

Addressing Challenges Faced by Early-Career Mathematics and Science Teachers: A Knowledge Synthesis

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Addressing Challenges Faced by Early-Career Mathematics and Science Teachers

In framing this review, we further address a question posed recently in a review by Davis, Petish, and Smithey (2006): What are the challenges that new science teachers face? That prior review about “new” teachers mostly focused on pre-service science teachers; this review focuses on early-career science teachers, and early-career mathematics teachers as well, i.e., beginning teachers of record in their first years of teaching mathematics or science. The article includes research about secondary teachers in these subjects but also studies of early-career elementary teachers’ instruction in them. In addition to examining the challenges that early-career teachers face, we review research about addressing those challenges: What do we know about how mentoring and induction efforts influence the retention of early-career teachers of mathematics and science? How do those efforts affect teaching quality and the learning outcomes of their students?

The review employs unusually intensive methods both for identifying relevant studies and for gauging their methodological rigor. Because the prior review found only 15 articles or an “overall dearth of studies of early-career science teachers” (Davis et al., p. 635), we experimented with different methods for searching literature and yielded 64 studies of early-career science teachers, as well as 24 about early-career teachers of mathematics as of May 2009. Despite an intensive search, we were able to identify only 25 articles on mentoring or induction interventions effects for mathematics and science teachers. We also used especially systematic methods to examine the studies’ methodological strength. Therefore, while the primary purpose of this article is to report our synthesis of substantive findings from research on early-career mathematics and science teachers, it secondarily also includes methodological review.

Perspectives of the Review

We believe that it is important to conduct reviews that focus specifically on early-career teachers, including those from alternate routes, in addition to reviews on beginning teachers than combine early-career teachers and pre-service teachers. Since both pre-service teachers and early-career teachers are novices in comparison with more experienced teachers, it can make sense that research about “beginning” or “novice” teachers may define them to encompass teachers in both situations. However, teacher induction is a distinct phase of teacher experience and development, one that differs from both pre-service and professional development at large. While teacher induction should be handled as part of a continuum, i.e., mindful of and articulated with the other two phases of the continuum, it also warrants inspection as a phase in its own right (Feiman-Nemser, 2001). In fact, a main implication of an early study among the focal set, one of the few studies having a strong methodology, was the importance of illuminating understanding of early-career middle school science teachers as distinct from pre-service and experienced science teachers (Sabers, Cushing, & Berliner, 1991). Until recently, the limited amount of research specific to early-career mathematics and science teaching may have limited the value of a research synthesis on this topic, but we now found 80 relevant studies.

Our own prior research and inspections of extant literature have led us to believe that experiences and needs of early-career teachers in mathematics and science include some important particulars that differ from the universal needs of all early-career teachers, and that

mentoring and induction programs should address those particulars (Britton, 2006; Davis et al, 2006; Luft, 2001). Prior reviews have included early-career mathematics and science teachers but not focused on them, as illustrated by an article from Reynolds (1992) in *Reviews of Educational Research* and three more recent RER articles. Reviews by Guarino, Santibañez, and Daley (2006) and Borman and Dowling (2008) included attention to early-career teaching, but across all school subjects. Those reviews addressed teacher recruitment, attrition and retention, but did not encompass research on teaching quality. The previously noted Davis et al. (2006) review addressed teaching quality by placing studies mostly of pre-service science teachers but also some of early-career science teachers in the frame of standards for beginning science teaching by the Interstate New Teacher Assessment and Support Consortium (INTASC, 2002a), but that review's scope did not include analogous work in beginning mathematics teaching (INTASC 2002b).

Review Method

This review is part of a larger Math and Science Partnership Knowledge Management and Dissemination project (MSP KMD), funded by the National Science Foundation and begun in 2004. The described methods were developed by that project's lead organization Horizon Research, Inc. and its main partner, the Education Development Center. These methods were carried out for this article by WestEd authors under the auspices of Horizon Research. The KMD project is charged with taking stock of what we know, how well we know it, and the implications for policy, practice, and future research in relation to key topics in mathematics and science education improvement.

Literature Search and Screen Methods

The search and screening of studies for this review yielded a set of 80 studies with a focus on early-career teachers of mathematics and/or science. Each study had to be conducted in the context of K-12 education, published in English since 1990, and meet the following parameters. (1) At least one of the major research questions or topics concerns understanding early-career teachers, or their induction or mentoring. (2) The study includes people within their first five years of teaching as paid teachers of record for their classes, having completed teacher preparation or entering teaching from alternative routes. Studies of pre-service teachers are included only if they are followed into their first years of teaching. (3) Studies can include subjects other than early-career mathematics and science teachers, i.e., some experienced teachers or early-career teachers in other school subjects, as long as the study design and the published article sufficiently disaggregate data and report substantial results specific to this review's focal teacher population; for example, a study might compare experienced and novice teachers (e.g., Hoz, Tomer, & Tamir, 1990; Meyer, 2004).

A set of about 60 search parameters was entered into EBSCO Education Complete and PsycInfo using a Boolean logic requiring both at least one term from a set describing early-career teachers and at least one term from a set describing mathematics and science education. Because ERIC does not allow long search strings, an ERIC search was done with more limited phrases. Such an extensive set of terms was needed in part because studies involving early-career teachers use a wide range of words or phrases to describe them. Unless a wide search net is cast, many relevant articles are not obtained. For example, an earlier review (Davis et al., 2006) primarily

identified articles by examining every article in seven journals selected for being particularly likely to publish research about new science teachers. When this direct canvassing of select journals was augmented by use of the ERIC search engine, the search yielded only a few more articles in additional journals. Instead using an extensive set of search terms, we found an additional 33 articles in 17 journals other than the seven canvassed by the earlier review. The screening also had to be intensive because some key terms are used inconsistently in the literature, particularly the use of ‘beginning’, ‘novice’ or ‘new’ teacher for referring to either pre-service teachers or early-career teachers, or both. However, using a wide net in search engines produced a very high number of non-relevant articles, creating a burdensome demand for screening articles to confirm or reject their relevance, even when using such software features as EBSCO’s artificial intelligence option to “sort by relevance” in relation to the search descriptors.

The search was completed in the spring of May 2009. Initial searches yielded approximately 4000 potential articles. A project team member read the title and abstract for each study to determine its initial potential for inclusion based on the criteria for the review. Close to 95 percent of the articles were eliminated in this initial screening for one or more of the following reasons: most commonly, the study did not include research questions or topics concerning induction or early-career teachers, or the article was not about empirical research, e.g., they only described induction activities rather than studying them. Frequently, the research did not focus on teachers of mathematics and science, or subject-specific particulars of their experience; and some studies dealt solely with pre-service teachers. The screening resulted in approximately 300 studies for further consideration. It was often problematic to make a clear determination from article titles or abstracts. Therefore, the more intensive screening consulted full articles as needed to make a final determination for inclusion. The entire screening process ultimately yielded 80 articles for the KMD review process.

