Teachers' Self-Efficacy for Science Instruction in Rural Schools in the Next Generation Science Standards Era

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Abstract

This longitudinal study examines elementary teachers' self-efficacy for science teaching in the years after professional development (PD) ended and during a subsequent 3-year period of follow-up support. Self-efficacy is important because teachers make decisions about classroom activities based, in part, on how confident they are in their abilities to carry out specific instructional strategies. The central research question was, How does teachers' personal science teaching efficacy change during periods with and without PD support? Data sources included semistructured interviews, a self-efficacy assessment, and surveys conducted at five time points. Overall findings show a decline in teachers' personal science teaching efficacy

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in the years after PD ended. However, during the years of follow-up support, elementary teachers' self-efficacy in science teaching increased and, by the end of 3 years, returned to nearly the same level as when the initial PD ended. Case studies of four teachers highlight the shifts that occurred during the years with and without follow-up support. This study reinforces the need for, and potential value of, providing follow-up support for teachers to sustain PD outcomes over time.

Introduction

The introduction of the Next Generation Science Standards (NGSS), content standards developed "collaboratively with states and stakeholders in science, science education, higher education, and industry" in the United States to improve science education for all students, brought a series of challenges for teachers in meeting the instructional needs of students (National Research Council, 2012). The drafts of the NGSS started in 2011, and in 2013, the final version was released. During this time period, schools were focused on implementing the Common Core State Standards (CCSS), which meant that teachers "may not be able to teach science in a given day as English and math dominated curricula" (Kumar, 2013, p. 167). Given the emphasis on mathematics and language arts instruction, teachers struggled to teach science on a regular basis, let alone adapt their science instruction to meet the NGSS. The standards shift the focus of student learning from rote memorization of facts to exploration of real-word phenomena and emphasize critical thinking, investigation, and evaluation of scientific evidence. In keeping with the standards, students should be engaged in exploring ideas, developing arguments, and defending conclusions based on evidence (NGSS Lead States, 2013).

This transition to the NGSS has been particularly challenging in elementary grades in rural settings for a range of reasons. Rural elementary teachers typically have limited backgrounds in science combined with limited access to professional development (PD; Burton et al., 2013; Zinger et al., 2020). For example, rural teachers have fewer opportunities for professional education offered by universities, corporations, and science organizations (Avery, 2013). In their small schools with a limited number of faculty members, teachers also have fewer opportunities for collegial interaction and lesson planning. In addition, rural schools typically face greater financial constraints, higher relative operating costs, and smaller facilities than nonrural schools (Burton et al., 2013; Farmer, 2009; Harmon & Smith, 2007; Showalter et al., 2019). Rural schools with lower student enrollment tend to fare even worse than schools with higher enrollment under historical school funding formulas (Strange, 2011). With limited financial resources, administrators have to prioritize spending (Farmer, 2009), and consequently, support for science education in elementary schools may be lessened.

Opportunities for professional learning are important because teachers' confidence to teach science and readiness to adopt new strategies can be enhanced through PD (Deehan et al., 2019; Dogan et al., 2016; Haag & Megowan, 2015; Mulholland

& Wallace, 2001). The teachers in this study all participated in science-based PD programs (that ended before implementation of the NGSS), and research comparing pre- and postprogram outcomes found significant and positive end-of-program growth in teachers' science teaching self-efficacy (Sandholtz & Ringstaff, 2022). But end-of-program outcomes may not last over time, especially in settings where support for science education is limited.

This study is part of a longitudinal research project examining the sustainability of PD outcomes. This project focused on early elementary teachers from rural districts in the United States who completed 100 hours of PD across 3 years. The program included intensive science content instruction, pedagogical training focused on science instruction and how to connect science to mathematics and English language arts (ELA) and mathematics, and support related to teacher collaboration. The program included intensive summer institutes, regional meetings, and school site sessions. The authors of this article were not involved in designing or facilitating the PD, but the third author served as an external evaluator. In this current study, we examine teachers' self-efficacy for science teaching in the years after the prior PD ended and during a subsequent 3-year period of follow-up support. The central research question was, How does teachers' personal science teaching efficacy change during periods with and without PD support? The longitudinal nature of this study combined with its focus on rural elementary teachers, a population that tends to be underrepresented in science education research, makes it uncommon and noteworthy. Moreover, the study is situated during an important contextual time period—the transition to NGSS-aligned instruction. Thus, this work contributes to extant literature that investigates how to support teachers during significant transitional periods in the field.

Theoretical Framework and Related Research

Our theoretical framework is grounded in Bandura's (1977) social cognitive theory, which distinguishes between perceived beliefs about one's capabilities and an individual's actual abilities. According to Bandura (1997), perceived self-efficacy is defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (p. 3). Individuals' beliefs about their capabilities will influence their actions regardless of whether their perceptions are entirely accurate (Bandura, 1997; Goddard et al., 2004). Consequently, perceptions, whether over- or underestimations of capabilities, may influence the extent to which individuals make good use of the skills they possess (Bandura, 1997; Goddard et al., 2004). Self-doubt, for example, may influence whether individuals take an action even if they possess sufficient skills to do so. Because it is specific to a particular task, perceived self-efficacy is different from self-esteem (Catalano et al., 2019; Goddard et al., 2004); individuals may have high self-esteem but low self-efficacy for a specific activity. Self-efficacy is described as what individuals believe they can accomplish using their task-specific skills (Lunenburg, 2011) within a particular context (Snyder & Lopez, 2007).

In the field of teaching, self-efficacy refers to teachers' beliefs about their ability to teach effectively (Ashton & Webb, 1986). Teachers' beliefs about their capabilities to plan, organize, and execute instructional strategies may vary by subject matter and classroom context. Researchers report differences in a teacher's perceived self-efficacy depending on the subject matter and students in a class (Raudenbush et al., 1992; Ross et al., 1996). Teachers make judgments about what is required for various teaching tasks as well as their personal competence in relation to the perceived requirements (Tschannen-Moran et al., 1998). These judgments may include aspects like content knowledge, time, resources, student behavior, and collegial and administrative support.

Perceived self-efficacy is important because teachers make decisions about classroom activities based, in part, on how confident they are in their abilities to carry out particular instructional strategies. For instance, elementary teachers who feel less confident about teaching science than other subjects may revert to textbook-based strategies rather than using student-centered activities (Sandholtz et al., 2016). They may value including science in the curriculum but perceive that teaching science in new ways requires greater personal teaching competence than they possess. Perceived self-efficacy also influences the amount of effort individuals will expend and how long they will persist in specific activities (Demir & Ellett, 2014). For teachers, less self-efficacy can lead to less effort in preparation and instruction coupled with less persistence when faced with challenges in curriculum development and instruction (Tschannen-Moran & Hoy, 2007).

