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ELEMENTARY SCIENCE TEACHER EDUCATION

Inspiring Instructional Change in Elementary School Science: The Relationship Between Enhanced Self-efficacy and Teacher Practices

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Abstract This longitudinal study examined the extent to which teachers' participation in a 3-year professional development program enhanced their self-efficacy and prompted changes in science instruction in the early elementary grades. The study used a mixed-methods design, and included 39 teachers who taught in kindergarten, first grade, or second grade classrooms in rural school districts. Data sources, administered pre-program and at the end of each year, included a self-efficacy assessment and teacher survey. Interviews and classroom observations provided corroborating data about teachers' beliefs and science instruction. Results showed significant increases in teachers' overall self-efficacy in teaching science, personal efficacy, and outcome expectancy efficacy during the 3 years. Gains in self-efficacy were correlated with changes in reported instructional practices, particularly student participation activities. However, changes in self-efficacy tended not to be correlated with changes in instructional time. Contextual factors beyond teachers' direct control, such as curricular and testing requirements in mathematics and language arts influenced time allotted to science instruction.

Keywords Self-efficacy · Teacher professional development · Science instructional strategies · Elementary education · Science education

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Introduction

Despite national standards that indicate science education should begin in the early grades, science is not a central part of curriculum and instruction in the early grades in the United States. Teachers have reported spending significantly more instructional time on mathematics and English language arts than science, a trend that increased after the No Child Left Behind legislation took effect in 2002 (McMurrer, 2007, 2008; Weiss, Banilower, McMahon, & Smith, 2001). Beyond the national emphasis on mathematics and English language arts in the early grades, elementary teachers do not feel qualified and confident to teach science. In elementary level classrooms, teachers typically are expected to teach all of the subjects included in the curriculum. However, elementary teachers do not report feeling equally qualified and prepared to teach every subject. In national polls in the US, few elementary teachers report feeling scientifically literate or having completed undergraduate majors in science or science education (Banilower et al., 2013; Olson & Labov, 2009; Weiss et al., 2001). A majority of elementary teachers report feeling less qualified to teach science than other academic subjects such as mathematics and language arts (Banilower et al., 2013; California Council on Science and Technology [CCST], 2010; Dorph, Shields, Tiffany-Morales, Hartry, & McCaffrey, 2011, Fulp, 2002; Olson & Labov, 2009; Weiss et al., 2001). In addition, elementary teachers indicate feeling more well-prepared to teach life science and earth science than physical science (Banilower et al., 2013).

Elementary teachers' reasons for not feeling qualified to teach science often stem from their preparation as undergraduates and credential candidates. Prospective elementary teachers tend to avoid pursuing coursework in science as undergraduates unless required to do so, and they report taking more science classes as high school students than as undergraduate students (Tosun, 2000). In their undergraduate coursework, elementary teachers take more college courses in biology than other science subfields. Whereas 90 % of elementary teachers complete at least one course in the life sciences as undergraduates, the percentage drops to 65 % for earth science, 47 % for chemistry, and 32 % for physics (Banilower et al., 2013). Although science is a component of elementary teacher certification, there is significant variation across universities in the number of science credits that are required and in the alignment with teacher preparation programs (CCST, 2010). Researchers report that prospective elementary teachers are less comfortable with science as undergraduate students and encounter entry-level science courses that are not specifically designed for those preparing to earn teaching credentials (CCST, 2010). Consequently, they are unable to see the connection between the content of their undergraduate science courses and the content they will be teaching to elementary-aged students. In addition, as undergraduates, prospective elementary teachers often develop science anxiety or negative attitudes about science that can be challenging to overcome in teacher preparation programs (Morrell & Carroll, 2003; Mullholland, Dorman, & Odgers, 2004; Palmer, 2006; Tosun, 2000). Science methods courses can help decrease anxieties about science for prospective elementary teachers (Morrell & Carroll, 2003; Palmer, 2006) but are insufficient or lacking in some programs. Moreover, student teaching does not appear to increase prospective teachers' confidence in teaching science but rather has been found to have a negative effect on their beliefs about being able to foster student learning in science (Plourde, 2002).

Without confidence in their abilities to teach science, many elementary teachers are inclined to devote more instructional time to other subjects in which they feel better prepared. In contrast to daily instruction in mathematics and reading/language arts, only 20 % of classes in kindergarten through grade 3 (K-3) receive science instruction on most days, and many classes receive science instruction only a few days a week or during some weeks of the year (Banilower et al., 2013). In the past decade, the amount of instructional time spent on science has declined rather than increased. In 2000, K-3 teachers in the US spent an average of 23 min a day teaching science (Weiss et al., 2001), but in 2012, K-3 teachers spent an average of 19 min on science instruction (Banilower et al., 2013). McMurrer (2008) reports that, in more than half of school districts, instructional time in science has been reduced by at least 75 min per week. When elementary teachers do teach science, a lack of confidence may influence the instructional strategies they use. In reporting about their most recent science lesson, 89 % of K-3 teachers explained a science idea to the whole class while 40 % conducted a demonstration while students watched, and 52 % involved students in doing hands-on activities (Banilower et al., 2013). Researchers find that teachers with more confidence in teaching science tend to use more student-centered approaches instead of relying on textbook-centered instruction (De Laat & Watter, 1995). Teachers with high self-efficacy are more likely to try new ideas and implement innovative and challenging instructional methods in the classroom (Ross, 1998; Tschannen-Moran, Hoy, & Hoy, 1998). Teachers who feel less confident teaching science avoid strategies, such as demonstrations and inquiry-based instruction, which may reveal their limited background knowledge in science. In a study of middle school teachers, researchers reported a positive correlation between teachers' gains in science teaching self-efficacy through professional development and their implementation of standards-based, inquiry-oriented instructional strategies (Lakshmanan, Heath, Perlmutter, & Elder, 2011).

Elementary teachers identify a substantial need for professional development to build their content knowledge in science; but they also report limited access to professional development (Fulp, 2002; Weiss et al., 2001). In a California study, 85 % of elementary teachers reported participating in no professional development in science in the preceding 3 years (Dorph et al., 2011). This lack of opportunities is problematic because researchers find that professional development offers a valuable means for improving teachers' ability to teach science. The Local Systemic Change through Teacher Enhancement Program, which involved 88 projects across the country that focused on STEM professional development, reported increases in teachers' preparedness in pedagogy and science content (Banilower, Boyd, Pasley, & Weiss, 2006; Bowes & Banilower, 2004). Researchers also identified a positive relationship between the extent of teachers' participation in professional development and their use of reform-oriented teaching practices and the quality of observed lessons (Banilower et al., 2006; Heck, Rosenberg, & Crawford, 2006; Supovitz & Turner, 2000). The Math and Science Partnership

Knowledge Management and Dissemination Projects (2008) similarly documented the value of professional development in building teachers' abilities to teach science. Results from the Rural Systemic Initiatives also indicated that professional development helped improve teachers' content knowledge and teaching practices in science (Harmon & Smith, 2007). In addition, research on smaller professional development programs reported that teachers' participation enhanced their content knowledge and instructional practices in science (Basista & Matthews, 2002; Gess-Newsome, 2001; Johnson, Fargo, & Kahle, 2010).