Analysis of Methodological Rigor

Drawing on the research methods typically found in doctoral-level texts and with the input and review of an advisory panel of research methodologists, researchers, and reform leaders, the MSP KMD project developed a set of 31 standards of evidence (SoE) for empirical research. The SoE and the process for applying them result in a careful review of the claims of individual studies, with ratings based on specific indicators, operationalized for different qualitative and quantitative research methodologies, and narrative justifications for these ratings in five areas: adequate documentation, internal validity (e.g., sample bias, investigator bias), analytic precision (e.g., reliable measures, systemic analysis), generalizability, and warrants for claims (i.e., article sections on conclusions and implications). Inspection of each article requires five to eight hours by a doctoral-level analyst who has been trained and evaluated for inter-rater reliability on the method. Complete SoE descriptions and process specifications in the MSP KMD *Standards of Evidence Codebook* are available at <http://www.mspkmd.net/pdfs/soe.pdf>.

As discussed later in the article, the methodological inspection revealed prevalent, serious weaknesses across the study set, with only 9% of the articles receiving a stronger overall rating that is termed “satisfactory” within the KMD project’s schema. (The other possible overall ratings were limited and poor.) The subsequent discussions specifically note these stronger articles; readers should keep in mind that the findings of all other articles must be considered to have more limited value due to weaknesses in the studies or the descriptions of them provided in the articles.

Landscape of Research Characteristics and Foci

As shown in Table 1, the great majority of studies examined secondary science teachers or the science instruction of elementary teachers, with far fewer studies including mathematics teachers or a focus on elementary teachers' mathematics instruction (79% and 30%, respectively). The majority of mentoring or induction interventions studied were conducted at the middle and high school levels. In contrast, studies for understanding early-career teachers without any focus on an intervention were more evenly distributed across the elementary, middle and high school levels. About three-fourths of the identified research employed only qualitative methods, and one-fourth employed mixed methods; only three studies were solely quantitative. Reflecting the mostly qualitative methods, three-fourths of the identified studies involved fewer than 20 teachers, and about one-third studied only one to three teachers. A third of the studies were conducted in countries outside the U.S., primarily in Australia. About two-fifths of the identified research on interventions included some subjects entering teaching from alternative routes, but only a quarter of studies of early-career teachers in the absence of any intervention included such teachers.

TABLE 1
Overview of characteristics, 80 studies of early-career mathematics and science teachers and their induction, by percentage of studies

Study characteristic	Majority of studies	Minority of studies
purpose of study	70 understanding beginning teachers and teaching context; no focus on interventions	30 investigating effects of mentoring and induction interventions
subject area *	79 science	30 mathematics
school level *	Studies of teachers 34 elementary 39 middle 59 high	Studies of interventions 25 elementary 50 middle 63 high
study methods	73 qualitative	24 mixed methods 4 quantitative
number of study subjects	78 fewer than 20	23 21 or more
country *	71 United States	34 Australia, other, or other plus U.S.
studies including any teachers from alternative routes	Studies of teachers - 23	Studies of interventions - 42

* Percentages exceed 100 because some studies addressed teachers in both subjects, or multiple school levels, or more than one country.

The overwhelming majority of identified research was conducted by faculty in mathematics or science teacher preparation who studied early-career teachers. The researchers' lenses often focused, formally or informally, on whether the early-career teachers' beliefs and practices were consistent with those espoused in their teacher preparation programs, e.g., whether science instruction was "inquiry-oriented", "student-centered", "reform-oriented", addressed multicultural issues, "science for all", etc. Researchers often explored explanations for any inconsistencies found with the teaching intended by pre-service programs. We use variants within this overarching research purpose to group the studies in this article and frame our

discussion of their relevant findings. Most study designs and resulting articles directly addressed this issue, while some other studies at least had some substantial treatment of it; this review does not summarize any other research questions and findings that the latter articles also may include.

This article organizes the identified research in two main sections. (1) Of the 80 studies identified for review, 64 illuminated the beliefs, practices, and experiences of the early-career teachers; however, the research designs of these articles did not also seek to formally understand any early-career teacher mentoring or induction services that might have been provided. (2) In contrast, another 26 articles primarily focused on the effects of mentoring and induction interventions for early-career teachers.

Studies of Early-Career Teacher Beliefs, Practices, Experiences,

Table 2 lists studies reviewed in this section, grouped by the topics discussed in it. The section begins with a few studies that provide existence proofs that intended instructional approaches from pre-service can be implemented by early-career teachers. However, early-career teachers across the studies did not often manifest mathematics and science teaching consistent with pre-service intentions. Based on data from six cohorts of science teaching interns taking a university science methods course, Moscovici (2009) created a list of 25 necessary but seldom achieved elements at the student, teacher, school, district, and state levels for translating “inquiry science” into urban secondary science classrooms. In this article, we derived groupings of barriers to implementation from patterns among the results across the reviewed studies.

Many articles investigated these barriers to implementation: limitations in content knowledge, conflicting views of instructional approaches held by people who interact with early-career teachers, and teaching conditions faced by early-career teachers that can dampen the feasibility of implementation. Some other articles revealed that teacher self-reports of their beliefs about instructional approaches and the instructional approaches that they use can be markedly different from those observed by researchers. Data from a few studies raised the possibility that teachers’ desires to use pre-service instructional approaches might manifest in their practice after the first few years of teaching. Versions of these phenomenon existed at both the elementary and secondary school levels, but some studies discussed toward the end of this section raise issues particular to elementary level mathematics or science teaching.

TABLE 2

Research on early-career mathematics and science instructors' beliefs and practices, and influences on them.

	Article by first author (year)
Studies emphasizing <u>existence proofs</u> of persistence with pre-service teaching methods	Avraamidou (05), Bianchini (03, 07), Clarke (09), Goos (05), Levin (09), Skott (01), So (05)
Studies emphasizing <u>barriers</u> to implementing pre-service teaching methods	
Limitations of content knowledge	Arzi (08), Hoz (90), Luft (07), Roehrig (04), Steele (01), Volkman (98)
Influence of counter-views to intended teaching:	
counterviews of schools, faculty, curriculum	Bianchini (03), Cady (06a), McGinnis (04), Mullholland (01, 03), Steele (01)
alternate experiences in K-12, college, or workplace	Adams (97a) Greenwood (03), Koballa (05), McNally (06), Meyer (04)
views of students	Greenwood (03), Loughran (04), Mullholland (03), Powell (97), Rodriguez (02), Sullivan (92)
unrecognized counter-views	Ensor (01), Huffman (08), Sammel (06), Shea (07), Simmons (99)
Early-career teaching conditions	Adams (97b), Anderson (04), Appelton (99), Dawson (08), Loughran (04), Mullholland (03), Powell (97), Varelas (05), Watson (06)
Issues particular to the elementary school level	Appleton (99,02,03), Beyer (08), Dragsted (06), Ginn (99), Smith (07)
Potential latent implementation	Adams (97a), Bradford (96), Cady (06b), Greenwood (03), Rodriguez (02)

