of teacher education. *Journal of Teacher Education*, *60*, 497-511.

Blank, R. K., de las Alas, N., & Smith, C. (2008). *Does teacher professional development have effects on teaching and learning: Analysis of evaluation findings from programs for mathematics and science teachers in 14 states*. Washington, DC: Council of Chief Sate School Officers.

Blömeke, S., Suhl, U., & Kaiser, G. (2011). Teacher education effectiveness: Quality and equity of future primary teachers' mathematics and mathematics pedagogical content knowledge. *Journal of Teacher Education,* 62, 154-171.

Borman, Geoffrey D., Adam Gamoran, and Jill Bowdon. 2008. A Randomized Trial of Teacher Development in Elementary Science: First-Year Effects." Journal of Research on Educational Effectiveness, 1, 237-264.

Boyd, D., Grossman, P., Lankford, H., Loeb, S., & Wyckoff, J. (September 2008). *Teacher preparation and student achievement* (NBER Working Paper No. W14314). Cambridge, MA: National Bureau of Economic Research. Available at: http://ssrn.com/abstract=1264576 .

Cochran-Smith, M., & Zeichner, K. (Eds.). (2005). *Studying teacher education: The report of the AERA Panel on research and teacher education*. Mahweh, NJ: Lawrence Erlbaum Associates.

Cohen, D. K., & Hill, H. (2000). Instructional policy and classroom performance: The mathematics reform in California. *Teachers College Record*, *102*(2), 294-343.

Cohen, D. K., & Spillane, J. P. (1992). Policy and practice: The relations between governance and instruction. In G. Grant (Ed.), *Review of Research in Education, 18*, 3-49.

Darling-Hammond, L., & Bransford, J. (Eds.). (2005). *Preparing teachers for a changing world: What teachers should learn and be able to do*. San Francisco: Jossey-Bass.

Darling-Hammond, L., & McLaughlin, M. W. (1995). Policies that support professional development in an era of reform. *Phi Delta Kappan*.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. *Review of Educational Research, 76*(4), 607-651.

Desimone, L., Porter, A. C., Garet, M., Yoon, K. S., & Birman, B. (2002). Effects of professional development on teachers' instruction: Results from a three-year longitudinal study. *Educational Evaluation and Policy Analysis*, *24*, 81-112.

Feiman-Nemser, S., Schwille, S. A., Carver, C., & Yusko, B. (1999). *A conceptual review of literature on new teacher induction*. Washington, D.C.: National Partnership for Excellence and Accountability in Teaching.

Fideler, E. F., & Haselkorn, D. (1999). *Learning the ropes: Urban teacher induction programs and practices in the United States*. Belmont, MA: Recruiting New Teachers, Inc.

Franke, M. L., & Chan, A. (2007, April). *Learning about and from focusing on routines of practice.* Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Fulton, K., Yoon, I., & Lee, C. (2005). *Induction into learning communities*. Washington, D.C.: National Commission on Teaching and America's Future.

Garet, M. S., Porter, A. C., Desimone, L., Birman, B. F., & Yoon, K. S. (2001, Winter). What makes professional development effective? Results from a national sample of teachers. *American Educational Research Journal 38*(4), 915-945.

Grossman, P., Compton, C., Igra, D., Ronfeldt, M., Shahan, E., Williamson, P. (2009). Teaching practice: A cross-professional perspective. Teachers College Record. 111 (9).

Grossman, P., Hammerness, K., & McDonald, M. (2009). Redefining teaching, re-imagining teacher education. *Teachers and Teaching: Theory and Practice, 15,* 273-289.

Grossman, P. L., Smagorinsky, P., & Valencia, S. W. (1999). Appropriating tools for teaching English: A theoretical framework for research on learning to teach. *American Journal of Education*, *108*, 1-29.

Guskey, T. R. (2003a). *The characteristics of effective professional development: A synthesis of lists*. Paper presented at the American Educational Research Association. from http://www.eric.ed.gov/ERICWebPortal/search/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED478380&ERICExtSearch_SearchType_0=no&accno=ED478380

Guskey, T. R. (2003b). What makes professional development effective? *Phi Delta Kappan, 84*(10), 748.

Hawley, W. D., & Valli, L. (1999). The essentials of effective professional development: A new consensus. In L. Darling-Hammond & G. Sykes (Eds.), *Teaching as the learning profession: Handbook for policy and practice* (pp. 127-150). San Francisco: Jossey-Bass.

Hatch, T., & Grossman, P. (2009). Learning to look beyond the boundaries of representation: Using technology to examine teaching (Overview for a digital exhibition: Learning from the practice of teaching). *Journal of Teacher Education. 60*(1), 70-85.

Hill, H.C. (2011). The nature and effects of middle school mathematics teacher learning experiences. *Teachers' College Record, 113,* 205-234.

Holmes Group. (199X).

Johnson, S. M., Kraft, M. A., & Papay, J. P. (2011, March). *How context matters in high need schools: The effects of teachers' working conditions on their professional satisfaction and their students' achievement*. Unpublished paper.

Kelly, L. M. (2004). Why induction matters. *Journal of Teacher Education, 55*(5), 438-448.

Lampert, M., & Graziani, F. (2009). Instructional activities as a tool for teachers' and teacher educators' learning in and for practice. *Elementary School Journal*, 109 *(5), 491-509.*

Lee, C., & Krapfl, L. (2002). Teaching as you would have them teach: An effective elementary science teacher preparation program. *Journal of Science Teacher Education, 13*, 247-265.