Although research has established the potential of professional development to improve science instruction and the importance of teachers' confidence in their abilities in classroom instruction, few studies focus on the impact of professional development on the self-efficacy of teachers in elementary schools (Brand & Moore, 2011; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013; Posnanski, 2002; Roberts, Henson, Tharp, & Moreno, 2001). Even fewer studies examine the science teaching self-efficacy of teachers in the early elementary grades (Duran, Ballone-Duran, Haney, & Beltyukova, 2009; Zhang et al., 2010). This study addresses this need by focusing on teachers assigned to K-2 classrooms. Moreover, the study includes data collected pre-program and over the subsequent 3 years. Whereas other research has investigated changes in self-efficacy in science based on the duration (number of weeks) of inservice activities (Roberts et al., 2001), this longitudinal study examines the impact of ongoing professional development over an extended time period.

In this study, we examine the extent to which early elementary teachers' participation in a 3-year professional development program enhanced teachers' self-efficacy and prompted changes in science instruction. Our specific research questions include: Does participation in a 3-year professional development program lead to changes in early elementary teachers' overall self-efficacy related to teaching science, personal beliefs about their abilities, outcome expectancy beliefs, and perceptions of their preparedness to use science instructional strategies? Do changes in teachers' self-efficacy correspond with changes in teachers' instructional practice in science?

Theoretical Framework

The theoretical framework for this study is based on two strands of research. The first strand focuses on the construct of self-efficacy and the second strand offers an operational theory of how professional development influences teachers' beliefs. Bandura (1997) defined perceived self-efficacy as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Applied to teachers, self-efficacy refers to teachers' beliefs about their ability to teach effectively and thereby promote student learning (Ashton & Webb, 1986). If teachers have confidence in their abilities, they take actions in the classroom that stand to influence student outcomes. Perceived self-efficacy not only influences choice of activities but also, depending on expectations of eventual success, influences how much effort one will expend and how long one will persist in these activities (Bandura, 1977). Teachers, for example, who do not anticipate being successful likely make less effort during preparation and instruction and give up more quickly in the face of difficulty (Tschannen-Moran & Hoy, 2007).

Bandura (1977) proposes that self-efficacy includes both personal efficacy and outcome efficacy. Personal efficacy involves the level of confidence about one's own abilities to engage successfully in activities that will produce certain outcomes. Outcome efficacy involves an individual's belief that given behavior will lead to specific outcomes. Bandura (1977) distinguishes between the two because individuals may believe that particular actions will produce certain outcomes but have doubts about their abilities to perform the necessary activities. In this type of situation, individuals may opt not to initiate or continue particular activities. In the case of teaching, teachers may believe that student learning depends on effective teaching but lack the confidence about their own abilities to engage in particular instructional activities. Conversely, teachers may have confidence in their teaching skills but have doubts about the extent to which their actions will influence student learning, given other factors such as student background or socioeconomic status (Gibson & Dembo, 1984).

According to Bandura's social cognitive theory (1977), the key construct is perceived beliefs about one's capabilities rather than an individual's actual abilities. Individuals may or may not have accurate assessments of their capabilities, but their estimations influence the courses of action they choose to pursue (Bandura, 1997; Goddard, Hoy, & Hoy, 2004). Over- or under-estimations of capabilities may influence not only one's actions but also the extent to which individuals make good use of the skills they possess (Bandura, 1997; Goddard et al., 2004). For example, teachers may have equivalent skills but self-doubt may influence one teacher's execution of a particular instructional strategy during classroom instruction. Perceived self-efficacy differs from other concepts such as self-esteem and self-worth because it is specific to a particular task (Goddard et al., 2004). An individual may possess low self-efficacy for a specific activity but maintain high self-esteem because the person is not invested in doing well at that particular activity. In addition, individuals may have high expectations for success in one activity but not another. Researchers who studied the high school level found variance in teachers' perceived self-efficacy depending on the particular subject matter and group of students (Raudenbush, Rowen, & Cheong, 1992; Ross, Cousins, & Gadalla, 1996). Given the multiple subjects included in the elementary level curriculum, elementary teachers' self-efficacy may differ across subject areas even with the same group of students.

Self-efficacy is not static but rather is subject to change. Researchers propose that personal self-efficacy, or confidence in one's abilities, tends to precede outcome efficacy and can contribute to outcome expectancies (Bandura, 1977; Tschannen-Moran et al., 1998). The reciprocal relationship between personal and outcome efficacy can create a cycle of reinforcement. As one's confidence increases and influences performance, the successful effects of one's efforts in turn build confidence. Bandura (1977, 1997) proposed four main sources of influence on self-efficacy: mastery experiences, vicarious experience, social and verbal persuasion; and affective state. Mastery experiences are a direct and powerful source. When individuals master a particular task, self-efficacy increases; but if individuals perceive failure at the task, self-efficacy is lowered and may contribute to expectations of failure in the future. For teachers, mastery experiences involve actual teaching experiences with students. The affective state of the teacher contributes to feelings of capability or incompetence. Feelings of pleasure from teaching a particular lesson may increase self-efficacy beliefs, but anxiety and worry, sometimes associated with fear of losing control, may lower self-efficacy (Tschannen-Moran & Hoy, 2007). With vicarious experiences, another person models the particular activity, and the observer's self-efficacy may be influenced depending on the extent to which the observer identifies with the model. Witnessing a competent performance may not enhance the self-efficacy of the observer if "the model differs in ways that seem salient to the observer, for examples in terms of the level of experience, training, gender, or race" (Tschannen-Moran & Hoy, 2007, p. 945). For teachers, social and verbal persuasion occurs when they receive positive or negative encouragement or verbal feedback from other people in the teaching context.

Teacher professional development has the potential to incorporate these four main sources of influence on self-efficacy. When teachers participate in professional development, they have the vicarious experience of observing another person model particular teaching strategies. Those providing the professional development typically have the background experience and qualifications to be viewed as competent by the participating teachers, which heightens the influence on self-efficacy. Following the vicarious experience, teachers engage in mastery experiences when they implement the teaching strategies in their classrooms. As teachers experience success with these new instructional practices, they feel more capable and confident in using them. Social and verbal persuasion may occur when teachers receive encouragement from leaders and other participants during the professional development as well as feedback following their implementation of new instructional strategies. Teachers' affective state may be enhanced if their anxieties about teaching are lessened as they gain knowledge and experience through professional development and if they feel gratification from successful teaching activities.

Teachers' beliefs about their ability to teach in a particular context stem from their judgments about the requirements of an anticipated teaching task and their assessment of personal teaching competence in relationship to those requirements (Tschannen-Moran et al., 1998). Elementary teachers may perceive, for example, that teaching science would require time to develop lessons, additional resources and materials, collegial and administrative support, and content knowledge across sub-fields in science. In assessing their personal capability to teach science in their particular context, teachers might question their background knowledge in science, the amount of time needed, or the availability of resources and support. Although they may believe that science is an important subject and that students' interest in science is high, they may perceive that the requirements of teaching science are greater than their personal teaching competence.

