



Integrating Service-Learning Pedagogy For Preservice Elementary Teachers' Science Identity Development

By: **Rachel E. Wilson**, Leslie U. Bradbury, and Martha A. McGlasson

Abstract

The purpose of this article is to explore how preservice elementary teachers (PSETs) interpreted their service-learning experiences within a pre-methods environmentally focused course and how their interpretations shaped their science teaching identities. Along a continuum of service-learning experiences were events that emphasized science learning, that focused on science teaching, and that were transitional, with elements of both science learning and science teaching. These various service-learning experiences were designed to be “boundary experiences” for professional identity development (Geijsel & Meijers in *Educational Studies*, 3(4), 419–430, 2005), providing opportunities for PSETs to reflect on meanings in cultural contexts and how they are related to their own personal meanings. We analyzed written reflections and end-of-course oral reflection interviews from 42 PSETs on their various service-learning experiences. PSETs discussed themes related to the meanings they made of the service-learning experiences: (a) experiencing science in relation to their lives as humans and future teachers, (b) interacting with elementary students and other PSETs, and (c) making an impact in the physical environment and in the community. The connections that PSETs were making between the discursive spaces (service-learning contexts) and their own meaning-making of these experiences (as connected to their own interests in relation to their future professions and daily lives) shows evidence of the potential that various types of science service-learning experiences have for PSETs in developing inbound science teaching identity trajectories (Wenger in *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press, 1998). The findings of this study point to positive outcomes for PSETs when they participate in structured service-learning experiences along a learning to teaching continuum.

Wilson, R.E., Bradbury, L.U. & McGlasson, M.A. Integrating Service-Learning Pedagogy for Preservice Elementary Teachers' Science Identity Development. *J Sci Teacher Educ* 26, 319–340 (2015). <https://doi.org/10.1007/s10972-015-9425-4>. Publisher version of record available at: <https://link.springer.com/article/10.1007/s10972-015-9425-4>

Integrating Service-Learning Pedagogy for Preservice Elementary Teachers' Science Identity Development

Rachel E. Wilson · Leslie U. Bradbury ·
Martha A. McGlasson

Published online: 3 March 2015

© The Association for Science Teacher Education, USA 2015

Abstract The purpose of this article is to explore how preservice elementary teachers (PSETs) interpreted their service-learning experiences within a pre-methods environmentally focused course and how their interpretations shaped their science teaching identities. Along a continuum of service-learning experiences were events that emphasized science learning, that focused on science teaching, and that were transitional, with elements of both science learning and science teaching. These various service-learning experiences were designed to be “boundary experiences” for professional identity development (Geijsel & Meijers in *Educational Studies*, 3(4), 419–430, 2005), providing opportunities for PSETs to reflect on meanings in cultural contexts and how they are related to their own personal meanings. We analyzed written reflections and end-of-course oral reflection interviews from 42 PSETs on their various service-learning experiences. PSETs discussed themes related to the meanings they made of the service-learning experiences: (a) experiencing science in relation to their lives as humans and future teachers, (b) interacting with elementary students and other PSETs, and (c) making an impact in the physical environment and in the community. The connections that PSETs were making between the discursive spaces (service-learning contexts) and their own meaning-making of these experiences (as connected to their own interests in relation to their future professions and daily lives) shows evidence of the potential that various types of science service-learning experiences have for PSETs in developing inbound science teaching identity trajectories (Wenger in *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press, 1998). The findings of this study point to positive outcomes for PSETs when they participate in structured service-learning experiences along a learning to teaching continuum (246).

R. E. Wilson (✉) · L. U. Bradbury · M. A. McGlasson
Curriculum and Instruction, Reich College of Education, Appalachian State University,
ASU Box 32047, Boone, NC 28608-2047, USA
e-mail: wilsonre3@appstate.edu

Keywords Preservice teachers · Professional identity · Service-learning · Elementary science

Introduction

The purpose of this article is to explore how preservice elementary teachers (PSETs) interpreted their experiences within a pre-methods, environmentally-focused curriculum course using service-learning pedagogy and how their interpretations are related to their science teaching identity development. Studies have shown that the personal science learning experiences of PSETs influence their ideas about science teaching and learning (Davis, Petish, & Smithey, 2006; Wilson & Kittleson, 2012) and the ways in which they identify as science teachers (Eick, 2009; Katz, McGinnis, Riedinger, Marbach-Ad, & Dai, 2012). As teacher educators, we have become increasingly concerned about our PSETs' preparation for teaching science in ways that meet the ambitious expectations for elementary teachers. The recent reform documents, *A Framework for K-12 Science Education* (National Research Council [NRC], 2012) and the corresponding *Next Generation Science Standards* (NRC, 2013), emphasize the need to educate students to become scientifically literate citizens by focusing on major science concepts and using scientific and engineering practices. This vision of science teaching with elementary-aged students is not new, but rather an extension of previous reform documents, such as the *National Science Education Standards* (NRC, 1996). Yet, the practice of reform-based science teaching in elementary schools has been severely hindered by a focus on language arts and mathematics due to the increased accountability placed on testing in these subjects (Griffith & Scharmann, 2008). Thus, the most recent reform documents for science education are being unveiled at a time when elementary teachers are spending less time teaching science.

As future elementary teachers, PSETs are trained as content generalists, and perhaps because of the breadth of their training, PSETs have relatively unsophisticated science content knowledge (Davis et al., 2006), yet they do not have anti-science views (Cobern & Loving, 2002). Though PSETs' experiences as science learners are not uniformly negative or positive (Davis et al., 2006), their personal learning experiences with science are often not with instructors who model inquiry-based practices (Windschitl, 2006). Therefore, their content and pedagogy for teaching science are often reliant on one semester of experience with and/or exposure to inquiry-based science teaching and learning. In this paper, we use the definition of inquiry-based science put forth by Minner, Levy, and Century (2010) in their review of inquiry science as having three elements:

- (1) the presence of science content,
- (2) student engagement with science content, and
- (3) student responsibility for learning, student active thinking, or student motivation within at least one component of instruction (p. 478).

We believe this definition of inquiry-science is appropriate and attainable for both PSETs and elementary students as science learners.