Because one's self-efficacy is not fixed but can change, teacher PD offers an avenue for enhancing self-efficacy, which potentially can affect classroom instruction (Kozcu Çakir, 2020) and is positively related to student achievement (Fauth et al., 2019). Well-designed PD can help to shift teachers' perceptions about the balance between their abilities and what is needed to teach science. PD offers vicarious experiences and mastery experiences, two key sources of influence on self-efficacy (Bandura, 1997). Vicarious experiences occur when teachers observe skilled and competent others modeling instructional strategies. Subsequently, as teachers implement the strategies in their own classrooms, they master the particular methods and feel more capable and confident in using them. In addition, they may receive feedback and encouragement from leaders and other participants in the PD. Researchers report that enhancing teachers' self-efficacy through PD can influence elementary teachers' instructional practices (Brand & Moore, 2011; Flores, 2015; Mintzes et al., 2012; Posnanski, 2002; Roberts et al., 2001). In some cases, researchers find a specific connection between elementary teachers' science teaching self-efficacy and inquiry-based instruction in science (Duran et al., 2009; Sandholtz et al., 2019; Zhang et al., 2010). Changes in teachers' self-efficacy and instructional practices can be prompted by PD but also are influenced by contextual factors and teachers' perceptions about contextual support (Friedman & Kass, 2002; Haney et al., 2002). Relevant contextual factors may include, for example, administrative support, collegial support, student characteristics, and resources. In this study, we focus on the extent to which modest PD support affected elementary teachers' science teaching self-efficacy during the transition to NGSS-aligned science instruction in rural settings.

Method

Study Context

The study took place in rural communities in California and included 34 elementary teachers who had previously completed one of four science-based PD programs (which ended between 2010 and 2014), had access to the supports described earlier, and had participated in data collection (i.e., self-efficacy assessment, teacher survey, and teacher interviews) at all five time points. Written informed consent from all participants was obtained through the institutional review board process prior to all data collection. The original PD programs varied in their specific focus, but each had an aim to prepare teachers to implement inquiry-based strategies. Although the NGSS had not been implemented at the time of the programs, the goal of preparing teachers and students to use scientific inquiry is aligned with the NGSS framework. Given teachers' needs in relation to the subsequent implementation of the NGSS, the follow-up support program focused on helping teachers understand the NGSS and create and implement curriculum aligned with the NGSS. This study examined teachers' efficacy, beliefs, and experiences related to NGSS-aligned science instruction. Drawing from the NGSS approach (Carlson et al., 2014), we define *NGSS-aligned science instruction* as the practices that help students develop an in-depth understanding of both content and skills (i.e., communication, collaboration, inquiry, problem solving) used by scientists and engineers.

This study was part of a larger longitudinal research project examining the extent to which modest forms of follow-up support provide enough reinforcement to sustain science PD outcomes, including increases in teachers' self-efficacy, over time. The key supports include (a) 2-day, face-to-face refresher sessions that were scheduled in the summer and included opportunities for teachers to collaborate on lessons, to share strategies, to make connections with new colleagues, and to reconnect with participants from their original programs; (b) after-school face-to-face meetings held twice during each academic year with teachers grouped by geographic proximity; (c) synchronous webinars facilitated by a science expert or PD leader, focused on topics requested by teachers and offered approximately once a month; (d) four forms of electronic support, including a dedicated email address for questions, a closed Facebook group, an electronic newsletter sent via email, and an online repository of materials; and (e) $150 per teacher each year to directly purchase needed science materials and supplies.

Sampling Procedure

To examine shifts in personal science teaching efficacy (PSTE) for the teachers, we ran a repeated-measures analysis of variance (ANOVA) looking at changes across time points within individuals within the full sample of 34 teachers who completed science-based PD, had access to the supports, and had participated in data collection (i.e., self-efficacy assessment, teacher survey, and teacher interviews) at all five time points. We adjusted for multiple comparisons using the Benjimini–Hochberg correction (Benjamini & Hochberg, 1995). After examining self-efficacy changes for the full sample of teachers, we used purposive sampling (Palinkas et al., 2015) to identify four teachers for critical case studies. A case study design is valuable when examining how and why contemporary events occur (Yin, 2003). Our critical cases allowed us to examine the factors that may affect teachers' professional practice but may not be evident with single cases (Patton, 2002) and are most likely to represent data needed to answer our central research question: How does teachers' personal science teaching efficacy change during periods with and without PD support? Given this rationale, our critical purposive sampling procedure first involved plotting data from the self-efficacy assessment to look at patterns in the PSTE scores. To examine critical cases that had "strategic importance in relation to the general problem" (Flyvberg, 2001, p. 78), we reviewed the plots and selected four teachers who (a) had differing patterns of PSTE scores across the first time points and who (b) taught in different schools. Here, we describe the different pattern of PSTE scores that each of the four critical cases represents. Mr. Harris had the expected pattern:[1] a significant drop in self-efficacy after years without PD and a significant increase during the follow-up PD. Ms. Trujillo, in contrast, had a decrease in self-efficacy after no PD followed by another decrease after 1 year of follow-up PD. Mr. Belzer's self-efficacy dropped slightly in the years without PD and increased slightly during the follow-up, but never reached its prior level. The high self-efficacy scores of Ms. Brown had slight decreases and increases over the five time points but remained consistently higher than the other teachers' scores.

Data Sources

The primary data sources for this study included a self-efficacy assessment, teacher surveys, and interviews. We describe these data sources and our analytical approaches in the following sections.

Self-Efficacy Assessment

The validated Science Teaching Efficacy Beliefs Instrument (STEBI-A; Riggs & Enochs, 1990) focused on teachers' beliefs about their effectiveness in teaching science and was developed specifically for elementary teaching. The assessment includes 5-point Likert-scale questions with responses ranging from 1 (*strongly* *disagree*) to 5 (*strongly agree*). High scores indicate a strong personal belief in one's own efficacy for teaching science. A sample statement from the instruction is "Even if I try very hard, I do not teach science as well as I do most subjects." For this study, we examined teachers' scores on the PSTE belief scale, which measures teachers' beliefs in their own abilities to teach science. Teachers completed the self-efficacy assessment at five time points: (a) at the conclusion of teachers' participation in the prior PD programs for science instruction that aligned with past science standards (2010–2014), (b) prior to the NGSS-aligned PD program (2017), and (c) at the end of each year of the NGSS-aligned program (2018, 2019, 2020).

Teacher Survey

The teacher survey was developed by Horizon Research in 2000 for national studies of science teaching at the elementary level. Relevant questions for this study focused on teachers' sense of preparedness and their instructional practices. Teachers completed the survey at the same time points that they completed the self-efficacy assessment.