Professional development, when well-designed and fully implemented, offers a means of shifting teachers' perceptions about the balance between the requirements and their capability to teach science. Researchers posit that changes in teachers' self-efficacy are an important step in influencing teachers' instructional practices. Drawing upon the research literature, Desimone (2009) presents a four-step model that "represents interactive, nonrecursive relationships between the critical features of professional development, teacher knowledge and beliefs, classroom practice, and student outcomes" (p. 184). In this model, teachers first participate in effective professional development. This participation increases their knowledge and skills and/or leads to changes in attitudes and beliefs. Given their new knowledge and skills (or attitudes and beliefs), teachers improve their instruction through changes in content, pedagogy or both. These changes in instructional practice promote increased student learning.

Methods

Participants

The professional development program drew participants from 16 schools in 16 small, rural school districts in four counties in northern California in the US. Half of the districts were one-school districts in which a particular grade level may have only one teacher. Student enrollment in the school districts ranged from 148 to 5,087, and the poverty level ranged from 11 to 30 % of families. Student performance on standardized tests indicated low academic achievement, with an average of only 32 % of students in the second grade scoring "proficient" in math, and only 27 % scoring "proficient" in English language arts. All K-2 teachers in the partner schools were invited to participate, and the program began with 44 teachers representing all 16 schools. Similar to national demographics for elementary teachers (National Center for Education Statistics, 2011), 91 % of the teachers were female and 89 % were white. All of the teachers had completed some university coursework in science; 26 % had completed 5 or more semesters and 9 % had completed only one semester. Participating teachers had a broad range of teaching experience; for example, 17 % had taught for 2 years or less and 17 % had taught for 22 years or more. By the end of the first year, two teachers had left the program, one was assigned to teach fourth grade, and two had died. Of the 39 remaining teachers, ten taught in kindergarten, nine in first grade, and 20 in second grade classrooms.

Program Description

The professional development extended over 3 years and focused on increasing teachers' content knowledge and fostering the use of research-based instructional strategies in science. Considered a characteristic of effective professional development (Hewson, 2007; Loucks-Horsley, Stiles, Mundry, Love, & Hewson, 2009; Weiss, 1999), a combined focus on content and pedagogy allows teachers to build subject matter knowledge while learning specific strategies to use in their classrooms. The program was developed by professional development experts who lived in the rural communities and who understood the contextual challenges.

To tailor the program to the K-2 level and the participants, the developers administered a pre-intervention survey to determine teachers' needs. Neither author of this paper was involved in designing or providing the program.

The program included three key components: (a) intensive adult-level science content instruction; (b) pedagogical training focused on science instruction and how to connect science to language arts and mathematics; and (c) training and support to facilitate teacher collaboration. Table 1 displays the program features within each component. The content and pedagogical instruction took place during summer institutes, regional meetings, and school site sessions that provided teachers with over 100 contact hours. Each summer, the teachers participated in an intensive 6-day institute led by a team that included a university professor (with expertise in science and advanced mathematics), an elementary teacher (with expertise in research-based instructional strategies and science inquiry), and an English language learning specialist. During each subsequent school year, teachers participated in additional sessions and follow-up activities held at both regional and school levels. A report by The National Staff Development Council (Darling-Hammond, Wei, Andree, Richardson, & Orphanos, 2009) indicates that the most effective professional development programs are sustained and intensive, offering 30–100 contact hours spread over time. The contact hours for this program were at the top of that range and extended over 3 years.

The content instruction was based on topics included in the California state science standards and focused on a different branch of science each year (physical science in year one, earth science in year two, and life sciences in year three). The program incorporated adult-level science content instruction with research-based instructional strategies. Teachers learned science content through pedagogical approaches that they could subsequently use in their classrooms. Instructors emphasized and modeled the use of scientific inquiry, such as hands-on investigations and experiments. They introduced teachers to the elements of scaffolded-guided inquiry and helped teachers develop inquiry-based science units. Students develop deeper conceptual understanding in science when teachers provide supports and scaffolds to guide students in scientific reasoning (National Research Council, 2005). In grade-level teams, teachers learned how to use a curriculum-mapping tool that included documenting curriculum,

Table 1 Professional development program

Science content instruction	Pedagogical training	Teacher collaboration
Summer institute	Research-based instructional strategies	Website
Regional meetings	Scientific inquiry	Team development of curriculum maps
School sessions	Hands-on experiments & investigations	Regional meetings
	Scaffolded guided inquiry	Special events
	Curriculum mapping tool	
	Integration of science/math/language arts	
	Mathematical processes in science	
	Student science notebooks	
	Sample lessons on website	

planning for implementation of standards, and matching assessment with instruction. The maps encompassed not only the content to be taught but also instructional and assessment strategies.

During the professional development, instructors also helped teachers integrate science with mathematics and language arts instruction and emphasized instructional strategies shown to be effective for English Language Learners (ELL). Science provides rich contexts and concrete phenomena for demonstrating mathematical patterns and relationships, and mathematics provides tools for analysis of science concepts and applications. To demonstrate these connections, professional development sessions included opportunities for teachers to estimate, use mathematical models, classify, and make and interpret graphs while learning science content. For integrating science and language arts instruction, the program taught participants how to use student science notebooks. Including more writing in science allows teachers to gauge students' explanations of their understanding of science concepts and uncover possible misconceptions. In addition, the integration of science and literacy benefits students' development and learning in both areas (Cervetti, Barber, Dorph, Pearson, & Goldschmidt, 2012).

The program also aimed to enhance collaboration among teachers in these rural settings in which a teacher often was the only one working at a particular grade level. By organizing teachers into "clusters" of schools determined by geographic proximity, the program wanted to create professional learning communities where teachers could support each other and offer curricular assistance. Teachers gathered in cluster meetings during each academic year to work on curriculum articulation, discuss curriculum maps and instructional strategies, and plan events such as family science nights. To further encourage and facilitate collaboration across schools, the program hosted a website where all participating teachers could communicate, share lesson plans, and access instructional resources.

Data Sources

Data sources for this study included a self-efficacy assessment, a teacher survey, interviews, and classroom observations. The self-efficacy assessment, the Science Teaching Efficacy Beliefs Instrument (STEBI), developed by Riggs and Enochs (1990), focuses on teachers' beliefs about their effectiveness in teaching science. The instrument was appropriate for this study because it was specifically designed to measure self-efficacy in science teaching, was developed for use with elementary teachers, and has been widely used in studies of teacher efficacy. The STEBI consists of 25 items with a 5-point Likert-scale response that ranges from strongly disagree (a score of "1") to strongly agree (a score of "5"). The instrument consists of two sub-scales, the personal science teaching efficacy belief scale (PSTE) and the science teaching outcome expectancy scale (STOE). The PSTE sub-scale measures teachers' beliefs in their own abilities to teach science and the STOE sub-scale measures teachers' beliefs about the extent to which student learning depends on effective teaching. Reliabilities for the two sub-scales are .91 for the personal science teaching belief scale and .73 for the science teaching outcome expectancy scale (Riggs & Enochs, 1990). Thirteen of the items are positively worded (e.g., I am continually finding better ways to teach science), and twelve are negatively worded (e.g., I generally teach science ineffectively). Teachers completed the self-efficacy assessment four times: prior to the program and in the spring of each of the three academic years.