There are promising implications of incorporating early experiences of teaching consistent with inquiry-based science instruction into an elementary teacher education program for developing prospective elementary teachers' science teaching identities (Katz et al., 2012). In recognition of the importance of lived experiences of science learning for PSETs' developing teacher identity, we are interested in the potential that science-focused service-learning experiences can have on PSETs' developing ideas about science teaching and learning before they begin their formal methods courses. Our research questions are:

- How do PSETs interpret their experiences within various science-related service-learning events?
- How do PSETs' interpret their science identities in light of their experiences within various science-related service-learning events?

Literature Review

Personal Learning Experiences

Teachers will teach in ways that match their professional identities and personal science learning experiences (Eick, 2009; Luehmann, 2007). Studies of preservice and inservice teachers have documented connections between their personal science learning experiences and their professional practices in science teaching (Davis et al., 2006; Eick, 2009; Eick & Reed, 2002). The ways in which preservice teachers' were taught science are important components in understanding their likelihood to implement inquiry-based activities as they are preparing for secondary (Eick & Reed, 2002) and elementary (Wilson & Kittleson, 2012) science teaching. Secondary science preservice teachers who were highly reflective of their personal learning experiences and their learning preferences were more successful in planning and teaching in ways that were consistent with their identities and learning preferences (Eick, 2009). This underscores the need for preservice teachers to have personal learning experiences in science that are inquiry-based, and to have time to reflect on these science learning experiences.

In addition to needing more time to experience science learning and teaching in inquiry-based ways, PSETs need to have more time to engage with science learning and teaching ideas before their end-of-program school-based internships (Cone, 2009; Eick & Reed, 2002; Katz et al., 2012), and need further opportunities for productive reflection (Davis, 2006). Preservice teachers' lack of meaningful reflection about their own identities, even with possibilities for explicit acknowledgement and reflection, is a significant stumbling block for the development of professional teaching identities (Timoššuk & Ugaste, 2010). Like many other programs, our elementary education program has only one science methods course for students, thus only one required opportunity to experience inquiry-based science instruction. With this structure, PSETs have only one semester to explicitly reflect on their ideas about science teaching and learning that have been formed throughout

their lifetimes and to try out university-endorsed ideas, which may or may not coincide with their personal science learning experiences, or with the practices in use by the community of practice in their school-based internships (Luehmann, 2007; Smagorinsky, Cook, Moore, Jackson, & Fry, 2004).

Service-Learning and Science Education

By incorporating service-learning into teacher preparation programs, teacher educators have sought to provide PSETs with possibilities for out-of-school engagement with students (Calabrese Barton, 2000; Cone, 2009, 2012; Wallace, 2013) and increasing preservice teacher comfort with inquiry-based science teaching (Cartwright, 2012; Cox-Petersen, Spencer, & Crawford, 2005; Jung & Tonso, 2006). Service-learning is a pedagogy employed in formal schooling that is characterized as “committed to connecting theory and practice, schools and community, the cognitive and the ethical” (Butin, 2003, p. 1675). Service-learning projects are incorporated into a school curriculum in a particular subject or course, with the goal of having students connect community-based issues to formal school topics to enhance students’ learning and interest in subjects like science (Reynolds & Ahern-Dodson, 2010).

Service-learning experiences in teacher education are seen as different from, and additional to, school-based internships in that they occur outside of regular school hours and the formal classroom (Cox-Petersen et al., 2005) and address a need in the community (Butin, 2003). The key components of quality service-learning courses in higher education are (a) relevance of service to academic content of courses, (b) multiple and consistent reflections on service experiences that ask students to think about personal values, experiences, and attitudes, and (c) reflections that include multiple means of expression (Hatcher, Bringle, & Muthiah, 2004). These components of quality service-learning courses are similar to the expectations for teacher preparation programs, in terms of the incorporation of elementary classroom internships to provide realistic and relevant professional experience (Settlage, Southerland, Smith, & Ceglie, 2009), of opportunities for students to be reflective of their values, experiences, and attitudes (Eick, 2009; Luehmann, 2007), and opportunities for productive reflection (Davis, 2006; Timoštšuk & Ugaste, 2010).

The benefits of close fit between service-learning and course work have been studied in relation to science learning (e.g. Reynolds & Ahern-Dodson, 2010) and science teaching (e.g. Cone, 2009). In elementary teacher education, research involving PSETs teaching elementary-aged students in community-based settings have focused on the outcomes of increased confidence for teaching inquiry-based science (Cartwright, 2012; Cox-Petersen et al., 2005; Spencer, Cox-Petersen, & Crawford, 2005) and for teaching science to diverse learners (Cone, 2009; 2012). As a result of their service-learning experiences, PSETs reported increased feelings of confidence in teaching science, increased “self-worth” as future educators, and pride in their service to others (Cox-Petersen et al., 2005). PSETs saw a benefit to working in teams to teach small groups of students, as the small student to teacher ratio gave them a better understanding of student learning, and allowed them to feel supported and have more confidence in trying inquiry-based science lessons (Spencer et al., 2005).

In addition to increasing preservice teacher confidence in teaching science, the inclusion of service-learning experiences is seen as beneficial to influencing students' perceptions of science learning as a cultural and contextual process. Service-learning in teacher education programs in Australia has been used as a pedagogical strategy to develop in preservice teachers a sense of community engagement to promote the importance of making content and learning relevant for their students (Butcher et al., 2003). In addition, by involving PSETs in working with students in community-based settings, preservice teachers can reflect on their own ideas about science, culture, and students outside of the meanings associated with formal classrooms (Calabrese Barton, 2000; Wallace, 2013). Therefore, involving PSETs in service-learning in community-based settings holds promise to help them become more reflective of their own values, attitudes, and interests towards science, and thus could help them develop science teaching identities. Yet, service-learning experiences for PSETs that involve them in science *teaching and learning* focused contexts have not been studied, nor have studies explored how using both science learning and science teaching focused service-learning experiences shape the science teaching identities of PSETs involved.

Theoretical Framework

By focusing on the development of teacher professional identity, the relationship between personal experiences and professional practices can be explored (Luehmann, 2007). Our framing of identity is consistent with a narrative definition of identity for learners (Sfard & Prusak, 2005) and teachers (Geijsel & Meijers, 2005), specifically, identity as narrated interpretations of self in a culturally constructed world, which is supported by the theoretical work of Wenger (1998) and Holland, Lachicotte, Skinner, and Cain (1998). If PSETs do not identify themselves as science learners or teachers, then they will be less likely to plan and implement meaningful science experiences for their students (Eick, 2009). Therefore, we are less interested in how others identify PSETs in relation to their aspirant profession, and more interested in how our PSETs identify themselves in relation to science (Sfard & Prusak, 2005).