Teacher Interviews

Teachers participated in semistructured interviews prior to the beginning of the NGSS-aligned program (2017) and at the end of each of the 3 years (2018–2020). These 45- to 60-min interviews provided additional data about self-efficacy and helped to contextualize teachers' beliefs, perceptions, and experiences related to science instruction. In the interview, teachers responded first to questions about their teaching context that provided information about working conditions (e.g., Are you still teaching at XX school, in XX grade? Has anything changed with regard to your teaching assignment? If so, what?) and prior science teaching experiences (e.g., This school year, how many times per week have you typically taught science?). Teachers were then asked questions about the challenges that they encountered in teaching science within their school context (e.g., What specific barriers, if any, make it challenging for you to teach science?). Interviewers also asked teachers about their instructional needs and sources of instructional resources and institutional support (e.g., What specific barriers, if any, make it challenging for you to teach science?). Next, teachers were asked about the support to which they may have access for teaching science in their classrooms, schools, and districts (e.g., Are there any specific support for NGSS implementation being offered by your district and/or school?). Each interview was audio taped, transcribed, and uploaded to qualitative analysis software (MaxQDA). Individual teachers received transcripts of their interviews for verification purposes. Although participants were offered opportunities to member check during the end of the interview process, they did not member check the researchers' codes.

Analytic Approach

We analyzed and plotted the case study teachers' responses to survey questions about their sense of preparedness across the five time points, reviewed their full interview transcripts from each year, and created data displays. Data analysis focused on explanation building (Yin, 2003) through descriptive coding (Saldaña, 2016). Specifically, we sought to understand why the shifts in self-efficacy occurred throughout the multiyear time period. In constructing each case, we focused on the teachers' lived experiences and their explanations about their preparedness to teach science in general and NGSS-aligned instruction in particular. First, using descriptive coding, one researcher coded 166 segments of the interviews as affordances (for teaching science), and 336 segments were identified as constraints. For instance, this segment was coded as a challenge: "We are struggling with . . . moving into the Next Generation Science Standards without the information we need to do it." This segment was descriptively coded as the teacher needing more information about science standards. Descriptively coded segments were then organized by theme. For example, the preceding segment was coded as a thematic challenge of lack of NGSS knowledge. A second researcher coded the segments based on the generated thematic codes. Any disagreements in coding were reconciled during face-to-face sessions. After developing each teacher case, we conducted a cross-case analysis by first examining similarities and differences across teachers. Our aim was to identify important factors across teachers and settings that influenced the teachers' efficacy for teaching science and their decisions about science instruction.

Findings

In the following sections, we first report on overall changes in 34 teachers' self-efficacy for science teaching across the five time points; then we examine changes for the four case study teachers. A repeated-measures ANOVA across the five time points was statistically significant, $p < .001$. As shown in Table 1, teachers' average

Table 1
ANOVA Pairwise Comparison

Time (I)	*Time (J)*	*Mean difference (I − J)*	*SE*	*Sig.*	*95% CI*
1	2	.402*	.064	.003	[.272, .532]
	3	.210*	.056	.004	[.097, .323]
	4	.129*	.052	.033	[.022, .236]
	5	.029	.062	.640	[−.097, .156]
2	3	−.191*	.060	.007	[−.313, −.069]
3	4	−.081	.056	.179	[−.195, .032]
4	5	−.100	.052	.092	[−.206, .007]

Note. Based on estimated marginal means.
*p < .05.

self-efficacy scores on the PSTE decreased significantly from Time 1 to Time 2, the period in which NGSS was being introduced, but before participants received support through the follow-up program. The decline suggests a fade-out effect of the outcomes from the previous PD programs. From Time 2 to Time 3, after the first year of follow-up support, teachers' average self-efficacy scores on the PSTE increased significantly, suggesting that initial involvement in professional learning opportunities for NGSS-aligned science teaching supported their confidence. Teachers' average PSTE scores continued to increase slightly during the second and third years of the follow-up support.

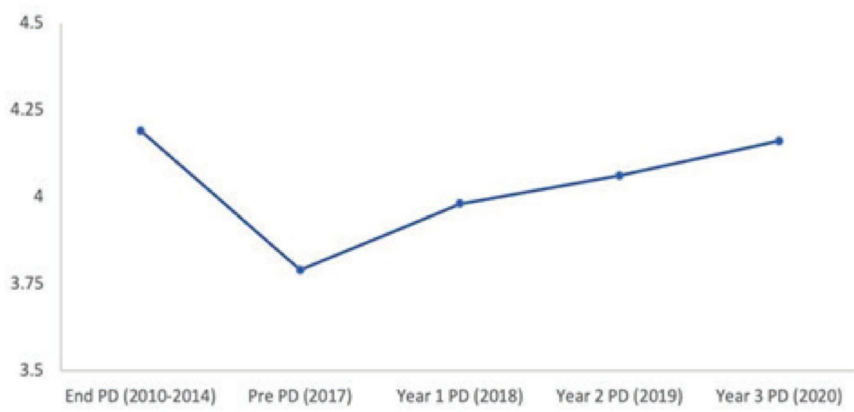
The change in teachers' average self-efficacy scores on the PSTE suggests that the follow-up support not only stopped the decline in teachers' confidence to teach science during the years without PD but also continually enhanced their science teaching self-efficacy over the 3 years when they were receiving modest support. By the end of the follow-up support (Time 5), teachers' average PSTE scores had increased significantly and almost returned to the level recorded at the end of the prior PD programs (Time 1). Figure 1 provides a visual representation of the change in teachers' average personal science teaching self-efficacy scores across all five time points.

Individual Cases

To better understand the shifts in teachers' personal science teaching self-efficacy during the years with and without follow-up support, we examine four individual cases. In each of the four case studies, we address three aspects: (a) the teacher's teaching assignments; (b) changes in the teacher's self-efficacy for science teaching; and (c) the teacher's reported science instruction during the years of follow-up support. Figure 2 shows the changes in the PSTE scores of the four

Figure 1

Changes in Teachers' Average Personal Science Teaching Efficacy Scores



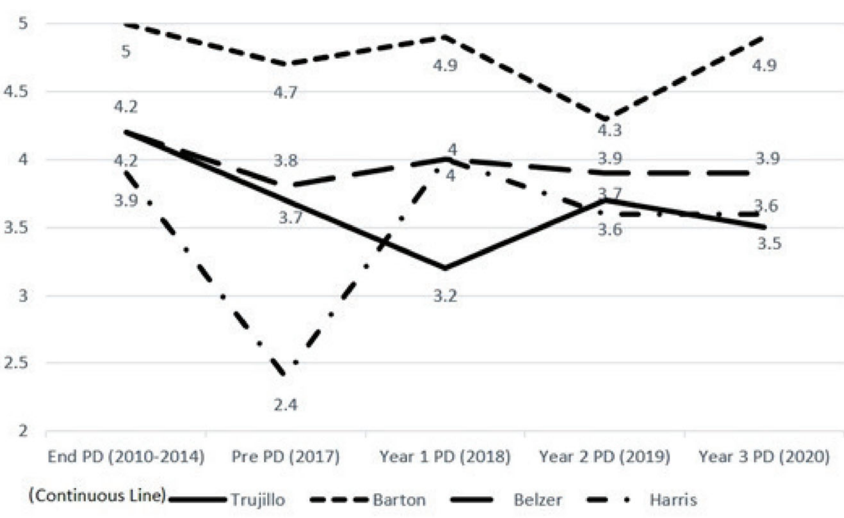
case study teachers across the five time points. After presenting the four individual cases, we discuss cross-case patterns.