The teacher survey focuses on teachers' opinions about science and science instruction, their preparedness, and their instructional practices. This instrument, prepared by Horizon Research (2000) with support from the National Science Foundation, was developed for national studies of science teaching at the elementary level. Reliabilities are .80 for each composite variable of the instrument (Germuth, Banilower, & Shimkus, 2003). Teachers completed the teacher survey before participating in the professional development and at the end of each academic year. For this study, we analyzed data from survey questions related to teachers' self-efficacy and to teachers' instructional practices. The questions about self-efficacy included a series of seven questions related to teachers' sense of preparedness to engage in various instructional strategies related to teaching science (e.g., leading a class of students using investigative strategies). The 4-point Likert scale response ranged from not adequately prepared (a score of "1") to very well prepared (a score of "4"). Another question, using the same 4-point scale, asked teachers how prepared they feel to teach various content areas including science, mathematics, reading/language arts, and social studies. The questions about instructional practices included a series of questions about frequency and length of science lessons and a series of questions about frequency of use of various instructional practices in science. Since the self-efficacy assessment and the survey are based on teachers' self-reports, it is possible that teachers overestimated their self-efficacy and sense of preparedness. However, we think this possibility was lessened in this study for three reasons. First, the data were collected by researchers not those who designed and implemented the program. Second, the instruments were administered four times: pre-program and in the spring of the subsequent 3 years. It is unlikely that teachers would remember their responses from 1 year to the next. Third, the instruments have been widely used in national studies of elementary teachers and were not created by the program designers.

As part of the larger research project, researchers conducted classroom observations of a strategic sample of 20 participating teachers in the spring of each year. Researchers selected teachers from five schools (one from each county, as well as the school serving as the Local Educational Agency) that were representative of the entire group of program schools in terms of student demographics. Observations were conducted by one of two researchers. Researchers scheduled the observation in advance on a day and time that would allow the researcher to watch an entire science lesson. The length of the observations varied depending on the duration of the science lesson. Researchers took notes, collected relevant documents, and used a rubric to rate lessons on instructional strategies promoted in the professional development sessions such as facilitated exploration, inquiry, literacy strategies, and content integration. For each item, the rubric included descriptions for ratings of 1–4. For example, for use of appropriate materials that support inquiry, the descriptions were: 1—lesson is not supported by use of appropriate materials; 2—lesson uses only text when inquiry is required (students read about it instead of "doing it"); 3—lesson uses appropriate inquiry-based materials; 4—lesson incorporates all materials as needed (may include text, support of worksheets, hands-on materials, etc.). To establish inter-rater reliability before conducting observations, the two observers watched videos of K-2 science lessons, individually scored the lessons using the rubric, and met to discuss their ratings. The classroom observations provided corroborating data about science instruction and pedagogical strategies.

Using strategic random sampling to ensure representation from each school district, researchers selected 12 of the 20 teachers who were observed to participate in semi-structured interviews at the end of each year. Interview questions, as part of the larger research project, covered a range of topics such as instructional time, content knowledge, curricular choices, instructional choices, confidence in teaching science, supports and resources for teaching science, and integration of science into other subjects. The interviews were audio-recorded and transcribed. For this study, the interviews provided both elaborated descriptions of teachers' perceptions of preparedness and corroborating data about teachers' beliefs about their effectiveness in teaching science.

Data Analysis

The study employed a mixed-methods design to take advantage of the complementary strengths of quantitative and qualitative approaches (Johnson & Turner, 2003). We adopted a quantitative dominant concurrent triangulation strategy (Creswell, 2003), in which the quantitative surveys and qualitative interviews and observations occurred in the same phases of the research. The primary data sources were the surveys; the data from interviews and observations were used for both elaboration of participants' perceptions and classroom instruction and for triangulation of findings. We analyzed data from the self-efficacy assessment to examine changes in teachers' overall self-efficacy, personal beliefs efficacy, and outcome expectancy efficacy, all related to teaching science. Responses of negatively worded items within each scale on the self-efficacy assessment were reversed and re-coded before analysis. We analyzed the data to examine changes over time in teachers' self-efficacy. We completed paired sample two-tailed *t* tests in order compare each individual teacher's response prior to the program to his or her response at the end of the program. We analyzed teachers' total scores on the assessment to determine changes in overall self-efficacy and then disaggregated the estimates for each sub-scale. We analyzed the PSTE sub-scale scores to identify changes in teachers' personal beliefs about their abilities to teach science and the STOE sub-scale to identify changes in student learning outcome expectancies. The number of paired samples used in the analysis differed each year for two main reasons. First, some teachers failed to list their identification number on the survey or listed an incorrect number, making it impossible to match their data from pre-program to the end of the program. Second, some teachers did not respond to all survey items. For each analysis using paired *t* tests, the sample included only those teachers for whom we could match pre-program and end-of-program data.

To examine changes in teachers' perceptions of their preparedness to use specific instructional strategies when teaching science, we analyzed data from the teacher survey and interviews. We first calculated percentages for each response category on relevant survey questions and looked for changes in the percentages across each administration of the survey. To compare individual teacher's responses prior to the program with responses at the end of the program, we completed paired sample *t* tests using individual teacher data from pre-program and end-of-program administrations. Analysis of the interview data followed qualitative research procedures such as coding and data displays (Bogdan & Biklen, 1998). As part of the larger research project, interview transcriptions were compiled in an electronic database and coded initially according to five a priori codes generated from the conceptual framework: content knowledge, self-efficacy, instructional time, instructional strategies, and contextual factors. A second round of coding identified emergent sub-categories; for example, sub-categories in the contextual factors category included curricular demands, administrative support, teacher support, and resources. For this study, we examined teachers' interview responses to corroborate and explicate the survey findings and to provide a more elaborated understanding of teachers' perceptions of their preparedness (Johnson, Onwuegbuzie, & Turner, 2007).

To investigate if changes in science teachers' self-efficacy corresponded with changes in teachers' instructional practice in science, we calculated change scores from pre-program to end-of-program for each teacher's overall self-efficacy, PSTE sub-scale, STOE sub-scale, and survey questions about instructional practices. Paired-samples correlations were completed with the change scores, whereby the quantitative software program could estimate the association between the change in teachers' self-efficacy and change in reported instructional practices. We analyzed the observation data to determine if instructional practices reported in the surveys corroborated with the teaching strategies observed by researchers.

Results

We organize the results according to the research questions. In the first section, we report on changes in teachers' overall self-efficacy related to teaching science, their personal beliefs in their own abilities to teach science, and their beliefs about the extent to which student learning depends on effective teaching. We then report on changes in teachers' perceptions about their preparedness to teach science, and finally examine if changes in teachers' self-efficacy corresponded with changes in their instructional practices in science.