Examining changes in identity as a process of learning, especially in an increasingly mobile and globalized world, is the goal of research on *identity work* and *identity trajectories* (Calabrese Barton et al., 2013; Leander, Phillips, & Headrick Taylor, 2010). The foundation for understanding learning as a change in identity comes from the work of Lave and Wenger (1991) on situated learning and Wenger (1998) on communities of practice. As aspirant legitimate peripheral participants in elementary education, the elementary education program and our service-learning course involve PSETs in beginning experiences in a community of practice, and as newcomers, they are learning how to be a part of a social group with all of its norms, practices, and meanings. In his social theory of learning, Wenger (1998) describes possible identity trajectories in regards to participation in a community of practice that are relevant in thinking about professional identity: peripheral, inbound, insider, boundary, and outbound trajectories (p. 155). In using Wenger's (1998) types of identity trajectories, we acknowledge that identity

trajectories can address how learning develops through multiple spaces and time (Calabrese Barton et al., 2013; Leander et al., 2010), for example, a teacher's professional identity trajectory. By focusing on identity across space and time, we are attempting to find traces of a dynamic process at the socio-cultural nexus of schools, home, and community.

We resonate with the work of Geijssel and Meijers (2005) who argue that learning by teachers can be motivated through a *boundary experience*: when one “encounters a situation in which one is unable to function adequately because one cannot fully identify with the new situation and its exigencies” (p. 424). If the nature of a boundary experience causes a person to have a harder time identifying with the situation, they may avoid future situations like it. If the nature of the boundary experience is not too unfamiliar, they may try to cope in the new situation, which is when the learning and potential for change can occur through experiences that provide PSETs with opportunities for educative struggle (Frykholm, 2004; Wilson & Kittleston, 2012).

In order for professionals to have a boundary experience, Geijssel and Meijers (2005) argue that there “needs to be a ‘double-dialogue’ concerning the meaning of the boundary experience for the community of practice, as well as one’s personal sense of the boundary experience” (p. 426). In the boundary experience, the person is involved in a socio-cultural context in which there is the possibility for the person to experience “discursive meaning-giving” through exposure to concepts, emotions, and shared values in the context. Equally as important is the opportunity for personal meaning making through what Geijssel and Meijers (2005) describe as “intuitive sense-giving,” in which the person considers their emotional experience, personal meanings of concepts, and their “life (hi)story” (p. 426). Based on this theoretical description of the role that boundary experiences can play in identity development, we believe that there is strong potential for science service-learning projects to act as boundary experiences for PSETs due to the opportunity to act within a community of practice and then individually reflect on that experience to make meaning of it in relation to the self. In addition, viewing boundary experiences as a framework for impacting identity trajectories has promise for thinking about how to prepare teachers for the possible discomfort of teaching inquiry-based science when it is often not the way they are used to learning or seeing science taught (Windschitl, 2006). Therefore, we are exploring how PSETs interpret their experiences of science-related service and how their interpretations shape the development of their science teaching identities.

Context

Two of the authors work in an elementary education program at a regional university in the eastern United States. The elementary education program is unique in that it has a service-learning program within the major, whereby undergraduates take a series of three service-learning courses. This study focuses on PSETs’ experiences within one of the various first service-learning courses in the sequence of three: an environmentally focused curriculum course taken before their methods courses.

The course for PSETs was designed using service-learning pedagogy to build science content knowledge, provide students with an inquiry-based science learning experience, and involve students in service projects related to science learning and teaching. To engage students with a topic that is relevant to them, the course has been revised to begin with a focus on environmental issues related to food production and consumption. During each class meeting PSETs are involved in hands-on activities that relate to a science topic from the state K-6 science standards and have a connection to an environmental issue connected to food production or consumption, such as the pervasiveness of pesticides and agrochemicals, habitat destruction for agriculture, and comparing the carbon footprint of local versus global diets. The common structure of these lessons is a 5E lesson format (Bybee et al., 2006), with the foundational science idea from the state science standards addressed in a concrete inquiry-based *Explore* activity (i.e. animal–plant relationships through pollination), and then applied to an environmental issue within the *Expand* activity (i.e. jigsaw documentary clip viewings about variations in agricultural methods and bee colony collapse disorder in United States and France). By using this approach, the intention is for PSETs to learn science content in a way that is relevant to their interests (food), to help them see how science knowledge is relevant to their daily lives, and piques their interest in learning more about their role within their local environment and community. This approach to teaching the course is compatible with the Minner et al. (2010) definition on inquiry-based science in that it helps students review science content, as well as participate in activities that require them to collect and analyze data, and connect their understanding to relevant environmental issues.

As the beginning step in the service-learning sequence, the environmentally focused course involves PSETs in several different service projects that are chosen by the instructor to provide them with science learning and teaching experiences outside of formal classrooms. The service-learning projects that PSETs engaged in were selected by the instructor to provide PSETs with experiences along a continuum from experiences that emphasized science learning, to some that involved PSETs in both science learning and science teaching, and finally to others with a more explicit focus on science teaching. Table 1 contains our definitions of each of these types of science service-learning, as well as specific examples of experiences that PSETs participated in during the spring and fall 2013 terms. By engaging PSETs in service-learning experiences along a continuum, the intention was to provide multiple opportunities for PSETs to reflect on various aspects of their identities as both as science learners and as future science teachers.