Existence Proofs of Implementing Teaching Approaches from Pre-Service

Introduction. While the preponderance of findings and discussion among all articles focus on early-career mathematics and science teaching that does not fulfill some key emphases of teacher preparation programs, it is important to note that those studies and this review do not claim that no early-career teachers strongly utilize the intended instructional approaches and methods. While discussing some pitfalls, a few articles predominantly emphasize substantial successes by early-career teachers with implementation of particular aspects of instruction that had been emphasized in their teacher preparation programs: using multicultural views of science and investigative methods, using investigative science methods at the elementary level, using inquiry-oriented mathematics approaches, emphasizing examining of student thinking, and using technology appropriately in mathematics instruction. Note that most of these articles are cases

studies of from one to four volunteer teachers, derived from only a few to several observations and interviews. Skott (2001) cautions that the relationship between a teacher's view of teaching mathematics and actual practice varied considerably in different situations; therefore, it is hard to generalize a constant characterization of the relationship from the moments observed by researchers, even for a single teacher in a single study.

Findings. Avraamidou and Zembal-Saul (2005) studied an early-career elementary teacher who succeeded in using scientific evidence in instruction: collecting, recording and presenting evidence, using evidence to construct scientific explanations, and having students write in terms of claims and evidence. So and Watkins (2005) observed that first year elementary teachers in Hong Kong used more constructivist instructional methods for science teaching than they had done during pre-service; however, the authors also noted that early-career teachers' lesson planning was more simplistic and less coherent than during pre-service. Bianchini, Johnston, Oram, and Cavazos (2003) found that three studied secondary teachers conveyed the nature of science to which they were heavily exposed in pre-service, e.g: broadening students' conceptions of who scientists are, and instructing students by means of investigative science practices. These teachers persisted and grew over time in their inclinations and abilities to make their instruction inclusive for the learning of all students (Bianchini & Cavazos, 2007).

Clarke and Thomas (2009) related how negative warnings from other teachers and initial adverse attitudes from their students did not deter four early-career mathematics teachers in urban contexts from implementing several aspects of instruction conveyed during their preparation program. In these urban contexts, teachers felt that explicitly and strongly exhibiting caring for the students and their learning was a pivotal factor. Levin, Hammer, and Coffey (2009) described how paid interns made understanding their students' thinking a strong instructional focus when their university courses provided heavy emphasis on this. Goos (2005) reported that an early-career mathematics teacher was able to work with technology in quite different school settings, and his modes of working with technology became more varied and sophisticated over time, consistent with his training. In many other studies that follow, some of the teachers had some success in implementing intended mathematics and science instruction; similar to the thrust of most of the reviewed articles, however, we subsequently focus on elaboration of the barriers that stopped more teachers than not.

Barriers to Implementation: Content Knowledge Limitations

Introduction. Studies of early-career secondary teachers' content knowledge raise several concerns about their career development. Evidence from one study suggests that teachers are most likely to continue enhancing their content knowledge when they are assigned to teach classes in the field of their major; however, science teachers generally have a major in one science discipline, but may be assigned to teach other sciences as well. In a few studies, limitations in early-career teachers' science or mathematics content knowledge raised concerns regarding their instructional practice, including the potential for content inaccuracies. Limited content knowledge was associated with instruction that focused on processes and teacher-centered pedagogies. Ongoing work to deepen early career secondary science teachers' content knowledge appears to be needed both in teachers' primary field of study as well as for "out of field" teaching assignments.

Findings. Arzi and White (2008) studied changes in teachers' science content knowledge, including specific changes occurring among 22 teachers from their pre-service years to their first two years of teaching. This report was one of the few having the strongest rating of methodological rigor in the SoE analysis. Early-career teachers' interests and efforts in enhancing their content knowledge were greatest when they taught within their particular science discipline, and the weakness of content knowledge growth for teachers assigned to out-of-field sciences persisted in subsequent years. The required school curriculum was the single most powerful factor affecting content knowledge development, including the curriculum previously learned as school students as well as the one now being taught. The authors' discussion highlights "the need for career-long support for growth [in content knowledge], even in teachers' major subjects where expertise is taken for granted". Hoz et al. (1990) found the content knowledge of three traditionally-prepared early-career biology teachers to be inadequate, and expressed concern that the teachers might be unaware of these deficits and the errors they could cause in their instruction. The study also found a similar situation among their focal experienced biology teachers, which argues for carefully screening when selecting teachers to help with the induction of the early-career teachers.

Research described by Roehrig and Luft (2004) and Luft, Lee, Fletcher, and Roehrig (2007) found that teachers with a minor or less in science were more likely to follow a prescribed curriculum or focus on process science instead of more inquiry-oriented science, also illustrated by a Volkmann and Anderson study (1998) of a first-year chemistry teacher. The teacher was certified based on limited college coursework, but was not a chemistry major. She initially believed it is possible to teach any chemistry as long as you have the mission of wanting to help students. When she encountered gaps in her knowledge, she emphasized interesting pedagogy for the students and "forgave herself for content errors or shortfalls"; her knowledge gaps also deterred her from doing labs. She concluded after her first year that teaching is inextricably connected to the disciplinary knowledge that one teaches. Similarly, Steele (2001) noted that weaker content knowledge deterred more reform-oriented mathematics teaching.

Barriers to Implementation: Counter-Views to Intended Teaching

Introduction. The body of studies in this section indicates that if early-career instructors have counter-views to the reform-oriented approaches of teacher preparation, then they are unlikely to pursue those methods to a significant extent, or at all. Teachers may be sorting out views of teaching and learning that differ from those in teacher preparation, arising from their own K-12 schooling or prior workplace experiences. They may not be explicitly aware of these counter-views or disclose them to researchers. Influential counter-views also can arise from many sources around the teacher: other mathematics and science teachers, prescriptive curriculum standards or materials, the nature of large-scale assessments, and parents uncomfortable with different teaching approaches, student reactions to these instructional approaches, or perceptions by the teacher or others in their teaching context that students are unable to learn from these methods.

In the earlier case studies of teachers who did pursue implementation of reform-oriented mathematics and science teaching, those teachers also had to overcome the same counter-views previewed above, but they often had received very intensive emphases on these aspects of instruction during pre-service. Because teachers were study volunteers or selected opportunistically rather than randomly, providing vastly more extensive treatments in pre-service

may not be a solution that would generalize to most early-career teachers. Given that early-career teachers understandably may be more apt to yield to counter-views and that district-based induction programs often emphasize counter-views, teacher education programs may need to consider more experiments with extended missions to include shaping and helping execute subject-specific aspects of teacher induction.