Teachers' Self-efficacy

Results from the self-efficacy assessment (STEBI) indicate that teachers' overall self-efficacy in teaching science increased throughout the professional development. Teachers' overall self-efficacy scores showed a significant increase after year one [$t(36) = 4.14$, $p = .000$] and again after year two [$t(32) = 5.62$, $p = .000$]. Paired sample *t* tests comparing pre-program and end-of-program data indicated a significant increase in teachers' overall self- efficacy in teaching science [t(22) = 5.94, *p* = .000].

Teachers' personal science teaching efficacy also increased during the professional development program. For example, 46 % of teachers questioned if they had the necessary skills to teach science before the professional development. This percentage dropped to 10 % a year later and to 7 % by the end of the 3-year program. In contrast to 51 % pre-program, no teachers reported not knowing the steps necessary to teach science concepts effectively by the program's end. The percentage of teachers who indicated they understood science concepts well enough to teach elementary science effectively was 43 % pre-program and 94 % at the end of the program. Paired sample *t* tests, comparing pre- and end-of-program data on the PSTE sub-scale, indicated a significant increase in teachers' beliefs about their own ability to teach science [t(23) = 6.46, *p* = .000].

Teachers' outcome expectancy efficacy, their beliefs about the extent to which student learning in science depends on effective teaching, followed a similar pattern over the course of the program. For example, prior to their participation in the professional development, 77 % of the teachers indicated that the teacher is generally responsible for the achievement of students in science. This percentage increased to 85 % after the first year and 96 % by the end of the program. In contrast to 62 % pre-program, 93 % of teachers reported, at the end of the program, that the inadequacy of a student's science background can be overcome by good teaching. The percentage of teachers who indicated that a student's increased interest in science at school is likely due to the teacher's performance shifted from 71 % pre-program to 97 % at the end of the program. Paired sample *t* tests, comparing pre- and end-of-program data on the STOE sub-scale, indicated a significant increase in teachers' outcome efficacy [t(23) = 4.19, *p* = .000].

Results from the self-efficacy assessment showed significant increases for each of the three measures: teachers' overall self-efficacy in science teaching, their personal beliefs about their ability to teach science, and their outcome expectancy beliefs about the extent to which student learning in science depends on effective teaching. Over the course of the professional development, teachers became more confident about their personal skills for teaching science and increasingly believed that their classroom instruction in science would promote student learning. Their overall attitudes about engaging in science instruction became more positive.

Teachers' Perceptions About Preparedness to Teach Science

In addition to the self-efficacy assessment, data from the teacher survey indicate changes in teachers' comfort level in teaching science and the extent to which they felt prepared to engage in various instructional strategies related to teaching science. Before the professional development, a majority of the participants (67 %) indicated that they felt "somewhat prepared" or "not adequately prepared" to teach science., and as displayed in Table 2, the teachers felt more prepared to teach mathematics, reading/language arts, and social studies than science. Each year, a higher percentage of teachers reported feeling "very well prepared" to teach science, shifting from 9 % pre-program to 78 % at the end of the 3 years. By the end of the program, 100 % of the teachers responded that they felt "fairly well prepared" or "very well prepared" to teach science. Teachers continued to feel more prepared to teach reading/language arts and mathematics than science, but by the second year, more teachers reported feeling "very well prepared" to teach science (59 %) than social studies (28 %).

Teachers' perceptions about their preparedness to engage in science-related instructional strategies also shifted over the 3 years. Prior to the program, only 7 % of the teachers reported feeling "very well prepared" to lead a class of students using investigative strategies. This percentage shifted to 21, 54, and 81 % at the end of years one, two, and three, respectively. Similarly, before the professional development, 16 % of the teachers felt "very well prepared" to manage a class of students engaged in hands-on/project-based work and 21 % felt "very well prepared" to help students take responsibility for their own learning. By the end of year three, the percentages had increased to 78 and 75 %, respectively. In contrast to 30 and 26 % pre-program, 84 % of teachers felt "very well prepared" to encourage students' interest in science and to recognize and respond to student diversity by the end of the program. The two areas with the smallest shifts from pre-program to end-of-program were involving parents in the science education of their students and using strategies that specifically encourage participation of females and minorities in science. Only 5 and 12 % of teachers reported feeling "very well prepared" for these strategies prior to the program; these percentages increased to 50 and 56 % by the end of year three. As displayed in Table 3, paired sample *t* tests showed statistically significant changes in teachers' perceptions about their preparedness to engage in each strategy included in the survey question.

In interviews, teachers described changes in their self-efficacy over the course of the professional development. Some teachers related how their lack of background knowledge in science had contributed to a lack of confidence, and how building their content knowledge in science was influencing their confidence to teach it, as quotes from two teachers illustrate:

> My confidence level was about a "1" twenty years ago. I felt more confident teaching other subjects. Now my confidence in science is about the same as in other subjects. The more knowledge I get about the content, and how to present it, the more confident I am… I am so much better educated in science due to [the professional development program].
>
> I feel like it is going back to college and getting the content. It is delivered in a more understandable way than when I was in college. The content sticks and stays with me. I think because it is relating to something that I am actually doing. When I was getting my BA, it was basically just doing a lab and reading a text. I wasn't applying it to anything. I am now getting all of this college level content, and I can apply it to my classroom.

In addition to increased content knowledge, teachers described how model lessons that were incorporated into the professional development helped them feel more prepared to teach science. One teacher suggested that the professional development had a "huge impact" on her confidence in teaching science because it

Table 2 Teachers' perceptions about preparedness to teach content areas

Content area	Pre-program				Year 1				Year 2				Year 3			
	1 (%)	2 (%)	3 (%)	4 (%)	1 (%)	2 (%)	3 (%)	4 (%)	1 (%)	2 (%)	3 (%)	4 (%)	1 (%)	2 (%)	3 (%)	4 (%)
Science	16	51	23	9	0	5	72	23	0	3	38	59	0	0	22	78
Mathematics	0	5	28	67	0	0	38	62	0	0	18	82	0	0	16	84
Reading/lang. arts	0	5	23	72	0	0	26	74	0	0	15	85	0	0	3	97
Social studies	9	42	33	16	3	13	62	23	0	18	54	28	0	13	44	44

1 Not adequately prepared, *2* somewhat prepared, *3* fairly well prepared, *4* very well prepared

Table 3 Changes in teachers' perceptions about preparedness to use instructional approaches

Instructional approach	Paired differences			
	Mean diff (Yr.3-Pre)	SD	t	Sig. (2-tailed)
Lead a class of students using investigative strategies	1.65	.90	9.33	.000
Manage of class of students engaged in hands-on/project work	1.12	.078	7.17	.000
Help students take responsibility for their own learning	1.08	.75	7.11	.000
Recognize and respond to student diversity	.80	.64	6.19	.000
Encourage students' interest in science	.92	.81	5.66	.000
Use strategies that specifically encourage participation of females and minorities in science	1.20	1.04	5.76	.000
Involve parents in the science education of their students	1.36	.81	8.39	.000

n = 24, *1* Not adequately prepared, *2* somewhat prepared, *3* fairly well prepared, *4* very well prepared

provided "the structure through scaffolded-guided inquiry and journals to be able to present science in a way that kids understand and are involved." A second grade teacher, whose teaching assignment had changed from first grade, stated that she felt "a lot more confident, even moving up to a new grade level. I feel I can do this. I know the model to follow… I know how to use it now, how to get the kids to come up with the questions they need, how to phrase things." Another second grade teacher commented,

> Being able to see the teachers give the lesson at our grade level at the summer institute showed me I could do that exact same thing. If they were to say to me, 'Oh, here is a bunch of rocks and minerals, and I want you to do a lesson,' I would be confused because I didn't know the difference between a rock and a mineral. But when the teachers showed me exactly what to it, it was like, 'Oh, I could do that.'