Mr. Harris

Teaching Assignment. Throughout the years of this study, Mr. Harris taught in a small K–8 school that enrolled approximately 350 students. The student population included approximately 56% White students and 26% Hispanic students. Approximately 9% of the enrolled students were English language learners, and approximately 74% qualified for free or reduced-priced lunch. The percentage of students qualifying for free or reduced-price lunch as part of the U.S. National School Lunch Program is often used as an indicator of the concentration of poverty within a school. However, the percentage may overestimate the actual number of students living in poverty. Mr. Harris was assigned primarily to a fourth-grade classroom and had 16 years of teaching experience. One year, his class consisted of a combination of third- and fourth-grade students, and another year, he taught a combination of fourth- and fifth-grade students.

Changes in Self-Efficacy. As shown in Figure 2, Mr. Harris's PSTE score dropped from 3.9 to 2.4 during the years between the end of the prior PD program and the beginning of the follow-up support program. After just 1 year of follow-up support, Mr. Harris's PSTE increased to 4 before holding steady at 3.6 for the last 2 years of support. In survey responses at the end of the prior PD program in 2014,

Figure 2
Case Study Teachers' Personal Science Teaching Efficacy Scores Across Time Points



Mr. Harris indicated that he felt “very well prepared” to teach science and that he was as prepared to teach science as mathematics and language arts. For specific instructional activities in science, such as engaging students in inquiry-oriented activities, leading students using investigative strategies, and managing hands-on, project-based work, he responded that he was “fairly well prepared.” During the years with no PD, his sense of preparedness declined. In 2017, before he began receiving follow-up support, he indicated being “somewhat prepared” to teach science and less prepared to teach science than mathematics and language arts. Moreover, he felt only “somewhat prepared” to lead students in investigative strategies and hands-on or project-based work and “not adequately prepared” to engage students in inquiry-oriented activities. In his interview prior to receiving follow-up support, he described the school’s emphasis on mathematics and language arts and its lack of focus on science as having a negative impact on his confidence in teaching science. He stated that he had the “ability to teach science if I had the money and materials to do it and also if the emphasis of the school was to do more science.”

During the years of follow-up support, Mr. Harris reported in survey responses that he felt “fairly well prepared” to teach science but still felt more prepared to teach mathematics and language arts. His ratings for specific instructional activities in science similarly improved to “fairly well prepared.” In interviews, he attributed his increasing confidence and sense of preparedness to teach science, specifically NGSS, to the follow-up PD. He described “spending several years understanding the new switch and changing in the way we deliver instruction for NGSS.” By the end of the follow-up support, he stated that he felt “as prepared as any teacher at our school who teaches NGSS science standards” but desired more NGSS-aligned assessments to gauge student learning.

Science Instruction. To expand his science instruction, Mr. Harris reported using “interdisciplinary types of lessons” where science and ELA were taught concurrently to “create a sense of wonder.” Although he explained that he would “feel better prepared if we had a set curriculum” for NGSS-aligned science instruction, Mr. Harris maximized his financial resources to purchase a “mega bundle” from an NGSS-aligned vendor and used his preparation period to set up the classroom for hands-on, inquiry-based science activities. Mr. Harris reported using more “group work where kids are working together to solve issues or to come up with conclusions on their own versus me reading from a text and then [students] taking a test.” He credited the follow-up support with helping him understand “what fits the standards” and suggested that without that support, he “wouldn’t have a clue.” He also acknowledged that “having a small manageable class” bolstered his ability and inclination to have students collaborate in inquiry-based activities. When asked what most helped build his confidence and preparedness to teach science, Mr. Harris responded in four words: “Doing it. Teaching it.”

Ms. Trujillo

Teaching Assignment. Throughout the years of this study, Ms. Trujillo taught first grade at a small K–8 school that enrolled approximately 560 students. Ms. Trujillo had 11 years of teaching experience. The student population included approximately 71% White students and 17% Hispanic students. Approximately 35% of the enrolled students were English language learners, and approximately 50% qualified for free or reduced-priced lunch.

Changes in Self-Efficacy. As shown in Figure 2, the pattern of PSTE scores for Ms. Trujillo differs from those of the other teachers. Her score dropped from 4.2 to 3.7 during the period of no PD and rather than increasing after the first year of follow-up PD, her score dropped further to 3.2. In the last 2 years of follow-up support, her PSTE score increased to 3.7 before decreasing slightly to 3.5. Her scores never returned to the highest level (4.2), which was reported at the end of the prior PD program.

In survey responses at the end of the prior PD program in 2011, Ms. Trujillo indicated feeling as prepared to teach science as mathematics and language arts—that is, “very well prepared.” She reported feeling “very well prepared” to lead students using investigative strategies and to manage students in hands-on, project-based work and “fairly well prepared” to engage students in inquiry-oriented activities. After a number of years without PD, her sense of preparedness decreased. In 2017, prior to receiving follow-up support, her overall sense of preparedness to teach science dropped to “fairly well prepared,” whereas she continued to feel “very well prepared” to teach mathematics and language arts. Moreover, she indicated being “fairly well prepared” to engage students in inquiry-oriented activities and to manage students in hands-on or project-based work but only “somewhat prepared” to lead students in investigative strategies. In her interview prior to follow-up support, she acknowledged that her confidence in teaching science “could be better,” though it was “not as bad” as prior to her participation in the first science-based PD. She reiterated that “math and language arts are the easy ones” to teach.

In keeping with a drop in her PSTE score after the first year of follow-up support, Ms. Trujillo reported in surveys an overall lack of preparedness to teach science. During 2 of the 3 years of follow-up support, she described herself as only “somewhat prepared” to teach science, in contrast to “very well prepared” to teach mathematics and language arts. Over the 3 years, she continued to feel “fairly well prepared” to engage students in inquiry-oriented activities and manage project-based work but only “somewhat prepared” to lead students in investigative strategies. In her interview after the first year of follow-up support, she stated, “I don’t feel very confident” because “of the new standards and the new way of teaching it.” She suggested, “It is just going to take a little more time and the more I do it, the better I am going to get at it.” After the second year, she described feeling “a little more doubtful” about teaching science than other subjects; she proposed,

> It's a lot of trial and error because, you know, the standards are kind of fresh. Without having any curriculum, we're trying to find things on the internet and sometimes just because they say NGSS doesn't really mean they are, you know. . . . You kind of have to modify it and change it up a little bit and you have to plan for everything.

She explained how a recent science lesson "didn't go as planned," leading her to make "side notes of what I should be doing for next time." At the end of 3 years, she indicated that she felt "pretty confident" but still "nervous" and always needed to check to "make sure that I'm on track" with the NGSS standards. She pointed out that the students' behavior in her class that year had negatively affected her confidence in teaching science and again concluded that "it's just going to take time" to build her sense of preparedness.