Methodology

We chose to pursue an interpretive qualitative inquiry because we were interested in the personal meanings that PSETs were expressing in their individual reflections on their service-learning experiences. Qualitative inquiry seeks to explore the perspectives of participants in their own words in a naturalistic setting (Patton,

Table 1 Service-learning experiences on a continuum of science learning to science teaching

	Science learning focused	Transitional	Science teaching focused
Definition of type of service-learning experience	PSETs apply science content knowledge in a community setting	PSETs work in outdoor learning spaces on school grounds	PSETs teach inquiry-based activities related to state curriculum science content knowledge to elementary-aged students in a community setting
Spring 2013 service-learning events	PSETs visited the university sustainable development farm where they harvested, washed and bagged kale for local delivery PSETs cleaned up trash along a local river and recreation trail after a major flooding event	PSETs reclaim overgrown nature trails and garden beds at a local elementary school with teachers on a Saturday	PSETs facilitate inquiry-based science center at a Family Science Night at a local elementary school with 3–5th graders and their families
Fall 2013 service-learning events	PSETs build a spur trail in a local national forest	PSETs construct school garden with elementary students	PSETs facilitate inquiry-based science center at a Family Science Night at a local elementary school with K-5th graders and their families

2002), “attempting to make sense of or interpret phenomena in terms of the meanings people bring to them” (Denzin & Lincoln, 2011, p. 3). Interpretive qualitative research is interested in answering questions related to not only “how social action and order are accomplished,” but “*what* is being accomplished, under *what* conditions, and out of *what* resources” (Holstein & Gubrium, 2011, p. 342). An interpretive lens allowed us to focus our analysis on the meaning-making of the PSETs within their narrative descriptions and reflections on their service experiences in the course (Polkinghorne, 1995). Therefore, we are purposefully choosing to highlight the voices of PSETs and the aspects of the service-learning experiences that they found meaningful.

Participants

Forty-two students were enrolled in an environmentally-focused curriculum course taught by the first author in the spring and fall 2013 terms, and all agreed to participate. At the time of the study, all students were intended elementary education majors in their second or third year of undergraduate study and were enrolled in pre-requisite courses for the elementary education major. All PSETs were traditionally-aged university students. There were 38 females and four males. 41 out of the 42 students were White, and one student was Black. These gender and race demographics are typical for elementary majors at our regional university.

Data Collection

In viewing the service-learning experiences as a possible influence on the development of PSETs science identities (Geijsel & Meijers, 2005), we formally incorporated opportunities for individual and collective reflection on the meanings they made after engaging in these events. This paper is informed by the data from participants' written reflection on their past science experiences at the beginning of the course, as well as three written reflections which they wrote after their participation in each of the three service-learning events in the course. In addition, PSETs met with the instructor for an end-of-course final individual oral reflection, which was recorded and transcribed. In alignment with a narrative conception of identity, we crafted the multiple, consistent written reflection prompts to encourage PSETs to include descriptions of their experiences to "promote and provide a window into their thinking" (Davis, 2006, p. 295) and to get an idea of their reflection-on-action (Schön, 1983). The written reflection prompts asked PSETs to describe their participation in the service-learning event, their most memorable moment, and what connections they saw between the service-event and their ideas about science learning, science teaching, and their role in the environment. In alignment with Sfard and Prusak's (2005) views of identity as stories about ourselves, we crafted the final individual oral reflection at the end of the course to encourage the students to re-tell narratives about their past science learning experiences and their experiences of the service-learning aspect of the course.

Data Analysis

Once each semester term was completed, all of the written reflections were compiled and oral reflections were transcribed for each PSET participant and assigned a pseudonym in place of their name. A three-person research team was formed to analyze the data from the PSETs, comprised of the instructor of the course, another science educator in the elementary education program, and a graduate student in middle grades science education. Because we were looking for themes related to PSETs' interpretations of the service-learning experiences, we used a constant comparative approach for our multi-step data analysis process (Charmaz, 2006). Our three-person research team individually coded a randomly chosen subset of five PSETs' final oral interview data to identify initial patterns of meaning related to the service-learning experiences. We then met as a research group to discuss our understandings and come to a consensus on the most prevalent and strongly supported emergent patterns. Subsequently each member of the team individually coded the same five PSETs' written reflections of their favorite service-learning event to identify confirmatory or non-confirmatory instances of the initial emergent patterns that we had identified. Then, each member of the team individually examined all service-learning written reflections from the same subset of five PSETs to determine whether there were additional patterns present. After this first round of data analysis, we met as a research team and identified four emerging themes about the meanings PSETs were making based on their experiences within the service-learning events and agreed on a definition for each of the four themes.

Table 2 Definitions and example quotations for themes

Theme	Definition of theme	No. of instances	Example quotation
Learning: PSETs physically experiencing science content	Science content that PSETs experienced in a physical setting through the service that reinforced academic course content	69	One of the interesting parts of this trip was seeing how they moved the animals around the same way that they were moved in <i>The Omnivore's Dilemma</i> . The cows are allowed time to graze, then the chickens are brought over to clean and sanitize the area that the cows had previously been on. (Jeff)
Learning: pedagogical perspectives of PSETs	Ideas that the PSETs say they formed about how they will teach students based on their service experience	87	The nature trail was cleaned up a bit so that students can walk through and use this area that was set up with information about certain tree's and plants. The more students can learn and experience nature, the more they can take care of it and appreciate it. (Audrey)
Interacting with others	PSETs were describing their experiences with others during their service	64 (with elementary students) 27 (with other PSETs)	What I enjoyed the most about family science night was getting to interact with the students and their families, as well as staff at the school...I loved seeing the students faces light up when they were experimenting at different stations. (Marla)
Making an impact	When PSETs described the effect of the service on the physical environment or in terms of peoples' reactions to the service, or how the service helped others	47 (in the physical environment) 11 (other people)	I also really liked going to the Greenway and cleaning it up because I feel like we really made a difference. And all the people were coming up to us and saying thank you, like that really meant a lot. Because it shows you that your hard work doesn't go unnoticed, and people really do appreciate it. (Renee)

These themes and their definitions are available in Table 2. Using the four themes to ground our continuing analysis, we individually coded the transcripts of the oral reflections and all written reflections for all 42 PSETs. For consistency in our coding, we met as a research team and reviewed our definitions of the four themes by choosing multiple data points, establishing that they were coded similarly by each of the members of the team (Mays & Pope, 1995).

Our final step in data analysis was to generate tables that included all of the data to support each theme. Each member of our research team then reread all data included for a particular theme to confirm that it was appropriately categorized. We then looked for evidence of triangulation of the themes between multiple data sources (Wolcott, 2001), by checking for whether or not students were discussing similar meanings related to the service-learning experiences immediately after the event in their written reflection, as well as in their final oral reflection at the end of the semester.