The teachers also noted how collaboration among participants contributed to increased confidence in teaching science. A first grade teacher related,

> The first year it felt very awkward [to teach science]. I had to keep referring to my notes. Am I doing that right? My colleague in first grade is great about sharing, and we bounced ideas off of each other. That has really helped my confidence, that we can talk about things first.

A kindergarten teacher, who indicated her confidence in teaching science was "much improved," similarly highlighted collaborative aspects of the program such as "working with other teachers, getting ideas, and having support from the leaders."

Teachers' Self-efficacy and Instructional Practices in Science

Teachers' self-efficacy in teaching science significantly increased over the course of the professional development, and these changes tended to correspond with changes

Table 4 Correlations of change scores from pre-program to end-of-program

Instructional outcome	Correlation with self-efficacy		
	Total efficacy	PSTE subscale	STOE subscale
Student participation in activities as part of science instruction			
Students engage in hands-on science activities	.736**	.455*	.755**
Students design or implement their *own* investigation	588**	.460*	.544**
Students write reflections in a journal or notebook	641**	.459*	.619**
Instructional strategies that teachers use in science instruction			
Demonstrate a science-related principle of phenomenon	.542**	.367	.536*
Teach science using real-world contexts	.521*	.377	.501*
Arrange seating to facilitate student discussion	.581**	.286	.640**
Use open-ended questions	.311	.213	.307
Require students to supply evidence to support their claims	.500*	.516*	.387
Encourage students to explain concepts to one another	.415	.327	.382
Encourage students to consider alternative explanations	.503*	.272	.540**
Allow students to work at their own pace	.352	.206	.368
Help students see connections between science and other disciplines	.400	.126	.484*
Instructional time			
Number of science lessons taught per week	.228	.253	.166
Length of typical science lesson	.293	.218	278
Number of days out of last five that teacher taught science	.361	.123	.431*

n = 22

* Correlation is significant at the .05 level (2-tailed)

** Correlation is significant at the .01 level (2-tailed)

in the instructional strategies they used to teach science. As displayed in Table 4, changes in teachers' reported self-efficacy were significantly correlated with teachers' reported changes in students' participation in activities as part of science instruction. From pre-program to end-of-program, teachers shifted toward having students more frequently engage in hands-on science activities, implement their own investigations, and write reflections in a journal or notebook. These shifts in student participation were strongly correlated with teachers' shifts on all three efficacy measures in the STEBI: total efficacy, the personal beliefs sub-scale (PSTE), and the outcomes expectancy sub-scale (STOE).

From pre-program to end-of-program, teachers reported on the survey that they significantly increased their use of each instructional strategy included in Table 4. Classroom observations corroborated the reported changes in instructional practices in science. In particular, researchers noted during classroom observations that teachers adopted more hands-on science activities and engaged students in scientific investigations through both student-conducted investigations and teacher-led demonstrations. Teachers and students investigated, for example, the properties of rocks, what types of surfaces have the most friction, classifications of parts of plants, what objects sink and float, and how we use the five senses. In these types of classroom activities, students often wrote about their observations, describing what took place and evaluating what happened and why.

The majority of the instructional changes reported in Table 4 corresponded with changes in self-efficacy. Changes in six of the nine instructional strategies were correlated with changes in one or more of the self-efficacy measures. Increases in teachers' total self-efficacy and the outcome expectancy sub-scale were strongly correlated with increased use of four instructional strategies: (a) demonstrating a science-related principle or phenomenon; (b) teaching science using real-world contexts; (c) arranging seating to facilitate student discussion; and (d) encouraging students to consider alternative explanations. Increases in teachers' total self-efficacy and the personal beliefs sub-scale were strongly correlated with teachers increasingly requiring students to supply evidence to support their claims. One instructional strategy, helping students see connections between science and other disciplines, was significantly correlated with changes in only one of the self-efficacy measures, the outcome expectancy sub-scale. None of the three self-efficacy measures correlated with changes in the extent to which teachers used open-ended questions, encouraged students to explain concepts to one another, and allowed students to work at their own pace.

Although teachers increased the amount of time they devoted to science instruction over the 3 years, these changes tended not to be correlated with gains in self-efficacy. As displayed in Table 4, there was a significant correlation between the outcomes expectancy sub-scale and the number of days out of the last five that the teacher had taught science. However, changes in self-efficacy were not significantly correlated with changes in the number of science lessons taught per week and the length of the typical science lesson.

Discussion

The results of this study highlight the need to build K-2 teachers' preparedness to teach science and the potential of professional development to increase their self-efficacy in science. After just 1 year of professional development, teachers' self-efficacy had increased significantly, and their confidence in their abilities to teach science continued to develop over the 3-year program. Their overall self-efficacy, personal science teaching efficacy, and outcomes efficacy showed significant gains from pre-program to end-of-program. Even though they were teaching in the early elementary grades, the majority of the teachers did not feel well prepared to teach science prior to the professional development. This shift in their self-efficacy is important because the emphasis on language arts and mathematics in the curriculum and in standardized testing, combined with teachers' higher confidence in teaching those subjects, had pushed science to the edges of the instructional program and led teachers to rely on teacher-centered instructional approaches.

Similar to other research results (Lakshmanan et al., 2011), we found that positive changes in teachers' self-efficacy corresponded with changes in their instructional practice in science. When teachers felt prepared to teach science and believed that students' learning and interest in science was based on effective teaching, they shifted towards student-centered rather than teacher-centered instructional approaches. Our analysis showed particularly high correlations between changes in their self-efficacy and changes in their use of student participation activities. Having students conduct their own investigations and engage in hands-on activities in science set up a positive cycle of teacher/student reinforcement. When teachers saw high student engagement in science activities, they felt encouraged to continue using student participation activities, and their ongoing use of these strategies reinforced students' interest in science.

In contrast to the correlation with instructional practices, positive changes in teachers' self-efficacy were not highly correlated with changes in instructional time. In earlier studies, we found shifts in the amount of time teachers devoted to science instruction as well as increased efforts by teachers to schedule science as a regular part of their instructional plans (Sandholtz & Ringstaff, 2011, 2013). In interviews, teachers described feeling much better prepared for science instruction because of the professional development and, consequently, more confident and inclined to teach science. Given these earlier findings, we expected to find a higher correlation between the changes in teachers' self-efficacy and the increased time teachers spent on science instruction. We are uncertain why this was not the case. Perhaps contextual factors had more influence on teachers' decisions about the number and length of science lessons while self-efficacy had more influence on their choices of instructional strategies. For example, preparation time and administrative support varied across schools, and, in schools with mandated reading programs, teachers found it more difficult to schedule science into the instructional day (Sandholtz & Ringstaff, 2013). The lack of correlation between changes in self-efficacy and instructional time allotted to science instruction may reflect contextual factors beyond the teachers' direct control.