Science Instruction. The implementation of NGSS-aligned instruction appeared to affect self-efficacy and sense of preparedness for Ms. Trujillo. In her interview after 1 year of follow-up support, she described knowing "what you are doing" in science until encountering a shift in standards and instructional activities. She indicated that implementing NGSS was "a bit difficult but getting easier," and she compared the transition to NGSS instruction to having an established recipe for a cake and then attempting to make a different type of cake. Ms. Trujillo expressed, "It's just going to take a little time." During the second and third years of follow-up support, she reported including more hands-on, investigative lessons in science and developing an NGSS-aligned lesson sequence with other first-grade teachers during the summer PD session. The lesson involved students in making predictions, working with mealworms, and recording their life cycle. Ms. Trujillo noted that instructional changes in her science instruction "happened gradually" as she gained "a little bit more confidence." She indicated that collaborating with other teachers, watching model lessons, and sharing experiences helped her feel "a little bit better" and like "OK, I can do this." Describing herself as someone who "complicates things in my head" and who gets "a bit overwhelmed and stressed," she highlighted how "talking with my other colleagues" made "it more manageable and it took some of the stress away."

Mr. Belzer

Teaching Assignment. Throughout the years of this study, Mr. Belzer taught sixth grade at a K–6 elementary school that enrolled approximately 500 students. Mr. Belzer had 26 years of teaching experience. The vast majority of the students were Hispanic (89%), and approximately 60% of the students were English language learners. Over 97% of the students at the school qualified for free or reduced-price lunch.

Changes in Self-Efficacy. As shown in Figure 2, Mr. Belzer had high and relatively steady PSTE scores over the five time points. His score dropped from 4.2 to 3.8 during the years of no PD before increasing slightly to 4 after 1 year of follow-up support and stabilizing at 3.9 for the last 2 years. Although Mr. Belzer's PSTE remained high, it never returned to its highest level. In survey responses at the end of the prior PD program in 2013, Mr. Belzer indicated feeling "very well prepared" to teach science, mathematics, and language arts. He also reported feeling "very well prepared" to manage hands-on, project-based work in the classroom and "fairly well prepared" to engage students in inquiry-oriented activities and lead students using investigative strategies. During the years with no PD, his sense of preparedness declined, particularly his overall preparedness to teach science. In 2017, before the follow-up support started, he indicated being only "somewhat prepared" to teach science but "fairly well prepared" to manage students in hands-on or project-based work, to lead students in investigative strategies, and to engage students in inquiry-oriented activities.

In his interview prior to follow-up support, he pointed out his lack of science knowledge prior to the original PD and how the 3-year program built not only his content knowledge but also his confidence. He often described "feeling like the weakest link in the room as far as science is concerned" and credited the collaboration among teachers, "the working together and problem solving," as the most helpful feature in building his confidence.

During the years of follow-up support, Mr. Belzer reported in surveys an increased sense of preparedness, moving from "somewhat prepared" to "fairly well prepared" to teach science. Over the 3 years, he consistently reported being "very well prepared" to engage students in inquiry-oriented activities and "fairly well prepared" to lead students using investigative strategies and to manage hands-on, project-based work in the classroom. In interviews, he described his preparation to teach NGSS-aligned science as "better. It's not 100% but I am getting there" and "on a rubric, I would say I am a 3 moving to a 4." He acknowledged that "science and math can be so intimidating" and proposed that he "just need[ed] to hone my skills." He appreciated looking at other teachers' lessons and figuring out the components of a good lesson. By the end of the 3 years, he stated that he would have been "completely overwhelmed" by NGSS-aligned instruction if not for the follow-up support and emphasized his perspective that "the more you do it, the better you get at it."

Science Instruction. Mr. Belzer viewed the follow-up support as "restarting" his motivation and his focus on teaching science; he expressed motivation to teach NGSS-aligned science because "student engagement really made me want to get even more serious." Reporting that he was "somewhat confident" to teach NGSS-aligned science, he still questioned his understanding of science principles (i.e., Do I have the knowledge to execute this?). After the first year of follow-up support, Mr. Belzer indicated that he was increasing the number of experiments included in his science instruction and adapting his lessons to be more NGSS-aligned because of the PD. By the following year, he had attempted a lesson based on biomimicry, and his students "were able to build this insect-looking thing with circuitry that lit up." Besides being "super-engaging" for the students, the activity modeled the connection to nature. After teaching the lesson, Mr. Belzer immediately reflected on how it "could have been so much more thoughtful" and had "deeper connections" if he had included other NGSS components. Describing himself as more purposeful in his science instruction, he aimed to move beyond "surface-level teaching" because he felt capable of better teaching and believed that his students deserved more. He believed the follow-up support gave him "a better mindset to teach science" and, given the focus on NGSS-aligned instruction, led to a "reversal in how I was designing my science lessons." He stated, "[The follow-up support] gave me a starting point of how to start with the end in mind and how to start to decipher the standard, the phenomena, what we're looking at then the activity, the support." By the end of the 3 years, he reported that there had been a "gradual shift" in his science instruction and that he was "doing science with a more regular focus." Mr. Belzer believed that the follow-up support provided "a good, solid foundation that I wouldn't have had otherwise."

Ms. Barton

Teaching Assignment. During the years of this study, Ms. Barton had had 26 years of teaching experience and taught a fifth/sixth grade combination class at an elementary school that included Grades 3–6 and had a population of approximately 30 students. The small student population consisted primarily of White (74%) and Hispanic (20%) students. Approximately 7% of the students were English language learners, and approximately 60% of the students qualified for free or reduced-price lunch.

Changes in Self-Efficacy. As shown in Figure 2, the PSTE scores for Ms. Barton remained high across the five time points. Her self-efficacy in teaching science decreased slightly (5 to 4.7) after the years with no PD but increased to 4.9 after the first year of follow-up support. During the last 2 years of support, her PSTE score dropped to 4.3 before returning to 4.9. At all five time points, her PSTE scores were higher than average for the full sample of teachers and higher than the other case study teachers' scores.

In keeping with her high PSTE, Ms. Barton reported feeling "very well prepared" to teach science in survey responses at the end of her prior PD program in 2014. Similarly, Ms. Barton reported feeling "very well prepared" to engage students in inquiry-oriented activities, lead students using investigative strategies, and manage students in hands-on, project-based work. During the years with no PD, her sense of preparedness to teach science declined slightly. In 2017, before follow-up support started, she indicated feeling "fairly well prepared" to teach science, in contrast to feeling “very well prepared” to teach language arts. However, she continued to feel “very well prepared” to manage students in inquiry-oriented, investigative, and project-based activities in science. In her interview prior to follow-up support, she linked her confidence in teaching science to her passion and interest in doing so. She noted the change in standards as giving her “some anxiety” about teaching new topics and concepts but suggested that would diminish as curriculum is developed for the standards.