Findings: Counterviews of Schools, Faculty, Curriculum. In a study by McGinnis, Parker, and Graeber (2004), one of the few reviewed studies that had a “satisfactory” methodological rating, early-career teachers who perceived their school culture as not supporting reformed-oriented instruction did not implement it. The article cites particulars of school culture that reflect ones prevalent in today’s schools: large number of objectives to meet, prescribed mathematics and science curricula and curricular materials, ongoing external standardized testing plus district testing, instructional interruptions, and parent suspicion of new ideas. Mulholland and Wallace (2001, 2003) found that early-career teachers had to overcome a negative disposition toward science held by their colleagues, as well as counter-views of science teaching methods.

Bianchini et al. (2003) found that the California state science standards sometimes inhibited teachers’ treatment of the nature of science topics. Cady, Meir, and Lubinski (2006a) found one teacher’s district encouraged reform-based curriculum, while the district of the other studied teacher did not; this difference was a major explanation of the different instructional styles that the teachers pursued in mathematics. Steele (2001) found that two teachers sustained “cognitively-based” conceptions of mathematics teaching and the other studied teachers did not; school culture about teaching mathematics was a major influence, as were prescriptive instructional materials.

Findings: Views from Alternate Experiences in K-12, College, or Workplace. Adams and Krockover (1997a) found that two of their four subjects’ initial teaching views reflected their own prior K-12 science learning experiences and similarly didactic college science courses, rather than the teaching approaches espoused in their methods courses. McNally (2006) reported that secondary level early-career teachers often found their attempts at formal science investigations to be overwhelming, especially because they had not experienced them in their own K-12 schooling. Meyer (2004) noted that novice teachers relied on their own childhood conceptions as a proxy for predicting students’ conceptions, which was problematic because students’ lives in urban settings differed considerably from most of the novice teachers’ background or experience.

Two of the identified studies examined the views held by career changers about science teaching and their prior workplace science experiences. In examining three such teachers who nevertheless entered teaching through a traditional preparation program, Greenwood (2003) observed that the teachers persisted in a science teaching orientation that was in contradiction to the views of science teaching in their pre-service methods course. Koballa, Glynn, Upson, and Coleman (2005) discovered that despite science methods courses in the alternative certification program focusing on contemporary views of the nature of science, teachers’ views and practices were resistant to change; they did not become student-centered or adopt expansive learning goals that included the nature of science.

Findings: Views of Students. Students’ reaction of not being interested in learning for understanding caused teachers difficulty in implementing methods from their pre-service courses, both for second career teachers (Greenwood, 2003) and traditionally-prepared teachers

(Rodriquez & Berryman, 2002). Loughran (2004) found teachers reluctant to implement investigative science because of student desire for structured knowledge, and student disinterest in investigation. In another study, early-career teachers were unable to effect positive student perspectives of and engagement with the kinds of instruction recommended in pre-service (Mulholland & Wallace, 2003).

Powell (1997) found that teachers began with modern views of science and science instruction, but felt limited in implementing them by a context of low-achieving students. Similarly, Rodriquez and Berryman (2002) concluded that a school-wide teaching culture of low expectations for students was a strong barrier to an early-career teacher's reform-oriented science instruction. Sullivan and Leder (1992) found that while teachers' pedagogical beliefs about mathematics instruction had not narrowed, their student-related concerns affected implementation. Three White, fully prepared teachers, who had the support of an intensive induction program specifically focused on aiding novices' implementation of inquiry-based science instruction, still had quite limited success dealing with multicultural aspects of instruction with their mainly Hispanic students (Luft & Roehrig, 2005). While all three subscribed to constructivist views, their instruction moved toward more didactic teaching, using modes with which they were familiar in their backgrounds prior to the induction program. They saw this move as driven largely by limits in the abilities of their students rather than any change in their teaching beliefs.

Findings: Undisclosed or Unrecognized Counter-views. Even when early-career teachers do not implement the kinds of teaching from their pre-service program, they may still express belief that those teaching methods are ideal. Alternatively, they may have transformed their pre-service conceptions, seeing their practice as consistent with them when the faculty researchers did not.

In one of the few studies that was judged "satisfactory" on the standards of evidence, researchers looked at first- and second-year teachers from nine major preparation programs across the country that had been involved in a federally-funded project of the 1990s to reform mathematics and science teacher preparation (Simmons et al., 1999). These teachers described their practices as student-centered. However, researcher observations of teaching practices contrasted substantially with the teacher beliefs; early-career teachers behaved in more teacher-centered ways. Sammel (2006) similarly found a discrepancy between how five secondary science teachers described their instruction as reform-oriented and the researcher's observations. Huffman, Thomas, and Lawrenz (2008) investigated effects of a federally-funded program in the 2000s, which also involved reformed mathematics and science teacher preparation across multiple institutions, using self-report surveys of early-careers teachers and their students. When comparing responses of teachers and students from participating institutions to ones graduating from other institutions, the reported instructional practices were slightly more reform-oriented, less so in science than mathematics. Both Sammel (2006) and Ensor (2001) found that early-career teachers used labels and concepts from their methods course in a different way than professors intended when describing their practice, i.e., they used words that seem consistent with the prior program content when their teacher practices actually were adaptations or quite different from it.

From surveys of about 80 first-year science teachers and another 80 teachers who mentored them, Shea and Greenwood (2007) reported that mentors of the mentees who entered teaching from alternative routes indicated stronger mentee needs related to both general pedagogical knowledge and pedagogical content knowledge (PCK) than did mentors of early-

career teachers from traditional preparation; however, there was no difference between the two groups of mentees in their own survey indication of these kinds of needs, and mentors generally perceived the content knowledge of both groups to be sufficient.

Barriers to Implementation: Early-Career Teaching Conditions

Introduction. Even if early-career teachers subscribe to pre-service instructional approaches and do not run into influential counter-views, they may be particularly impacted by another set of barriers, that is, unsupportive teaching conditions: having an out-of-field teaching assignment; the lack of more extensive time often needed to prepare such instruction; and a lack of mathematics or science instructional supplies, equipment or facilities. Even if induction programs seek to bolster early-career teachers' subscription to and implementation of pre-service instructional methods, perhaps the impact of those efforts can be diminished when such teaching conditions are not also addressed.

Findings. Adams and Krockover (1997b) and Watson (2006) found teachers' concerns were around teaching out-of-field, including science teachers assigned out of their science field. As a result of the Watson study, his institution changed its preparation program to move prospective science teachers through an interdisciplinary science major rather than a major in a single science. Loughran (1994) found that by their second year, teachers felt more confident to consider student-centered instruction, but still felt constrained by time; they generally subscribed to views of student-centered instruction experienced in their pre-service programs, but felt it was more possible then due to more time available for preparation and support in helping them do so. Other researchers found that teachers became ambivalent about instilling characteristics of scientific investigation into their instruction because of limitations on its possibilities in the school conditions, including time and availability of appropriate curricular materials (Varelas, House, & Wenzel, 2005).