Our findings suggest that teachers' self-efficacy is an important factor influencing decisions about science instruction. Gains in self-efficacy corresponded with changes in instructional practices in science, particularly the use of student participation activities. The professional development program included design features that contributed to the elementary teachers' gains in self-efficacy. In keeping with research identifying core components of effective professional development (Darling-Hammond et al., 2009; Desimone, 2009; Hawley & Valli, 1999), the program was intensive and sustained over several years; connected to district and school goals; involved active learning; encouraged collegiality; and focused on specific curriculum content rather than abstract principles. Beyond these characteristics, the program developers included features that were targeted to the specific needs of the participants. To build teachers' content knowledge in science, the program focused on a different branch of science each year and began with physical science, the branch of science that elementary teachers feel least prepared to teach and complete the fewest courses in as undergraduates (Banilower et al., 2013). The professional development also combined adult-level science content with instructional strategies appropriate for early elementary students. Given the large student population of English-language learners, the program prepared teachers not only to integrate science and language arts but also to implement applicable literacy strategies. In response to the rural setting and the number of one-school districts, the program developers aimed to create professional learning communities and hosted regional meetings during the school year as well as a website to help facilitate communication and sharing among participants. The targeted and contextualized design of the professional development likely contributed to the significant changes in teachers' self-efficacy and instructional practices after just 1 year and to the ongoing development of their confidence to teach science over the course of the 3-year program.

Conclusion

The results of this study highlight three issues related to teachers' self-efficacy and science education. First, the research demonstrates the value of building teachers' confidence and preparedness to teach science in the early elementary grades. Efforts to improve science teaching in elementary schools tend to focus more on upper grades and not on the early elementary grades. Yet national standards in the US include science in the early grades, and research reinforces the value of teaching science in early childhood. Including science in the K-2 curriculum develops young children's scientific thinking and positive attitudes toward science and contributes to better understanding of scientific concepts studied in later grades (Eshach & Friend, 2005; Keeley, 2009). Moreover, young children possess a natural curiosity and enter school with knowledge of the natural world, and the ability to use a range of reasoning processes (Duschl, Schweingruber, & Shouse, 2007). Whereas students in the early elementary grades are primed for science education, their teachers often lack the confidence and background preparation to include science as a regular part of the curriculum. Professional development that increases K-2 teachers' self-efficacy in science may yield benefits for students that extend beyond the early elementary grades.

Second, efforts to improve science education may have underestimated the importance of teachers' self-efficacy in relationship to the use of particular instructional strategies. Recommendations that teachers adopt student-centered and inquiry-based approaches provide a foundation for science instruction, but if teachers do not feel prepared and confident in using those approaches, they may be unlikely to change their practices. Implementation of the national Next Generation Science Standards (Achieve, 2013), which emphasize critical thinking and inquiry-based problem solving, will require classroom instruction that extends beyond teacher-centered approaches. But shifting to student-centered practices requires changing the roles of both teachers and students, who may have become comfortable in their traditional roles in the learning process (Anderson & Helms, 2001). As highlighted in this study, teachers with higher self-efficacy in science are more likely to shift from the traditional role and implement instructional strategies centered on student participation.

Third, the findings of this study support the theoretical relationships between self-efficacy and actions (Bandura, 1977) and between professional development and teachers' beliefs and attitudes (Desimone, 2009). The teachers in this study participated in effective professional development which increased their knowledge of science and their confidence in teaching science. Given their changed beliefs about their personal capabilities to teach science, teachers perceived a better balance between their personal teaching competence and the requirements to teach science. Consequently, teachers changed their instructional practice in science. As teachers experienced success with new instructional strategies in science, they felt more capable and confident in using them. This relationship between professional development, teachers' self-efficacy, and instructional practices suggests that offering targeted and sustained professional development holds significant potential for promoting science education.

References

Achieve, on behalf of the twenty-six states and partners that collaborated on the NGSS. (2013). *Next generation science standards*. Washington, DC: Achieve.

Anderson, R. D., & Helms, J. V. (2001). The ideal of standards and the reality of schools: Needed research. *Journal of Research in Science Teaching, 38*, 3–16.

Ashton, P. T., & Webb, R. B. (1986). *Making a difference: Teachers' sense of efficacy and student achievement*. White Plains, NY: Longman.

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review, 84*, 191–215.

Bandura, A. (1997). *Self-efficacy: The exercise of control*. New York, NY: W.H. Freeman.

Banilower, E. R., Boyd, S. E., Pasley, J. D., & Weiss, I. R. (2006). *Lessons from a decade of mathematics and science reform*. Chapel Hill, NC: Horizon Research.

Banilower, E. R., Smith, S., Weiss, I. R., Malzahn, K. J., Campbell, K. H., & Weis, A. H. (2013). *Report of the 2012 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research.

Basista, B., & Mathews, S. (2002). Integrated science and mathematics professional development programs. *School Science and Mathematics, 102*, 359–370.

Bogdan, R. C., & Biklen, S. K. (1998). *Qualitative research for education: An introduction to theory and methods* (3rd ed.). Boston: Allyn & Bacon.

Bowes, A. S., & Banilower, E. R. (2004). *LSC classroom observation study: An analysis of data collected between 1997 and 2003*. Chapel Hill, NC: Horizon Research.

Brand, B. R., & Moore, S. J. (2011). Enhancing teachers' application of inquiry-based strategies using a constructivist sociocultural professional development model. *International Journal of Science Education, 33*, 889–913.

California Council on Science and Technology. (2010). *The preparation of elementary school teachers to teach science in California*. Sacramento, CA: California Council on Science and Technology.

Cervetti, G., Barber, J., Dorph, R., Pearson, P. D., & Goldschmidt, P. (2012). The impact of an integrated approach to science and literacy in elementary school classrooms. *Journal of Research in Science Teaching, 49*, 631–658.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches*. Thousand Oaks, CA: Sage.

Darling-Hammond, L., Wei, R. C., Andree, A., Richardson, N., & Orphanos, S. (2009). *Professional learning in the learning profession: A status report on teacher development in the United States and abroad*. Oxford, OH: National Staff Development Council.

De Laat, J., & Watter, J. J. (1995). Science teaching self-efficacy in a primary school: A case study. *Research in Science Education, 25*, 453–464.

Desimone, L. M. (2009). Improving impact studies of teachers' professional development: Toward better conceptualizations and measures. *Educational Researcher, 38*, 181–199.

Dorph, R., Shields, P., Tiffany-Morales, J., Hartry, A., & McCaffrey, T. (2011). *High hopes-few opportunities: The status of elementary science education in California*. Sacramento, CA: The Center for the Future of Teaching and Learning at WestEd.

Duran, E., Ballone-Duran, L., Haney, J., & Beltyukova, S. (2009). The impact of a professional development program integrating informal science education on early childhood teachers' self-efficacy and beliefs about inquiry-based science teaching. *Journal of Elementary Science Education, 21*, 53–70.