Validity

The first author was the instructor of the environmentally focused service-learning course. Therefore, the second author recruited students to participate in the study. As teachers and researchers, we recognize that in asking students within the course to write and talk about their service learning experiences, there is potential for students to highlight only the positives of the experiences due to a perception that mentioning negatives may have a negative influence on their grades. As a regular part of the course, the instructor discussed with students that written reflections were to be graded using a rubric that stressed the use of evidence to support written arguments revised from Ash, Clayton, and Moses (2009). In addition, during data analysis, our three-person research team kept a tally of negative reactions to the service-learning experiences. While the preponderance of students expressed positive reactions to the service-experiences, there were a small number of students who mentioned unpleasant aspects of the events, such as getting bitten by an insect, getting lost on the way to an event, cold weather, and being upset about having to get up early on a Saturday morning. Even though these students wrote about their negative reactions to components of the service-experiences, these same students reflected on other aspects of their experiences in a positive manner. We focused our research question and analysis on the meanings that PSETs were making from these experiences.

Findings

Learning

As participants described their service-learning experiences during the environmentally focused curriculum course, the importance of learning through experiences emerged most frequently as a theme in their written reflections and interviews. This learning appeared in two distinct areas: physically experiencing science content and shifting pedagogical perspectives. Appearing within both of these themes was the importance that the PSETs ascribed to connecting science content that they were learning in the environmentally focused course with their own “real life” experiences in service projects, day-to-day activities, and their future elementary classrooms.

Physically Experiencing Science Content

Through their service experiences in a variety of settings along the science focused and teaching focused continuum, PSETs consistently remarked that physically experiencing the use of science concepts in the service-learning settings helped them reinforce their science content knowledge.

During the spring 2013 semester, a visit to the university sustainable development farm for a tour and work on greenhouse maintenance left a strong impression on several PSETs. More than half of the participants who visited the farm described the science concepts that they felt were reinforced through the experience, which included soil formation (composting), the interdependence of plants and animals (rotational grazing, poly-culture practices, and symbiotic relationships), and energy conservation and transfer (season extension practices). The PSETs commented on the clear connections between reading *The Omnivore's Dilemma* in the course and the powerful impact made when they could see the concepts described in the book played out in a real life context. Jeff's interpretations of the visit to the farm is consistent with his classmates' comments: "I learned that the idea of sustainability is no longer just something in a book but in fact is being put to good use and practice." Some PSETs linked their experiences at the farm with their own lives and lifestyle choices. For example, Evan described how the trip sparked his thinking about implementing practices he saw in use at the farm, such as collecting rainwater and composting, while Stephanie wondered how people who weren't growing their own food would get enough to eat if we ran out of transportation fuel.

In the fall of 2013, PSETs were involved in the construction of a new trail spur in a local national forest with the guidance of an employee of the National Forest Service, Zeb. Over the course of the day, PSETs engaged in physical labor to construct the trail such as the removal of tree roots and clearing of leaves and debris, learning, as Amber explained, "you have to make it a certain slope so the water runs off in the correct way without causing erosion." Additionally, Zeb provided commentary during the day related to the natural history of the area that the PSETs found engaging, such as locally important herbaceous plant and tree species. Erin wrote, "this is something that you can see in a book all day long but until you see it firsthand it would be hard to identify in nature on your own." Like the visit to the sustainable development farm, the service experience constructing the trail provided a physical context in which PSETs could consider how science topics such as erosion and the natural history of a particular setting are used to make decisions in an applied science setting.

In addition to the science concepts that PSETs believed were reinforced in the service experiences, some students were surprised to reconnect to positive feelings related to nature and the environment that they had not felt since they were much younger. Alice explained her thinking before her trip to the national forest in this way, "I am not what you would call a nature girl. ...Somewhere between the ages of five and twenty, I developed this allergic reaction to nature and haven't been outside for more than 5 min since." However, as she reflected on the experience of spending the day constructing the trail, Alice had changed her perspective, writing, "Just being out there in it for that little bit of time brought out the nature girl I used

to be and I liked it.” Like Alice, McKenzie poetically described a “new found love of nature” as she contemplated her time in the national forest. For these two PSETs, as well as others, the experience of spending time in a more natural setting provided them with a context that sparked them to reflect on an aspect of their identity on which they had not been actively focused.

Pedagogical Perspectives of PSETs

As the PSETs reflected on the different types of service experiences they engaged in, they described how the events influenced their thoughts about themselves as future teachers. In their initial written reflections, many of the PSETs expressed the idea that “hands-on” teaching was important. As they reflected on the individual service projects and on the course as a whole, PSETs frequently commented that they had developed a better understanding of what “hands-on” meant and how it could be enacted in an elementary setting. For example, Bethany described her thoughts about “hands-on” teaching in relation to her experience at Family Science Night where she co-facilitated a center with live earthworms. She noted that if she had to lecture about earthworms it “would be super boring!! Students would have zoned out and not retained much of the information...Having the students discover the answers to the questions themselves and seeing if their predictions were correct was fun and informative for the students.” Like Bethany, many of the PSETs began to express concrete ideas about hands-on teaching (e.g. investigating, predicting, and questioning) and noted benefits of using these specific pedagogical strategies.

PSETs frequently remarked on the value of direct experience with natural sites on school grounds as a way to support elementary student learning. PSETs commented on both nature trails and school gardens in their discussion of this topic and referred to their own experiences in these areas during their service projects. Bridget explained, “If a lesson is about the environment, plants, animals, etc. I now know that going outside and experience [sic] it first hand is a great way to teach and learn.” In addition, the PSETs envisioned opportunities to connect school science and life outside of school by having elementary students grow food that they could take home or helping to clean up areas in their local communities. Brie explained that she hoped that she would help her own students understand the importance of topics like “recycling” and “growing our own food” that she was just coming to appreciate as an adult. Arlene went further, writing about the importance of direct experiences to both students and teachers and their continuous learning, commenting that to be an effective science teacher, “your students should actually experience it; moreover, you should be having your own experiences too-volunteering, gardening, taking nature walks, recycling, keeping up with the weather, etc. This makes the curriculum real to you and your students.” In their reflections, many PSETs discussed the importance of connecting science that was learned at school with elementary students’ and their own lived experiences.

The PSETs described how the service activities in the course had provided them with an opportunity to be excited about teaching science. This outlook was shared by students who had come into the course with a positive attitude, as well as by PSETs who started the semester expressing some reluctance about science and

science teaching. For Kristen, participating in Family Science Night reinforced her positive feelings: “working at Family Science Night just reaffirmed my feelings. I am now even more excited about being a teacher and teaching my students science.” Unlike Kristen, Caroline and Meredith represent students who were less enthusiastic about science and science teaching. Caroline described a change in her perspective after Family Science Night, sharing, “I have realized that teaching science is both interesting and fun...I am now excited to teach science and am motivated to find fun activities and experiments to do with my future students.” Meredith admitted that before the course, she was “very anti-science”, but like Caroline, she had begun to have more positive feelings about including science in her future teaching and experienced a positive change in her comfort level with science and science teaching. In comparison to their reflections written at beginning of the semester, by the end, many PSETs indicated that they could envision teaching science as a positive aspect of their elementary teacher identity.