Several studies noted how lack of resources for science teaching limited the kinds of science taught (e.g., Appelton & Kindt, 1999; Mulholland & Wallace, 2003; Powell, 1997) and one study noted this issue for early-career mathematics teachers (Swan & Dixon, 2006). Teachers participated in multiple sessions and follow-up support on how to incorporate educational technology in secondary mathematics instruction: spreadsheets, motion detectors with graphing calculators, tours of available mathematics instructional software, and tutorials for the state's mathematics exam. The early-career mathematics teachers' interest in and intention to use of the technology shifted meaningfully on questionnaire responses, but actual use was limited due to serious school issues of access to computers and online connections. However, all teachers took their students to the computer lab more often than they had prior to the intervention. Similarly, Dawson (2008) found that while early-career teachers may be perceived as more willing and able to implement educational technology because they often are younger, science teachers who faced conditions that limited technology use did not overcome those barriers. Their pre-service program included explicit education about technology use in science teaching and end-of-program data had indicated strong intentions and interest in implementing educational technology.

Barriers to Implementation: Issues Particular to the Elementary School Level

Introduction. The cross-study findings discussed thus far emphasized secondary teachers, but they also were applicable to elementary teachers' mathematics or science instruction (Cady et al., 2006b; Ensor, 2001; Mulholland & Wallace, 2001, 2003; Steele, 2001, Sullivan & Leder, 1992; and Varelas et al., 2005). However, some studies of early-career elementary teachers focused on issues more particular to that school level: elementary teachers' confidence and efficacy in teaching science, or development of their identity as science teachers in the larger context of being an elementary teacher.

Findings. Early-career elementary teachers' low confidence in teaching science seemed to dampen the frequency and amount of science taught, but teaching more science led to more confidence in science teaching (Appelton, 2003; Appelton & Kindt, 1999, 2002). An analysis by Anderson Dragsted, Evans and Sorensen (2004) showed a correlational relationship between the change in elementary teachers' efficacy in teaching science over their first year with positive environmental conditions for teaching science. Ginns and Watters (1999) observed that positive reactions by elementary students to science instruction prompted early-career teachers to feel more confident in science instruction, but the increased confidence did not necessarily lead to increased science instruction. Beyer and Davis (2008) found that even an elementary teacher who was enrolled in a master's degree program in science education and had an uncommon confidence and record of focusing on teaching science effected only limited implementation of having students engage in constructing and communicating scientific explanations. In studying four subjects' identities and abilities as science teachers from pre-service through their first year teaching, Smith (2007) found that, as early-career teachers, they did not substantially include science teaching in describing their teaching identity, even when prompted; the researcher observed some growth but also continued notable teaching challenges in their subject matter knowledge and pedagogical content knowledge.

Potential Latent Implementation

Introduction. Secondary research findings in a few studies noted that early-career teachers who subscribed to reform-oriented instruction but were not implementing it, began to do so after a few years, without any early-career teacher invention being noted in the studies. It could be premature to discount the seemingly limited effects often found so far found in studies of early-career teacher interventions discussed in the next section, without first conducting more longitudinal investigation of the effects of induction programs or the effects of longer induction programs in augmenting this potential maturation phenomenon.

Findings. Bradford and Dana (1996) found that a biology teacher's pedagogical knowledge and skill was still developing in the third year, and the subject desired more opportunity for feedback than generally was available. Cady, Meier, and Lubinski (2006b) observed that subjects who had not exhibited practices consistent with pre-service in their first years were doing so in their sixth year of teaching, exceeding project expectations. The extent to which they were effecting desired instruction correlated with their locus of control, i.e., an internal locus of control correlated with more student-centered instruction. Greenwood (2003) noted that one teacher only began having serious interest in teaching revision in the third year. Two studies suggested that early-career

teachers' reflection on beliefs and practices for research purposes catalyzed changes in later stages of the studies (Adams & Krockover, 1997b; Rodriguez & Berryman, 2002).

Studies of Mentoring and Induction Interventions

Up to this point, we have discussed studies that investigated early-career teachers' beliefs and practices, without a study focus on any support or development provided to the teachers. In contrast, studies treated in this second of the two main article sections generally were designed primarily to investigate the effects of interventions intended to aid and develop early-career mathematics and science teaching. Table 3 groups the studies using two dimensions of the interventions: (1) Whether it was a single induction strategy, such as mentoring, or a larger induction program that involved a range of strategies or greater level of effort; and (2) the kinds of effects examined by each study.

TABLE 3

Research on early-career teacher interventions, by intervention type and types of outcomes studied

Intervention	Outcomes studied	Article, by first author(year)
induction strategy		
experienced teacher mentor	teacher beliefs, practices	Cwikla (04), Gustafson (02)
peer mentoring	teacher beliefs, practices	Britt (01); Cwikla (04), Dalgarno (06); Danielowich (07); Eick (02); Forbes (04), Goos (07);
facilitated action research	teacher beliefs, practices	Buck (05), Danlielowich (07), Justi (06); Lynch (97), Souto-Manning (07); Sweeney (01,03);
induction program		
	teacher beliefs, practices	Cwikla (04); Lee (07), Luft (01, 03, 05, 07a, 07b); Roehrig (06)
	teacher retention	Bang (07), Patterson (03)
	student achievement	Gimbert (06); Glazerman (06)

All identified studies of induction strategies focused on such proximal effects as teachers' beliefs and practices: Given the typically more limited nature of induction strategies (versus programs), these studies were not designed to clearly investigate more distal, robust effects such as teacher retention or student outcomes. Even the majority of studies focused on programs were limited to investigating the proximal effects of teachers' beliefs and practices. However, four studies of programs did investigate their effects on teacher retention or student achievement.

Three other studies investigated aspects of teacher retention that were not connected to any induction support or program. Noyes (2008) looked at the sociological strategies by which two prospective mathematics teachers chose, and were chosen, for their first teaching position. Both teachers quickly moved to different schools because they did not experience a strong fit

with the original teaching situation in ways that they either did not recognize or did not fully appreciate in advance. The author points out that the predominantly market-based mechanisms for determining where prospective teachers first teach are likely to produce such mismatches, resulting in teacher attrition from the school, or from the profession entirely. Two other studies were identified as investigations of “retention” of early-career mathematics or science teachers. However, they defined retention as graduates of teacher preparation program models initially entering teaching (Chuene, 1999; LaTurner, 2002); they are not discussed further because they do not fall in the scope of this review, i.e., retention of early-career teachers.

Before discussing results of the studies of interventions, we note some caveats about extant research into the effects of mentoring and induction programs.

(1) We often found that the description of the interventions were not sufficiently detailed for other researchers to be able to replicate the study, or for readers to consider in detail the generalizeability of the study.