After the first year of follow-up support, Ms. Barton reported again feeling “very well prepared” to teach science and to engage students in inquiry-oriented, investigative, and hands-on, project-based activities in science. Her high ratings of preparedness on the survey continued throughout the 3 years of follow-up support. In interviews, Ms. Barton confirmed her high level of confidence in teaching science as well as the NGSS-aligned science curriculum. In contrast to other teachers, she attributed her preparedness to “working through NGSS since it came out, so I’ve been doing it [for] quite a few years.” Similar to other teachers, she pointed to practice as the way to build confidence: “getting used to the standards and just doing it more than once . . . modifying my lessons as I practice.” By the end of 3 years of follow-up support, Ms. Barton concluded that she was “highly prepared” to teach NGSS-aligned science due to “evolutionary change over time” that allowed her to better understand the various components and acronyms associated with the standards, to observe model lessons, and to develop curricula with other teachers.

***Science Instruction*.** Ms. Barton’s science instruction reflected her high self-efficacy and sense of preparedness to teach science and NGSS-aligned lessons. In interviews, she described modifying her lessons and shifting toward “more student-centered, student-driven” science instruction. She shifted her role toward “giving them the tools,” “setting up really good phenomena,” and “asking a lot of questions.” Ms. Barton stated that “having them [students] direct a lot of the teaching” was important because “they’re motivated and they’re in charge and they get excited about that.” For example, she developed an NGSS-aligned lesson sequence focused on an environmental area near the school “that has some really rare plants and animals.” The lessons included field experiences, experiments, and classroom components. Another science lesson centered on an ice cream making experiment that involved “a controlled study with different amounts of salt.” The students “noticed that the temperatures were really significantly different with higher amounts of salt.” Beyond the experiment, making ice cream was part of “an integrated study where the kids are actually entrepreneurs and they’re going to sell their ice cream products.” To address engineering standards, she developed a task that involved creating a water wheel that used rice instead of water. “I give them some simple tools, give them the task, and don’t let them look it up on Google, and just experiment.” Ms. Barton identified collaboration as a key factor in her confidence not only to teach science but also to “go deeper into the NGSS formats.”

> It's just motivating to be with other people that enjoy science, and it just spurs me on, personally, to just continue to keep trying and do my best with just delving through all the new stuff. I just feel great confidence because I know that I can always call on people if I need help.

Given the extremely small size of her school, Ms. Barton had few opportunities to collaborate with other teachers and viewed the "collaboration aspect" as the most important part of the follow-up support, particularly meeting with other teachers "to discuss science curriculum, what's out there, what is aligned with NGSS, and any kind of lesson plans that work really well."

Cross-Case Findings

In our cross-case analysis, five key findings emerge. First, all four teachers experienced declines in their PSTE during the years without any PD or follow-up support. The extent of the decrease in PSTE scores varied across teachers, but the pattern of decline after the prior PD programs ended was consistent. Teachers' sense of preparedness to teach science and to implement specific instructional strategies, as reported in surveys, followed a similar pattern of decline during the years without PD, but there were variations across teachers' decline. Even Ms. Barton, who maintained high levels of self-efficacy and preparedness over a 6-year period, experienced small decreases after the prior PD ended. This pattern of decline is not surprising, but it highlights the need to find ways to sustain PD outcomes over time.

Second, three of the four case study teachers' PSTE scores increased to some extent after 1 year of follow-up support. In contrast, Ms. Trujillo reported an additional drop in her PSTE after the first year of follow-up support. The transition to NGSS-aligned science instruction was particularly worrisome for her, and she expressed concerns about her preparation to make the switch. In addition, Ms. Trujillo pointed out that she typically tends to question her abilities and "make everything more complicated." Her self-efficacy and sense of preparedness to teach science gradually improved after more follow-up support and more "trial and error" in teaching NGSS-aligned lessons. The case study teachers exhibited differing levels of self-efficacy and differing patterns over the five time points, but, across cases, the follow-up support positively influenced their preparedness and self-efficacy for teaching science. This finding underscores the potential value of offering modest ongoing support to sustain PD outcomes over time.

Third, the timing of the transition to NGSS had a substantial influence on teachers' confidence to teach science as well as their focus on science instruction. In the years after their prior PD programs ended, teachers faced the realization that adoption of NGSS would be forthcoming. Whereas Ms. Barton, who had the highest levels of PSTE, started adjusting to NGSS when it was first released, other teachers paid less individual attention and received no district or school PD related to NGSS. Consequently, when teachers encountered the beginning stages of NGSS adoption, their confidence to teach science tended to decline, reflecting their concerns about shifting to NGSS-aligned instruction. As described earlier, Ms. Trujillo was particularly concerned about the transition, which led to decreased self-efficacy. During the years of follow-up support, the teachers not only exhibited a renewed focus on science instruction but also expressed interest in securing NGSS-aligned curricula, ideas for developing NGSS-aligned lessons, and materials to use in implementing the new standards.

Fourth, in interviews, teachers consistently highlighted collaboration with other teachers as an important feature of the follow-up support and a key factor in building their confidence to teach NGSS-aligned science. Given that teachers taught in small, rural schools, some of them were the only ones assigned to a particular grade level and had no opportunities for collaboration at their schools. The teachers valued collaboration in and of itself, but their need to develop NGSS-aligned lessons heightened the importance they placed on sharing ideas and working together. Teachers also described gaining more personal motivation for teaching science from interacting, problem solving, and reflecting on science instruction with other teachers. Ms. Trujillo, who struggled with her confidence and sense of preparedness to teach NGSS-aligned science, emphasized that talking with other teachers reduced her personal stress and her perspective about being able to manage the changes.

Fifth, the case studies suggest that the teachers' PSTE influenced their implementation of NGSS-aligned instruction. Ms. Barton, who had higher PSTE scores than the other case study teachers for all five time points, readily developed and implemented NGSS-aligned lessons, including activities to address the engineering standards, which other teachers tended to view as the most challenging. In contrast, Ms. Trujillo, whose PSTE scores declined the most among the case study teachers, struggled with NGSS-aligned lessons but gradually began to shift her science instruction as she collaborated with other teachers to develop NGSS-aligned lessons as part of the follow-up support. Her PSTE scores showed a corresponding rise but remained lower than the other case study teachers at the end of the follow-up support. This connection between teachers' self-efficacy and classroom instruction is supported by research indicating that gains in science teaching self-efficacy correlate with implementation of inquiry-oriented instructional strategies in science (Lakshmanan et al., 2011; Sandholtz & Ringstaff, 2022). Similarly, teachers with higher self-efficacy tend to use more student-centered and challenging instructional methods in the classroom (de Laat & Watter, 1995; Ross, 1998; Tschannen-Moran et al., 1998). Teachers' instructional choices are influenced by how teachers see themselves as science teachers, their reflections on prior episodes of science instruction, and the availability of support.

Discussion of Findings

The findings from the entire group of teachers suggest that modest forms of follow-up support can help to maintain and improve teachers' confidence to teach science. The follow-up support brought teachers back to nearly the same level as when the initial PD ended, suggesting that immediate follow-up support could have prevented the decline in self-efficacy that the teachers in this study experienced in the years after the PD ended. These findings also echo the documented value of sustained and ongoing PD (Catalano et al., 2019; Sandholtz & Ringstaff, 2022), especially in the face of changing policies such as the implementation of the NGSS.