Interacting with Others

PSETs placed importance on the opportunities they had to interact with elementary students, other preservice teachers, classroom teachers, community members, and parents during the service-learning events. Not surprisingly, the most valued interactions that PSETs felt they had during their service experiences were with elementary-aged students. These service-experiences with elementary students occurred in a more science teaching focused context at Family Science Nights (in both semesters) and in a transitional science learning-science teaching context in the school garden construction (only fall 2013).

The PSETs felt that the Family Science Night events gave them an important opportunity to interact with elementary students because they got to see students excited, curious, and engaged by science learning activities in an informal science learning setting. The PSETs discussed how much they appreciated being able to see the elementary students express their personalities more freely than in a formal school setting. PSETs discussed situations where they got to see a change in interest or excitement for science at their Family Science Night centers. Kristen and Renee mentioned a disinterested sibling of an elementary student who became excited about planting his own radish seeds at their seed center. Evan and Leigh discussed a group of young elementary girls who were initially “grossed out” at their earthworm station. Leigh noted that “as they got more comfortable around them and realized they weren’t going to hurt them they started picking them up, putting them on their arms, and playing with them.” The PSETs mentioned seeing students’ faces “light up” with excitement, “accomplishment”, and wonder when they saw something new at their centers. PSETs felt that these opportunities to interact informally with elementary students in the context of an environmentally focused activity helped them to see not only student interest and curiosity, but to think about how students’ interests outside of school might be related to school subjects like science.

The PSETs also mentioned surprise at how much science content the elementary students knew and their willingness to test their own ideas at their centers. PSETs wrote about elementary students who were interested in manipulating materials and

testing their ideas, such as Noah who saw a father and son at his center construct a circuit that made a light bulb explode: “I did not take into account that students would want to try new things and the curiosity to which they approached the activity.” The Family Science Night service-learning experience helped to reinforce to PSETs how meaningful these learning experiences were for parents and elementary students alike. The opportunity for PSETs to work with elementary students in an informal science learning setting helped them to see the interest and curiosity that elementary students have for things related to science topics with real world applications.

In addition, PSETs in the fall 2013 semester mentioned elementary students’ interest and curiosity for the natural world that they saw during their work with small groups while constructing a school garden. PSETs were surprised by how many of the students were interested and excited about working in the garden, noting that the elementary students “loved it,” were curious about all of the organisms that they saw, and didn’t seem to mind exploring the dirt. In addition to noting the positive responses of the elementary students to working in the school garden, the PSETs noted how much science content the elementary students were applying while they were working. Alice wrote “I was completely blown away by the amount of knowledge that these students had about the way animals, soil, and sunlight worked when it came to growing plants.” What PSETs noticed about their experience in the school garden was how engaged, knowledgeable, and curious the elementary students were about what they were doing, and how, overall, these qualities kept them motivated to work longer than the PSETs expected them to.

In addition, the various service-learning events were valued by most PSETs because of the opportunities to work with fellow PSETs. Some PSETs found the opportunities to interact with their fellow classmates in the science learning focused events meaningful because they interacted with each other in a context in which they depended more on each other, realizing that working alone on all projects is not always feasible. The PSETs valued how participation in the service-learning experiences gave them the opportunity to develop an authentic sense of teamwork. For many PSETs, having an opportunity to connect with other PSETs outside of class was important to them personally. Arlene explained how in working in small groups to build a trail, “I felt like I bonded with my classmates.” Similarly, for Evan, the most memorable part of his time spent at the school cleaning up the outdoor learning area “was getting to know the four ladies I was working with.” For another male student, working with his classmates helped him find commonalities with his mostly female PSETs.

Finally, during the Family Science Nights, the PSETs felt that they were a social support to each other when they felt nervous about working with elementary students. Working together at their Family Science Night centers, they noted, helped them deal with anxiety, as well as feeling more confident in teaching science: “Annie is really good at working with kids, and is super active and engaging when teaching a lesson. I don’t think I would have been as outgoing with the children if I didn’t have Annie to help!” PSETs felt that through their interactions with each other, they felt supported and more confident in situations that they were unsure about before they participated.

Making an Impact

When PSETs were involved in science learning oriented service, they were working in small groups within a larger group of people at an event, usually for half a day. Seeing the impact of their service was made meaningful because despite the short nature of their service events, they consistently remarked on the visible and significant changes they had made in the environment or the appreciation expressed by people for whom they were working as a result of their service.

In terms of their impact on the physical environment, many PSETs discussed how working together with other PSETs in small groups helped them make more of an impact than they would if they were working by themselves. For example, Bridget worked with a partner on an overgrown walking trail at a local elementary school and described the value of:

Seeing the difference that we as a class made from simply being there a couple of hours. The whole area was much more cleaned up and turned into a usable space...even though you can't always see something through entirely, the work you put in makes a difference.

PSETs made similar remarks about their work on the trail spur in the national forest and on the construction of garden beds at the elementary school. Mary noted that for her: "Walking to and from breaks we were able to see the progress we were making and that had the most impact to me." Erin wrote about how powerful it was to see the progress that the PSETs and elementary students were making on the garden beds: "from the time that we got there to the time that we left there had been a major change and that made me feel like I had done something so great with my Friday instead of just laying around." Like Erin, many PSETs felt that the impact of their service was meaningful because of the personal gratification of seeing their hard work visibly manifested. For example, Arlene noted the potential for the impact to be felt by the elementary students working in the gardens based on her own feelings about her experience with the trail work in the National Forest: "I'm sure those kids are going to feel a much greater connection to the little plots they worked on now. The land is partially theirs now. I know that's how I feel about the work I did on the trail." Thus, the opportunity to complete environmentally focused service helped many of the PSETs to see that even a small amount of time with others could make a visible impact in the physical environment.