(2) Study designs or reports seldom gave serious consideration to the possibility that the early-career teachers could be experiencing benefits from informal sources of support, in addition to or instead of the delivered induction strategy or program. This hazard is illustrated by Friedrichsen, Chval, & Teuscher (2007) who did ask early-career, secondary mathematics and science teachers about both the informal and formal sources of induction utilized. Participants especially discussed the value of the informal sources of support.

(3) Studies often tacitly make an assumption that teachers experienced the intervention mostly as intended, seldom clearly investigating or perhaps just documenting whether this is the case. The potential limitation of this for a study is illustrated in an investigation about implementation of a national induction program in England by Soares, Lock, & Foster (2008). They reported that while most teachers received the stipulated reduced teaching load, it was commonplace for administrators to usurp the intended planning time for non-teaching duties. Additionally, most teachers were assigned the required induction mentor, but the time spent together was irregular and sometimes infrequent.

(4) With respect to standards for general research study design, execution, analysis or reporting, there often were substantial methodological weaknesses among the entire set of studies in this review, as discussed in a later section.

Effects of Induction Strategies

As noted in Table 3, the identified articles treated three induction strategies: mentoring by an experienced teacher, peer mentoring, and facilitated action research.

Introduction: Experienced Teachers as Mentors. The most prevalent induction strategy employed in the field is using an experienced teacher as a mentor. No studies were designed to concertedly investigate the most common version of such mentoring, that is, day-to-day support and development from an experienced teacher or a full-time mentor. While such mentoring studies exist, they are not designed to expressly focus on specific understandings for mentor work with early-career teachers of mathematics or science. In this review, Gustafson (2002) studied a less common variant of mentoring. Cwikla (2004) did examine the mentoring component within a larger induction program and raised cautions about implementing the mentoring model.

Findings. Gustafson (2002) studied mentoring by experienced teachers in the context of a one-shot university session on elementary science teaching and a couple of follow-up observations by novices of the experienced teachers' instruction. Despite this limited level of effort, examples were observed of early-career teachers gaining science-specific teaching knowledge: appropriate grade-level science vocabulary; ideas for assessing students' science knowledge and skills; systems for identifying, purchasing, organizing and storing science resource materials; conducting science field trips; and higher levels of questioning.

Although the broader focus of a study by Cwikla (2004) was an intensive, multifaceted professional development program for early-career mathematics teachers, much of the article's emphasis is on the program's mentoring component. Both mentors and novices were mathematics teachers. Nevertheless, participants did not find the mentors to be valuable, noting that mentors spoke about logistics instead of mathematics content or teaching issues, or were negative about teaching. The problems appeared to be accentuated by the experience gap between mentors and early-career teachers; the novices felt that their mentors did not value their input. All the early-career teachers felt their content knowledge was stronger than that of the experienced teachers, and the illustrated examples seem to bear this out.

Introduction: Peer Mentoring and Online Peer Communities. While this induction strategy is a prominent, intentional element of some countries' induction systems (Britton, Paine, Pimm & Raizen, 2003), facilitated peer mentoring in the identified studies more often was a phenomenon that occurred naturally than a strategy explicitly utilized by the induction providers. Yet the early-career teachers indicated the importance of this strategy over the main induction strategy or program. Articles by Forbes (2004) and Eick (2002) as well as parts of some studies of other interventions attested to the potentially valuable role of face-to-face peer mentoring. Participants in two online modes of peer-communities for early-career mathematics teachers found them to be helpful.

Findings. Forbes (2004) describes changes they observed in early-career science teachers, which they attributed to facilitated peer mentoring activities: learned techniques for managing classroom environment with regard to safe conduct of student science activities; gained prompts for how content might be taught in ways that incorporate more student inquiry; better determined the level of content appropriate for their students; and joint planning of a lesson delving into the societal and technological implications of a science topic, a type of lesson that participants had not attempted previously. From a study of two early-career science teachers who job-shared a full-time position for their first year of teaching, Eick (2002) argued the importance of including peer-mentoring in induction models for the following reasons: more authenticity and relevance of peer perspectives, outside status to school culture fosters a vantage point that permits reflection on possible changes, and greater willingness to share and risk changes.

Cwikla (2004) also found that peer interactions were more valued by some mathematics novices than was the studied induction program treatment. In this case, experienced mathematics mentors provided weekly sessions about mathematics teaching. Interactions were sustained through email and calls between program sessions, primarily at the initiation of the participants. When asked how to improve the program, the most requested change by novices was an opportunity to observe their peers' mathematics teaching. In a study intended to investigate the effects of interventions by university faculty with three early-career teachers, one subject related that the power of study sessions was more strongly from the peer interaction that arose during

them, e.g.: “risks were taken”; “got validation from other teachers”; “heard what didn’t work” (Britt et al., 2001, p. 45). Friedrichsen et al. (2007) also noted that other early-career teachers offer a unique type of support, allowing novices to share their common experiences.

In two studies about peer communities among early-career mathematics teachers, an online site was created for use during the pre-service phase and on into the early-career phase of elementary or secondary teaching (Dalgarno & Colgan, 2007, and Goos & Benninson, 2008, respectively). The site for elementary teachers had wide-ranging purposes, interactions and resources, and was co-developed by faculty and the pre-service students with an explicit expectation of use in the early-career phase. Participants interacted extensively in the early-career phase and viewed its value for their development and practice as complementary to, and stronger than, that of typical professional development offerings for all teachers. The site for secondary teachers was primarily an online bulletin board discussion with less formal expectation of continued use into the early-career phase; a majority of early-career teachers did make use of the site. However, these early-career teachers also formed a user group for their peer interactions separate from the main site, which also housed interactions with later cohorts of pre-service students, in order to handle discussions in ways that they felt had important differences from the pre-service context.

Introduction: Intensive, Facilitated Action Research. Six studies of science teaching and one in elementary mathematics teaching indicated that early-career teachers’ instruction became substantially more reform-oriented and/or attentive to needs of diverse students when they conducted intensive action research into their practice in collaboration with university faculty. Tillman (2003) also examined effects of collaborative action research on an early-career science teacher, but data collection and results focused on general aspects of teaching rather than specifics of science instruction. Previously, we mentioned the potential need for teacher preparation programs to participate in subject-specific aspects of teacher induction. While this collaborative action research was a fruitful exemplar, it is not scaleable since only one or a few early-career teachers were impacted in these studies by a very intensive time investment from college faculty. However, such studies may develop more detailed understanding of early-career teachers’ subject-specific needs and suggest what should be addressed by other early-career teacher interventions.