Levine, A. (2006). *Educating school teachers*. Washington, DC: Education Schools Project.

Lopez, A., Lash, A., Shaffner, M., Shields, P., & Wagner, M. (2004). Review of research on the impact of beginning teacher induction on teacher quality and retention. Retrieved from http://policyweb.sri.com/cep/publications/Induction_LitReviewFeb_2004.pdf.

Luft, J.A., Roehrig, G.H. & Patterson, N.C. (2003). Contrasting landscapes: A comparison of the impact of different induction programs on beginning secondary science teachers' practices, beliefs, and experiences. *Journal of Research in Science Teaching, 40*(1), 77-97.

Mikeska, Rozelle, Galosy, & Wilson (2009)

Mikeska, J. N., Green, K. R., Rozelle, J. J., Galosy, J., & Wilson , S. M. (2011). *Examining relationships between professional development and teachers' preparation, teaching context, knowledge, confidence, instructional practice, and student achievement*. Paper presented at the annual meeting of the American Educational Research Association, New Orleans, LA.

National Academy of Education. (2009). *Teacher quality: Education policy white paper*. S. Wilson (Ed.). Washington, DC: Author.

National Council for Accreditation of Teacher Education (NCATE). (2010). *Transforming teacher education through clinical practice: A national strategy to prepare effective teachers*. Report of the Blue Ribbon Panel on Clinical Preparation and Partnerships for Improved Student Learning. Washington, DC: Author.

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

National Research Council . (2000). *Educating teachers of science, mathematics, and technology: New practices for the new millennium*. Committee on Science and Mathematics Teacher Preparation. Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Research Council. (2010). Preparing teachers: Building evidence for sound policy. Committee on the Study of Teacher Preparation Programs in the United States, Center for Education. Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

National Staff Development Council (2001). *National staff development council: Implementing the standards for staff development*. Oxford, OH: National Staff Development Council.

Odell, S. J. (1986). Induction support of new teachers: A functional approach. *Journal of Teacher Education, 37*(1), 26-29.

Penuel, W. R., Fishman, B. J., Yamaguchi, R., & Gallagher, L. P. (2007). What Makes Professional Development Effective? Strategies That Foster Curriculum Implementation. *American Educational Research Journal, 44*(4), 921-958.

RAND Mathematics Study Panel. (2003). *Mathematical proficiency for all students: Toward a strategic research and development program in mathematics education*, RAND, MR-1643-OERI, 2003.

Roschelle, J., Shechtman, N., Tatar, D., Hegedus, S., Hopkins, B., Empson, S., Knudsen, J. & Gallagher, L. (2010). Integration of technology, curriculum, and professional development for advancing middle school mathematics: Three large-scale studies. *American Educational Research Journal*, 47(4), 833-878.

Sanford (1988)

Schmidt, W.H., Blömeke, S., & Tatto, M.T. (2011). *Teacher education matters: A study of middle school mathematics teacher preparation in six countries.* New York: Teachers College Press.

Serpell, Z., & Bozeman, L. A. (1999). *Beginning teacher induction: A report on beginning teacher effectiveness and retention*. Washington, D.C.: National Partnership for Excellence and Accountability in Teaching.

Shulman, L. S. (2005, Fall). Teacher education does not exist. *Stanford Educator*, 7.

Smith, T. M., & Ingersoll, R. M. (2004). What are the effects of induction and mentoring on teacher turnover? *American Educational Research Journal, 41*(3), 681-714.

Strong, M. (2005). Teacher induction, mentoring, and retention: A summary of the research. *The New Educator, 1*(3), 181-198.

Supovitz, J. A., & Turner, H. M. (2000). The effects of professional development on science teaching practices and classroom culture. *Journal of Research in Science Teaching, 37*(9), 963-980.

Tatto, M. T., & Senk, S. (2011). The mathematics education of future primary and secondary teachers: methods and findings from the Teacher Education and Development Study in Mathematics. *Journal of Teacher Education, 62(2), 121-137.*

Wang, J., Odell, S. J., & Schwille, S. A. (2008). Effects of teacher induction on beginning teachers' teaching: A critical review of the literature. *Journal of Teacher Education, 59*(2), 132-152.

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* (Vol. 24). Washington, D.C.: American Educational Research Association.

Wilson, S.M., Floden, R.E., & Ferrini-Mundy, J. (2001). *Teacher preparation research: Current knowledge, gaps, and recommendations.* Seattle, WA: Center for the Study of Teaching and Policy. *Retrieved September 30,* 2009, *from* http://depts.washington.edu/ctpmail/PDFs/TeacherPrep-WFFM-02-2001.pdf

Wilson, S. M., Rozelle, J., & Mikeksa, J. (in press). Cacophony or embarrassment of riches? Building a system of support for teacher quality. *Journal of Teacher Education*.

Windschitl, M., Thompson, J., Braaten, M., Stroupe, D., Chew, C., & Wright, B. (2010, April). *The beginner's repertoire: A core set of instructional practices for teacher preparation*. Paper presented at the annual meeting of the American Educational Research Association, Denver, CO.

Yusko, B., & Feiman-Nemser, S. (2008). Embracing contraries: Combining assistance and assessment in new teacher induction. *Teachers College Record, 110*, 123-953.