Duschl, R., Schweingruber, H., & Shouse, A. (2007). *Taking science to school: Learning and teaching science in grades K-8*. Washington DC: The National Academies Press.

Eshach, H., & Friend, M. (2005). Should science be taught in early childhood? *Journal of Science Education and Technology, 14*, 315–336.

Fulp, S. L. (2002). *Status of elementary school science teaching*. Chapel Hill, NC: Horizon Research.

Germuth, A., Banilower, E., & Shimkus, E. (2003). *Test–retest reliability of the Local Systemic Change teacher questionnaire*. Chapel Hill, NC: Horizon Research.

Gess-Newsome, J. (2001). The professional development of science teachers for science education reform: A review of the research. In J. Rhoton & P. Bowers (Eds.), *Professional development: Planning and design* (pp. 91–100). Arlington, VA: NSTA Press.

Gibson, S., & Dembo, M. (1984). Teacher efficacy: A construct validation. *Journal of Educational Psychology, 76*, 569–582.

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2004). Collective efficacy beliefs: Theoretical developments, empirical evidence, and future directions. *Educational Researcher, 33*, 3–13.

Harmon, H., & Smith, K. (2007). *A legacy of leadership and lessons learned: Results from the rural systemic initiatives for improving mathematics and science education*. Charleston, WV: Edvantia.

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 of policy and practice* (pp. 127–150). San Francisco: Jossey-Bass.

Heck, D. J., Rosenberg, S. L., & Crawford, R. A. (2006). *LSC teacher questionnaire study: A longitudinal analysis of data collected between 1997 and 2006*. Chapel Hill, NC: Horizon Research.

Hewson, P. W. (2007). Teacher professional development in science. In S. Abell & N. Lederman (Eds.), *Handbook of research on science education* (pp. 1177–1203). London: Erlbaum.

Horizon Research. (2000). *Local systemic change through teacher enhancement science teacher questionnaire.* Chapel Hill, NC: Horizon Research. http://www.horizon-research.com/instruments/lsc/tq_k8sci.php

Johnson, C., Fargo, J., & Kahle, J. B. (2010). The cumulative and residual impact of a systemic reform program on teacher change and student learning of science. *School Science and Mathematics, 110*, 144–159.

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a definition of mixed methods research. *Journal of Mixed Methods Research, 1*, 112–133.

Johnson, R. B., & Turner, L. A. (2003). Data collection strategies in mixed methods research. In A. Tashakkori & C. Teddlie (Eds.), *Handbook of mixed methods in social and behavioral research* (pp. 297–319). Thousand Oaks, CA: Sage.

Keeley, P. (2009). Elementary science education in the K-12 system. *Science and Children, 46*(9), 8–9.

Lakshmanan, A., Heath, B. P., Perlmutter, A., & Elder, M. (2011). The impact of science content and professional learning communities on science teaching efficacy and standards-based instruction. *Journal of Research in Science Teaching, 48*, 534–551.

Loucks-Horsley, S., Stiles, K. E., Mundry, S. E., Love, N., & Hewson, P. W. (2009). *Designing professional development for teachers of science and mathematics* (3rd ed.) Thousand Oaks, CA: Corwin Press.

McMurrer, J. (2007). *Choices, changes, and challenges: Curriculum and instruction in the NCLB era*. Washington, DC: Center on Education Policy.

McMurrer, J. (2008). *Instructional time in elementary schools: A closer look at changes for specific subjects*. Washington, DC: Center on Education Policy.

Mintzes, J. J., Marcum, B., Messerschmidt-Yates, C., & Mark, A. (2013). Enhancing self-efficacy in elementary science teaching with professional learning communities. *Journal of Science Teacher Education, 24*, 1201–1218.

Morrell, P. D., & Carroll, J. B. (2003). An extended examination of pre-service elementary teachers' science teaching self-efficacy. *School Science and Mathematics, 103*, 246–251.

Mulholland, J., Dorman, J. P., & Odgers, B. M. (2004). Assessment of science teaching efficacy of preservice teachers in an Australian university. *Journal of Science Teacher Education, 15*, 313–331.

National Center for Education Statistics. (2011). *Fast facts: Teacher trends*. Washington, DC: U.S. Department of Education.

National Research Council. (2005). *How students learn: History, mathematics and science in the classroom*. Washington, DC: The National Academies Press.

Olson, S., & Labov, J. (2009). *Nurturing and sustaining effective programs in science education for grades K-8*. Washington, DC: The National Academies Press.

Palmer, D. H. (2006). Durability of changes in self-efficacy of preservice primary teachers. *International Journal of Science Education, 28*, 655–671.

Plourde, L. A. (2002). The influence of student teaching on preservice elementary teachers' science self-efficacy and outcome expectancy beliefs. *Journal of Instructional Psychology, 29*, 245–253.

Posnanski, T. J. (2002). Professional development programs for elementary science teachers: An analysis of teacher self-efficacy beliefs and a professional development model. *Journal of Science Teacher Education, 13*, 189–220.

Raudenbush, S., Rowan, B., & Cheong, Y. (1992). Contextual effects on the self-perceived efficacy of high school teachers. *Sociology of Education, 65*, 150–167.

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an efficacy belief instrument for elementary teachers. *Science Education, 74*, 625–637.

Roberts, J. K., Henson, R. K., Tharp, B. Z., & Moreno, N. P. (2001). An examination of change in teacher self-efficacy beliefs in science education based on the duration of inservice activities. *Journal of Science Teacher Education, 12*, 199–213.

Ross, J. A. (1998). The antecedents and consequences of teacher efficacy. In J. Brophy (Ed.), *Advances in research on teaching* (Vol. 7, pp. 49–74).

Ross, J. A., Cousins, J. B., & Gadalla, T. (1996). Within-teacher predictors of teacher efficacy. *Teaching and Teacher Education, 12*, 385–400.

Sandholtz, J. H., & Ringstaff, C. (2011). Reversing the downward spiral of science instruction in K-2 classrooms. *Journal of Science Teacher Education, 22*, 513–533.

Sandholtz, J. H., & Ringstaff, C. (2013). Assessing the impact of teacher professional development on science instruction in the early elementary grades in rural US schools. *Professional Development in Education, 39*, 678–697.

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

Tosun, T. (2000). The beliefs of preservice elementary teachers toward science and science teaching. *School Science and Mathematics, 100*, 374–379.

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education, 23*, 944–956.

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research, 68*, 202–248.

Weiss, I. R. (1999). *Evaluating science and mathematics professional development programs*. Chapel Hill, NC: Horizon Research.

Weiss, I. R., Banilower, E. R., McMahon, K. C., & Smith, P. S. (2001). *Report of the 2000 national survey of science and mathematics education*. Chapel Hill, NC: Horizon Research.

Zhang, M., Passalacqua, S., Lundeberg, M., Koehler, M. J., Eberhardt, J., Parker, J., … Paik, S. (2010). "Science talks" in kindergarten classrooms: Improving classroom practice through collaborative action research. *Journal of Science Teacher Education, 21*, 161–179.