Findings. Sweeney (2003) and Sweeney, Bula, and Cornett (2001) found that a chemistry teacher from an alternate route to teaching shifted his beliefs from being teacher-centered to more student-centered, and from using more didactic practices to more inquiry-oriented practices. Buck and colleagues (2005), in one of the few studies judged to have strong methodology, found that an early-career science teacher at the middle grades could better address needs of mainstreamed English Language Learners in science instruction when she engaged in action research on this aspect of her instruction, in collaboration with a university faculty member and a graduate student. In another study, two university faculty met weekly with an early-career elementary teacher for collaborative action research on how to make her mathematics instruction reform-oriented and effective for her very diverse students (Souto-Manning & Dice, 2007). The focal teacher was able to make data-based decisions and defend her methods to colleagues who held strongly different views on instructional methods. Students became more able to recognize mathematics in everyday life and began to perform better on standardized tests. Danielowich (2007) met weekly with a group of five early-career, secondary science teachers who had very

diverse students. The action research moved teachers from first recognizing conflicts between their own goals and practices toward taking action to systematically negotiate those conflicts with the support of their peers.

The phenomena in two other articles were more university course activities than formal action research. Justi and van Driel (2006) had five early-career science teachers enrolled in a university course use some action research to increase their content, PCK and curricular knowledge about models and modeling. Lynch (1997) had nine early-career science teachers teamed with pre-service teachers examine science education reform documents in depth and then create teaching units intended to fulfill those recommendations; while resulting units moved substantially more toward reform characteristics, only some teachers reported using the units in their classrooms.

Effects of Induction Programs

Introduction. Among the identified studies of induction programs, only three examined effects on early-career teachers' mathematics instruction (Cwikla, 2004; Gimbert et al., 2007; Glazerman et al., 2006). While the Cwikla study investigated a program, our discussion of it is placed in the previous section because that article primarily focused on the mentoring strategy within the program. The latter two, quantitative studies indicated that two prominent national programs for alternative routes to teaching did not disadvantage students' mathematics achievement.

Seven articles by one research group examined effects of a single induction program designed exclusively for early-career teachers of science, or compared their science-specific program with general induction programs. The reported effects generally are mildly positive. Patterson, Roehrig, and Luft (2003) found that personal factors can trump the influence of a program when it comes to why an early-career teacher stays or leaves a teaching position, or the profession. Several of the studies make an analogous point about how effects of programs on the nature of mathematics and science teaching can be dampened by the kinds of barriers discussed previously in this review. The potential influence of an induction program also may interact with a participant's route to teaching. Such a relationship could suggest the need for subject-specific induction programs to further differentiate some of their work for teachers having the different content backgrounds and experiences commonly found among teachers from different routes to teaching.

Findings: Difficulty of Sustaining Inquiry-oriented Science Instruction. Luft and colleagues developed an intensive, multi-year induction program specifically for early-career science teachers, with a heavy emphasis on empowering use of inquiry-oriented teaching and learning methods. All of the identified, available empirical research about subject-specific induction programs in science or mathematics comes from this team's study of participants in their program, with the exception of the Cwikla (2004) study mentioned above. At the outset, Luft (2001) examined the effects of a professional development effort for all science teachers on its early-career teacher participants. There was little shift in early-career teachers' beliefs about or use of inquiry-oriented science instruction.

After establishing a similar program tailored specifically to early-career teachers, the researchers found that participants in the science-focused induction program, compared to those in general induction programs or without an induction program, more frequently incorporated

labs (albeit traditional ones), group work, and instructional and technology-based materials (Luft, Roehrig, & Patterson, 2003). Assessment occurred infrequently among all teachers, but those in the science-focused program used less traditional forms of assessment, instead using frequent short quizzes with short answer and open response questions; the other two groups of teachers used more multiple-choice tests. The teachers in the science-focused induction group held significantly less didactic beliefs about teaching than did the teachers in the other two groups; they also commented on the student-centered, inquiry-based environments they were able to create because of their induction program, and they used the Internet in lesson preparation more than teachers in the other induction programs (Luft et al., 2003; Luft, Lee, Fletcher, & Roehrig, 2007).

In one of the few studies with a “satisfactory” SoE rating, Luft and Roehrig (2005) found that the type of previous science teacher preparation influenced what teachers derived from the induction program. Teachers from a M.Ed. pre-service program with extended student teaching and two science methods courses held beliefs aligned with student-centered practices and implemented more reform-based methods than did other teachers. They moved more seamlessly from their pre-service program to their first years of teaching. However, by the end of the first year, most teachers from an elementary-level program and the alternatively certified teachers also had beliefs and practices that were more reform-based. The teachers from the traditional undergraduate certification program had knowledge of a variety of inquiry-based strategies, but only one of them actually implemented any inquiry-based lessons.

In subsequent years, Luft, Roehrig, and colleagues launched another study in this line of investigation, again comparing effects of different kinds of induction programs on science teachers, but this time examining longitudinal changes. In results from the pilot study year, Lee, Brown, Luft, and Roehrig (2007) found that early-career science teachers, even ones with strong content backgrounds, had substantial weaknesses in PCK at the outset of their first year of teaching; their PCK became only marginally stronger after participation in a year of an induction program. Further, there were no significant differences in PCK when they began their first year of teaching, or growth after a year, among teachers in the different induction programs.

Findings: Teacher Attrition and Student Achievement. Patterson et al. (2003) investigated reasons that early-career science teachers in their induction program left teaching or moved to another school by their fourth year. They found that personal and contextual factors can trump even an intensive, science-specific induction program, i.e., these science teachers still quit teaching or changed positions. Some factors that were identified in this research are clearly outside a system’s control, but others could be addressed, e.g., the desirability or suitability of the initial teaching assignments in which early-career teachers are placed, in such characteristics as number of science preparations and diversity of students. Bang and colleagues further examined retention issues, this time in part by comparing retention issues among early-career science teachers in four different induction programs (Bang, Kern, Luft, & Roehrig, 2007). There were no significant differences in rates among teachers from the different programs. The researchers noted that many people who left teaching had made the decision to do so by February of their first year. The authors argue for more concerted teacher induction efforts in the earlier months of teaching rather than waiting toward the end of the year to check on teachers’ intentions.

In another study that had “satisfactory” SoE ratings, Glazerman et al. (2006) found that using Teach for America (TfA) teachers in elementary school did not disadvantage students in

their standardized test scores, when compared to students of all other teachers – novice, experienced, etc. In fact, students of TfA teachers had slightly better mathematics scores. Gimbert et al. (2007) investigated students’ mathematics scores for secondary teachers from the Transition to Teaching program, who also received a general induction mentor and a mathematics content coach. Students’ algebra test scores were comparable to those of students taught by early-career, traditionally-certified teachers.

Methodological Strength of Studies

As can be seen in Table 4, half of the studies analyzed for this review received an overall rating of poor, and 41 percent were rated limited in overall quality; only 9 percent were rated satisfactory. It is interesting to note that nearly half of the studies were rated satisfactory in their documentation of project activities, while relatively few studies were rated satisfactory in the areas of internal validity, analytic precision, or generalizability/external validity.