The PSETs felt that the impact they were making in changing the physical environment had social meaning for those whom they were helping, such as the national forest employee, Zeb. Many of the fall 2013 PSETs noted how their experience working on the trail spur was made more meaningful because of how much it helped Zeb in his job. Cassie summed up the sentiments of her fellow classmates well: "It is rewarding to think of how we were able to help him out but also how we were able to help out hikers for many years to come." Many of the PSETs noted that the impact of their service was made meaningful due to the recognition of those they were serving, making the PSETs feel as if their efforts were important. This was especially significant for the PSETs who helped clean up the Greenway after a flooding event. Kristen described how "It was also nice to talk

to people who were running on the Greenway, and for them tell us that they were grateful for our help. It made it seem like our work was important to someone else.” Thus, the act of serving in the environment and making an impact physically and socially was felt to be a rewarding and gratifying experience by the PSETs.

Discussion

In their interpretations of their service-learning experiences, PSETs discussed three aspects that were meaningful to them: (a) science in relation to their lives as humans and future teachers, (b) interacting outside of a formal classroom with elementary students and other PSETs, and (c) making an impact in the physical environment and in the community. The PSETs were engaging with issues that were connected to their personal lives, their community, and their professional aspirations. Therefore, our findings indicate that through the PSETs’ participation in the various service-learning experiences, they were engaging multiple aspects of their identity.

The service-learning experiences provided opportunities for PSETs to see how course content connected to people and issues in the community, including themselves. The service-learning experiences provided PSETs with opportunities for developing their science identities through the connections that PSETs were making to their own life (hi)stories (Geijsel & Meijers, 2005). Both explicitly and implicitly, the PSETs addressed personal relevance in each of the three themes. Previous research has emphasized the value in having students, in this case PSETs, connect their “school learning” with their “real lives” (i.e. Aikenhead, 2006; Costa, 1995; Hurd, 2002). When school science is directly connected to learners’ experiences they are better able to understand the science content and how it impacts peoples’ lives (Price & McNeil, 2013) and can become more confident about their knowledge of the topic (King & Ritchie, 2012). PSETs found connections between the service-learning experiences and their personal and home lives, allowing for PSETs to consider their science identities as learners and teachers.

These service-learning experiences, therefore, provided a discursive space for PSETs’ meaning-making (Geijsel & Meijers, 2005) related to science content knowledge in practice. When content is connected to community contexts, learners can come to understand how scientific knowledge is produced for real purposes (Fusco, 2001). Examples included when Evan discussed sustainable practices at the farm he was interested in trying, as well as when the PSETs saw how the National Forest Service employee, Zeb, used science concepts that they had discussed in class in his work with trail building and maintenance of forest ecosystems. Though the contexts were different, the PSETs’ perceptions of the relevance of the service-learning experiences may be due to the service-learning events sharing aspects of a *practicing culture of science* as discussed by Fusco (2001). These shared aspects include both experiences based in community contexts and related to learners’ interests and out of school experiences. In addition, PSETs were involved in service-learning experiences where people (Zeb and the SD Farm manager) were using science knowledge to address issues in the community. These service-learning experiences enabled the PSETs to not only see themselves and others as users of

science content knowledge, but also as contributors to others and the environment, feeling pride in their efforts and accomplishments. Previous research has described the positive opportunities for learning which occur when people are allowed to be “givers” (Fusco, 2001), and experience feelings of self-worth and increased confidence when they can support each other in service-learning events (Cox-Petersen et al., 2005). The science learning focused service experiences involved community science-related issues that were of relevance to students, which is evidenced in the connections they were making to their own emotions and life histories.

We believe that this trend of PSETs developing positive attitudes towards science is intertwined with their development of positive attitudes towards inquiry-based science teaching. The developing pedagogical perspectives towards inquiry-based science teaching that many of the PSETs expressed as they described their service experiences are similar to trends highlighted by Cartwright (2012), Cox-Petersen et al. (2005), and Cone (2009) who found that PSETs felt more confidence in their inquiry-science teaching abilities as a result of participating in service experiences teaching elementary students. Our analysis of PSETs’ reflections on their service-learning experiences builds on their work and highlights the added benefits of using a variety of service-learning experiences along a continuum of science learning to science teaching focused events to provide more opportunities to learn science and teach science in concrete, experiential, and inquiry-based ways. After the more science teaching focused (Family Science Night) and the transitional (working on school grounds but not teaching) service-learning experiences, PSETs consistently reflected on their interactions with elementary learners as they envisioned how they might engage in science teaching practices in their own future classrooms. Working with elementary students on school grounds, but not in formal instruction, provided an opportunity for PSETs to talk *with* elementary students about science, rather than talk *to* students. Working with elementary learners in a science learning context allowed the PSETs to make meaning of the students’ reactions to alternate science learning contexts (i.e. not in the classroom) that may not have been possible if PSETs were focused on performing an expected role of science teacher (with all of their assumptions about what that means). While the PSETs described the type of teaching that they wanted to engage in within their future classrooms as “hands-on” rather than inquiry-based, they discussed two of the three aspects of inquiry-based science teaching as defined by Minner et al. (2010): the science content they felt they developed, as well as the elementary learners’ engagement with science content. Therefore, having PSETs participate in science teaching focused and transitional service learning experiences on the continuum is providing the PSETs with a “meaning-giving” space (Geijsel & Meijers, 2005) within which they can consider what it means to learn science in a significant way.

Although we are only capturing the perceptions of PSETs over the course of one semester, we are hopeful that the service-learning experience embedded throughout the course may put PSETs on a positive science teaching identity trajectory (Leander et al., 2010). We believe that the service-learning aspect of the course provided PSETs the opportunities to connect their home cultures to school science culture, which has been described in other research on relevant science learning as

pivoting (Price & McNeil, 2013) or border crossing (Aikenhead & Jegede, 1999). The experience of both learning and teaching in ways that are consistent with inquiry-based practices is an important step in forming a reform-based science teaching identity (Eick, 2009; Eick & Reed, 2002; Wilson & Kittleson, 2012). The connections that PSETs were making between discursive spaces (where they were experiencing the use of science content and inquiry-based science teaching methods) and their own meaning-making of these experiences (as connected to their own interests in relation to their future professions and daily lives) shows evidence of the potential that various types of science service-learning experiences have for PSETs in developing their science teaching identities.