The case studies provided an opportunity to gain insight into how policy changes impacted the teachers as a whole. We note that their self-efficacy with English and mathematics was generally higher than in science, consistent with prior research (Kozcu Çakir, 2020), where teachers often see science as "intimidating" and "anxiety" inducing. This is consistent with prior findings connected to the policy and resource allocation related to implementation of the CCSS, where science is often underresourced in comparison to English language arts and mathematics (Sandholtz & Ringstaff, 2022). The individual case studies also provided an opportunity to gain insights about how modest support interplays with varied individual teacher backgrounds and histories, their science knowledge, and their self-efficacy. Specifically, the modest support was able to meet a wide range of teachers' needs, especially as they related to NGSS-aligned curriculum. For instance, Mr. Harris was able to obtain curriculum, and the PD worked to facilitate explicit connections between the curriculum and NGSS, whereas for Ms. Trujillo, the PDs provided opportunities to develop and validate curriculum.

Conclusion

This study highlights changes in teachers' PSTE over an extended period. After years without PD, teachers' PSTE scores declined, but during years when teachers had access to modest follow-support, their scores improved. It is noteworthy that the decline in the average PSTE score stopped after just 1 year of follow-up support. Our findings demonstrate the potential for modest follow-up support to enhance teachers' self-efficacy in science and prompt teachers to shift toward NGSS-aligned science instruction. The availability of follow-up support had particular relevance due to the timing of the implementation of NGSS and teachers' uncertainty about shifting from their state science standards to the NGSS. Beyond the direct assistance with understanding the NGSS and designing NGSS-aligned lessons, teachers credited collaboration with other teachers as fostering their confidence and motivation to teach science and adapt their instruction to the new standards. The collegial support helped to counter the limited opportunities for teacher collaboration with grade-level peers in their small, rural schools. Teachers across countries report that the most impactful PD is based on collaborative approaches (Organisation for Economic

Co-operation and Development, 2019), but the lack of human resources in rural settings (Hellsten et al., 2011) makes opportunities to lessen teacher isolation and increase collegial support particularly valuable (Boyer, 2006; Harmon et al., 2007). Our study suggests that collaboration is a critical element of follow-up support for teachers in rural settings.

The case studies demonstrate differing patterns for individual teachers over the five time points that correspond with personal perspectives combined with school-level context. Whereas one teacher with lower self-efficacy described a personal tendency to stress about and avoid changes, another teacher reported high confidence stemming from her focus on the new standards as soon as they were released. In years when teachers struggled with student behavior or larger class sizes, they reported less confidence and motivation to adapt their science instruction. One teacher identified a lack of content knowledge in comparison with other teachers as an influence on his confidence to teach science. Working with other teachers during the follow-up PD exposed that difference but, more importantly, provided the support needed to foster his sense of preparedness. Although the patterns of PSTE scores varied for the case study teachers, the follow-up support had a positive influence on each teacher's sense of preparedness and self-efficacy for teaching science. In contrast to providing narrow approaches, offering teachers a range of options for follow-up support affords a way to meet teachers' individual and differing needs (Zinger et al., 2017).

The findings of this study reinforce the need for, and potential value of, providing modest follow-up support for teachers to sustain PD outcomes over time, building on studies that indicate the same need (Sandholtz & Ringstaff, 2022), particularly in rural settings (Avery, 2013). Ongoing yet modest support may be particularly important during periods when different standards are being implemented and teachers need to adapt their instruction accordingly. Other studies are needed to understand which follow-up supports influence teachers' instructional time and instructional practices in science as well as the costs and benefits of offering particular types of supports. Given this study's specific focus on four elementary school teachers during the NGSS era, other research is needed to understand the extent to which modest support sustains the impacts of PD in other content areas, at other grade levels, in other geographic spaces, and with a large sample of teachers.

Note

[1] All names are pseudonyms.

References

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

Avery, L. M. (2013). Rural science education: Valuing local knowledge. *Theory Into Practice*, *52*(1), 28–35. https://doi.org/10.1080/07351690.2013.743769

Bandura, A. (1977). Self-efficacy: Toward a unifying theory of behavior change. *Psychological Review*, *84*(2), 191–215. https://doi.org/10.1037/0033-295X.84.2.191

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

Benjamini, Y., & Hochberg, Y. (1995). Controlling the false discover rate: A practical and powerful approach to multiple testing. *Journal of the Royal Statistical Society, Series B*, *57*(1), 289–300. https://doi.org/10.1111/j.2517-6161.1995.tb02031.x

Boyer, P. (2006). *Building community: Reforming math and science education in rural schools.* Alaska Native Knowledge Network.

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*(7), 889–913. https://doi.org/10.1080/09500691003739374

Burton, M., Brown, K., & Johnson, A. (2013). Storylines about rural teachers in the United States: A narrative analysis of the literature. *Journal of Research in Rural Education*, *28*(12), 1–18.

Carlson, J., Davis, E. A., & Buxton, C. (2014). *Supporting the implementation of the Next Generation Science Standards (NGSS) through research: Curriculum materials*. https://narst.org/blog/ngss-curriculum

Catalano, A., Asselta, L., & Durkin, A. (2019). Exploring the relationship between science content knowledge and science teaching self-efficacy among elementary teachers. *IAFOR Journal of Education*, *7*(1), 57–70. https://doi.org/10.22492/ije.7.1.04

Deehan, J., McKinnon, D. H., & Danaia, L. (2019). A long-term investigation of the science teaching efficacy beliefs of multiple cohorts of preservice elementary teachers. *Journal of Science Teacher Education*, *30*(8), 923–945. https://doi.org/10.1080/1046560X.2019.1672377

de Laat, J., & Watter, J. J. (1995). Science teaching self-efficacy in a primary school: A case study. *Research in Science Education*, *25*(4), 453–464. https://doi.org/10.1007/BF02357387

Demir, K., & Ellett, C. D. (2014). Science teacher self-efficacy beliefs, change processes, and professional development. In *The role of science teachers' beliefs in international classrooms* (pp. 179–190). Sense. https://doi.org/10.1007/978-94-6209-557-1_12

Dogan, S., Pringle, R., & Mesa, J. (2016). The impacts of professional learning communities on science teachers' knowledge, practice and student learning: A review. *Professional Development in Education*, *42*(4), 569–588. https://doi.org/10.1080/19415257.2015.1065899

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*(4), 53–70. https://doi.org/10.1007/BF03182357

Farmer, T. A. (2009). Unique rural district politics. *Rural Educator*, *30*(2), 29–33. https://doi.org/10.35608/ruraled.v30i2.451

Fauth, B., Decristan, J., Decker, A. T., Büttner, G., Hardy, I., Klieme, E., & Kunter, M. (2019). The effects of teacher competence on student outcomes in elementary science education: The mediating role of teaching quality. *Teaching and Teacher Education*, *86*, 102882. https://doi.org/10.1016/j.tate.2019.102882

Flores, I. M. (2015). Developing preservice teachers' self-efficacy through field-based science teaching practice with elementary students. *Research in Higher Education Journal*, *27*.