TABLE 4
Percentages of “satisfactory”, “limited” and “poor” ratings on measures of adequacy of documentation of project activities, internal validity, analytic precision, generalizability/external validity, and overall.

	Adequate Documentation	Internal Validity	Analytic Precision	Generalizability/ External Validity	Overall
Satisfactory	48	9	16	5	9
Limited	31	49	38	31	41
Poor	21	43	46	64	50

Reviewers especially looked at the extent to which the studies had the following “substantial limitations” in key areas, including: Sample Bias, Response Bias, Attrition Bias, Missing Data Bias, Investigator Bias, Qualitative Descriptive Validity, Measurement Validity, Reliable Measures, Appropriate and Systematic Analysis, and Selected Unit of Analysis. One-third of the studies had two or three substantial limitations; another third had four or five; and one-tenth of the studies had from six to nine substantial limitations. The most common substantial limitation was sample bias, with 60 percent of studies either not sufficiently explaining the sampling strategy or using a biased sample without taking any steps to ameliorate for possible effects of this. The other substantial limitations were each found in a third to half of the studies.

Applying the standards of evidence is not intended to make ‘good/bad’ or ‘in/out’ judgments on studies, or to suggest that all studies should be strong on every standard. Rather, the application of standards of evidence is conducted to aid understanding of the strengths and limitations of each study’s contributions to the knowledge base. Based on the above results, findings from most individual studies in the synthesis must be considered with caution. For example, logic suggests that sample bias and investigator bias could mean that the incidences of intended mathematics and science teaching modes being implemented by early-career mathematics and science teachers at large are even less common than the low frequencies found in these studies.

Implications for Induction Research and Practice

There are substantial gaps in what has been studied about early-career teachers and/or their induction in the specific subjects of mathematics and science; more studies are particularly needed in mathematics. Further, researchers have rarely differentiated specifics among teachers of different disciplines within mathematics or science. There is a pressing need for research on teachers who enter mathematics or science teaching through alternate routes.

More research on mentoring and induction interventions is needed. Few of such studies were designed to examine effects on student outcomes; preliminary results of a national, randomized treatment/control study of the effects of comprehensive teacher induction on early-career elementary teachers' retention, teaching practices, and their students' mathematics scores indicates no significant differences from teachers in more limited induction programs (Glazerman et al., 2008)¹. In a recent, in-depth discussion of research on teacher induction in general, the patterns that Strong (2009) found are similar to those in this review in mathematics and science teacher induction: "While most published findings, though few, are positive, taken as a whole they provide us with only thin evidence of the effectiveness of induction and mentoring (p.103)". He also points out many practical, methodological and financial barriers specific to conducting research in teacher induction that examines the phenomenon more rigorously and/or focuses on teacher retention, teaching quality or student outcomes rather than changes in teachers' beliefs and practices.

It is interesting to note that most subject-specific research to date has not focused on mentoring of early-career teachers by experienced teachers, the most prevalent kind of intervention. In a seminal, secondary analysis of a major national teacher database, the Schools and Staffing Survey, Smith and Ingersoll (2004) found that having subject-matched mentors was more strongly correlated with early-career teacher retention than having mentors from a different subject area. These researchers recommend more studies targeted on mentoring of early-career teachers in specific subjects to better understand that relationship.

The terrain of research into challenges and needs of early-career teachers needs to be expanded from PCK to also include content, curricular, and practical knowledge. Few studies identified for this review examined content knowledge among early-career teachers. Even fewer pursued curricular and practical knowledge as express study foci. By curricular knowledge, we mean such aspects of mathematics and science teaching as selection of topics, pacing of lessons, overarching flow and timing of lessons in units, etc. Examples of practical needs are how to teach investigative science safely, conducting field trips, and budgeting and ordering mathematics and science equipment and supplies.

In terms of methodology, there is no such thing as a perfect study, but more are needed that reduce threats to validity and increase generalizability, for example: Most extant studies rely on volunteers rather than randomly selected teachers; and more studies need to be conducted by researchers with greater independence from the study subjects or the interventions. Qualitative studies are needed that include greater numbers of teachers. A considerable amount of the

¹ While this paper does not treat research published after May 2009, we note that subsequent publications of this study in out years of its longitudinal tracking of impacts on beginning teachers indicated some positive findings for the induction program (Glazerman et al., 2010).

reviewed work is dated and cannot speak to developments of recent years that presumably exacerbate some of the tensions documented previously: more tightly prescribed content, curricula, lessons, and pedagogies as illustrated by today's district pacing guides or the like and accentuated by more large-scale assessments with higher stakes attached.

In some ways, the status of studies that investigate the effects of mentoring and induction interventions on early-career mathematics and science teachers parallels the development of such activities so far. The field of induction has only for a decade or so been seriously experimenting with development of programs that focus on novice mathematics and science teachers. Among mainstay induction programs serving early-career teachers of all grades and subjects, some do include program elements specifically tailored to mathematics and science teachers. However, studies of such general induction efforts generally examine the program as a whole, rather than including among their study foci any look at just the mathematics and science teacher participants. The studies of science teachers identified for this review were conducted by one research group on several aspects of a single science-specific program, which they had developed. Independent research of a wider variety of subject-specific mentoring and induction programs is needed. Longitudinal research could investigate the possibility raised in a few studies that early-career teachers who participate in these kinds of programs and initially do not implement reform-oriented instructional practices might do so later.

The topic of teacher induction lies within the larger field of professional development, but peer-reviewed journals are not a routine publication route for many who study and evaluate professional development. Therefore, a comprehensive knowledge synthesis on this emerging topic would need to include additional sources wherein such study and thought are more commonly found: research studies and evaluations by professional development and other organizations published in venues that are not research journals, as well as published expert advice, very current advice from experts that is not yet published, and expert advice from studies having negative results, which are unlikely to gain publication

The studies in this review illustrate many and substantial barriers that can inhibit early-career teachers' implementation of the mathematics and science teaching found in pre-service courses. Therefore, induction and mentoring programs should incorporate stronger subject-specific components. More experiments should be attempted in designing the recent types of secondary level programs that attempt this through specifically serving only teachers of mathematics or science. Limited evidence to date of the effectiveness of such programs does not mitigate the need to continue attempts to meet these needs while research is formulated. However, a range of constraints will limit the feasibility of subject-specific programs in many jurisdictions. Therefore, it is also important that induction programs that serve all early-career teachers experiment with ways to more expressly and concertedly differentiate some aspects of their service for teachers of different subjects. Addressing subject-specific needs on top of general needs common to all early-career teachers is likely to necessitate a more complex induction program or system for more than a year, and the involvement of subject-matched expertise in the relevant components. A study of teacher induction in five countries revealed such comprehensive induction systems that included strong attention to subject-specific needs of teachers (Britton, 2008; Britton, Paine, Pimm, & Raizen, 2003).

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