Flyvberg, B. (2001). *Making social science matter*. Cambridge University Press.

Friedman, I. A., & Kass, E. (2002). Teacher self-efficacy: A classroom-organization conceptualization. *Teaching and Teacher Education*, *18*(6), 675–686. https://doi.org/10.1016/S0742-051X(02)00027-6

Goddard, R. D., Hoy, W. K., & Hoy, A. W. (2004). Collective efficacy beliefs: Theoretical developments, empirical evidence, and future directions. *Educational Researcher*, *33*(3), 3–13. https://doi.org/10.3102/0013189X033003003

Haag, S., & Megowan, C. (2015). Next Generation Science Standards: A national mixed-methods study on teacher readiness. *School Science and Mathematics*, *115*(8), 416–426. https://doi.org/10.1111/ssm.12145

Haney, J. J., Lumpe, A. T., Czeriak, C. M., & Egan, V. (2002). From beliefs to actions: The actions of teachers implementing change. *Journal of Science Teacher Education*, *13*, 171–187. https://doi.org/10.1023/A:1016565016116

Harmon, H., Gordanier, J., Henry, L., & George, A. (2007). Changing teaching practices in rural schools. *Rural Educator*, *28*(2), 8–12. https://doi.org/10.35608/ruraled.v28i2.480

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

Hellsten, L. M., McIntyre, L. J., & Prytula, M. P. (2011). Teaching in rural Saskatchewan: First year teachers identify challenges and make recommendations. *Rural Educator*, *32*(3), 11–21. https://doi.org/10.35608/ruraled.v32i3.425

Kozcu Çakir, N. (2020). The relation between self-efficacy beliefs towards science teaching and learning strategies of primary school teacher candidates. *International Journal of Research in Education and Science*, *6*(2), 347–360. https://doi.org/10.46328/ijres.v6i2.975

Kumar, M. (2013). New K–12 science education standards may face implementation challenges. *EOS*, *94*(18), 166–167. https://doi.org/10.1002/2013EO180002

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*(5), 534–551. https://doi.org/10.1002/tea.20404

Lunenburg, F. (2011). Self-efficacy in the workplace: Implications for motivation and performance. *International Journal of Management, Business, and Administration*, *14*(1), 1–6.

Mintzes, J. J., Marcum, B., Messerschmidt-Yates, C., & Mark, A. (2012). Enhancing self-efficacy in elementary science teaching with professional learning communities. *Journal of Science Teacher Education*, *24*, 1201–1218. https://doi.org/10.1007/s10972-012-9320-1

Mulholland, J., & Wallace, J. (2001). Teacher induction and elementary science teaching: Enhancing self-efficacy. *Teaching and Teacher Education*, *17*(2), 243–261. https://doi.org/10.1016/S0742-051X(00)00054-8

National Research Council. (2012). *A framework for K–12 science education: Practices, crosscutting concepts, and core ideas.* National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For states, by states.* National Academies Press.

Organisation for Economic Co-operation and Development. (2019). *Executive summary in TALIS 2018 results: Vol.* 1. *Teachers and school leaders as lifelong learners*. OECD Publishing. https://doi.org/10.1787/ca047707-en

Palinkas, L. A., Horwitz, S. M., Green, C. A., Wisdom, J. P., Duan, N., & Hoagwood, K. (2015). Purposeful sampling for qualitative data collection and analysis in mixed method implementation research. *Administration and Policy in Mental Health and Mental Health Services Research*, *42*(5), 533–544. https://doi.org/10.1007/s10488-013-0528-y

Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). SAGE.

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*(3), 189–220. https://doi.org/10.1023/A:1016517100186

Raudenbush, S., Rowan, B., & Cheong, Y. (1992). Contextual effects on the self-perceived efficacy of high school teachers. *Sociology of Education*, *65*(2), 150–167. https://doi.org/10.2307/2112680

Riggs, I. M., & Enochs, L. G. (1990). Toward the development of an elementary teacher's science teaching efficacy belief instrument. *Science Education*, *74*(6), 625–637. https://doi.org/10.1002/sce.3730740605

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*(3), 199–213. https://doi.org/10.1023/A:1016708016311

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). Emerald.

Ross, J. A., Cousins, J. B., & Gadalla, T. (1996). Within-teacher predictors of teacher efficacy. *Teaching and Teacher Education*, *12*(4), 385–400. https://doi.org/10.1016/0742-051X(95)00046-M

Saldaña, J. (2016). *The coding manual for qualitative researchers* (3rd ed.). SAGE.

Sandholtz, J. H., & Ringstaff, C. (2022). Offering modest supports to extend professional development outcomes and enhance elementary science teaching. *Professional Development in Education*, *48*(4), 672–687. https://doi.org/10.1080/19415257.2020.1725594

Sandholtz, J. H., Ringstaff, C., & Matlen, B. (2016). Temporary fix or lasting solution? Investigating the longitudinal impact of teacher professional development on K–2 science instruction. *Elementary School Journal*, *117*(2), 192–215. https://doi.org/10.1086/688920

Sandholtz, J. H., Ringstaff, C., & Matlen, B. (2019). Coping with constraints: Longitudinal case studies of early elementary science instruction after professional development. *Journal of Educational Change*, *20*, 221–248. https://doi.org/10.1007/s10833-019-09338-2

Showalter, D., Hartman, S. L., Johnson, J., & Klein, B. (2019). *Why rural matters 2018–2019: The time is now.* Rural School and Community Trust.

Snyder, C. R., & Lopez, S. J. (2007). *Positive psychology: The scientific and practical explorations of human strengths.* SAGE.

Strange, M. (2011). Finding fairness for rural students. *Phi Beta Kappan*, *92*(6), 8–15. https://doi.org/10.1177/003172171109200603

Tschannen-Moran, M., & Hoy, A. W. (2007). The differential antecedents of self-efficacy beliefs of novice and experienced teachers. *Teaching and Teacher Education*, *23*(6), 944–956. https://doi.org/10.3102/00346543068002202

Tschannen-Moran, M., Hoy, A. W., & Hoy, W. K. (1998). Teacher efficacy: Its meaning and measure. *Review of Educational Research*, *68*(2), 202–248. https://doi.org/10.3102/00346543068002202

Yin, R. K. (2003). *Case study research design and methods* (3rd ed.). SAGE.

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*(2), 161–179. https://doi.org/10.1007/s10972-009-9161-8

Zinger, D., Haymore Sandholtz, J., & Ringstaff, C. (2020). Teaching Science in rural elementary schools: Affordances and constraints in the age of NGSS. *Rural Educator*, *41*(2), 14–30. https://doi.org/10.35608/ruraled.v41i2.558

Zinger, D., Naranjo, A., Gilbertson, N., Amador, I., & Warschauer, M. (2017). A design-based research approach to improving professional development of the Smithsonian Learning Lab. *Contemporary Issues in Technology and Teacher Education*, *17*(3).