Implications

The findings of this study point to positive outcomes for PSETs when they participate in structured service-learning experiences in multiple community contexts. Therefore, a major implication for elementary science teacher educators is the possibility of incorporating service-learning pedagogy to promote the positive development of science identities for PSETs. The service-learning experiences, however, must meet certain criteria consistent with the work of Hatcher et al. (2004): (a) allow for multiple types of service that enable PSETs to see course content applied in various community settings (oriented to both science learning and science teaching), (b) allow PSETs to consistently reflect on the experiences to make connections with their own learning and life (hi)story, and (c) provide opportunities for reflection on their values and ideas about science, science learning, and science teaching. In addition to meeting the above key criteria for service-learning experiences, we also think it is important that PSETs engage in service that allows them to interact with elementary students and other members of the larger community in order to see the excitement that others have for science. Finally, these service-learning experiences should allow PSETs to address real needs in the community so that they can feel that the service that they provide is authentic and important. All of these criteria for meaningful service-learning experiences enable PSETs to make explicit links between science content and their own lives.

We believe that the most significant finding of this study is the potential benefit of using service-learning experiences along a continuum of science learning and science teaching oriented events with PSETs to develop their science teaching identities. Building on previous research which identified benefits when PSETs engaged in science teaching oriented service-learning experiences (Cartwright, 2012; Cox-Petersen et al., 2005; Wallace, 2013), our findings support the incorporation of science learning oriented, science teaching oriented, and transitional service-learning experiences to address multiple aspects of their present identity as science learners and future elementary teachers. PSETs at the beginning of their elementary education program are strongly tied to their identity as college students, even though they are aspirant elementary teachers. Having service-learning experiences along a continuum of science learning to science teaching oriented events provided various contexts in which PSETs connected to multiple

aspects of their science identities (teaching and learning) and made personal connections to the science course content.

Thus, while there is additional research needed to determine whether these types of service-learning experiences have lasting impact on PSETs' ideas about science learning and teaching, we believe that having these experiences before their elementary methods courses could provide a foundation for an "inbound" trajectory for identity development (Wenger, 1998) related to inquiry-based science teaching. If PSETs are able to personally connect to science content and science learning experiences that are designed using reform-based principles, they could be orienting themselves on an inbound trajectory, beginning to think about "joining the community with the prospect of becoming full participants in its practice...even though their present participation may be peripheral" (Wenger, 1998, p. 154). Luehmann (2007) argues there is a need to develop teacher education programs to mitigate the difficulties inherent in developing an inquiry-based teaching identity. Our hope is that the PSETs' experiences within this course helped them bridge the potential gap between their previous science learning lived experiences and reform-based science teaching practices by providing them with inquiry-based science learning and teaching opportunities both in the classroom and in the service experiences.

As King and Ritchie (2012) state, "Fluid transitions between the sanctioned science content of school curriculum and student worlds can be realized when students actively engage in fields that contextualize inquiry and give purpose for learning (p. 77)." Thoughtfully structured service-learning experiences in an elementary education program may be able to provide PSETs with boundary experiences (Geijsel & Meijers, 2005) along a continuum of science learning and teaching which have potential to facilitate these transitions. Incorporating such service-learning experiences early in the elementary education program may allow PSETs to develop stronger science teaching identities along inbound trajectories to reform-based science teaching.

References

- Aikenhead, G. S. (2006). *Science education for everyday life: Evidence-based practice*. New York, NY: Teachers College Press.
- Aikenhead, G. S., & Jegede, O. J. (1999). Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching*, 36(3), 269–287.
- Ash, S., Clayton, P., & Moses, M. (2009). *Learning through critical reflection: A tutorial for service-learning students [instructor version]*. Raleigh, NC: Center for Excellence in Curricular Engagement.
- Brown, T. (2006). Negotiating psychological disturbance in pre-service teacher education. *Teaching and Teacher Education*, 22, 675–689.
- Butcher, J., Howard, P., Labone, E., Bailey, M., Smith, S. G., McFadden, M., ... Martinez, K. (2003). Teacher education, community service learning and student efficacy for community engagement. *Asia-Pacific Journal of Teacher Education*, 31(2), 109–124.
- Butin, D. W. (2003). Of what use is it? Multiple conceptualizations of service learning within education. *Teachers College Record*, 105(9), 1674–1692.
- Bybee, R. W., Taylor, J. A., Gardner, A., Van Scotter, P., Powell, J. C., Westbrook, A., & Landes, N. (2006). *The BSCS 5E instructional model: Origins and effectiveness*. Retrieved from: <http://bscs.org/bscs-5e-instructional-model>

- Calabrese Barton, A. (2000). Crafting multicultural science education with preservice teachers through service-learning. *Journal of Curriculum Studies*, 32(6), 797–820.
- Calabrese Barton, A., Kang, H., Tan, E., O'Neill, T. B., Bautista-Guerra, J., & Brecklin, C. (2013). Crafting a future in science: Tracing middle school girls' identity work over time and space. *American Education Research Journal*, 50, 37–75.
- Cartwright, T. J. (2012). Science talk: Preservice teachers facilitating science learning in diverse afterschool environments. *School Science and Mathematics*, 112(6), 384–391.
- Charmaz, K. (2006). *Constructing grounded theory: A practical guide through qualitative analysis*. Los Angeles: Sage.
- Cobern, W. W., & Loving, C. C. (2002). Investigation of preservice elementary teachers' thinking about science. *Journal of Research in Science Teaching*, 39(10), 1016–1031.
- Cone, N. (2009). A bridge to developing efficacious science teachers of all students: Community-based service-learning supplemented with explicit discussions and activities about diversity. *Journal of Science Teacher Education*, 20, 365–383.
- Cone, N. (2012). The effects of community-based service learning on preservice teachers' beliefs about the characteristics of effective science teachers of diverse students. *Journal of Science Teacher Education*, 23, 889–907.
- Costa, V. B. (1995). When science is "another world": Relationships between worlds of family, friends, school, and science. *Science Education*, 79(3), 313–333.
- Cox-Petersen, A. M., Spencer, B. H., & Crawford, T. J. (2005). Developing a community of teachers through integrated science and literacy service-learning experiences. *Issues in Teacher Education*, 14(1), 23–37.
- Davis, E. A. (2006). Characterizing productive reflection among preservice elementary teachers: Seeing what matters. *Teaching and Teacher Education*, 22, 281–301.
- Davis, E. A., Petish, D., & Smithy, J. (2006). Challenges new science teachers face. *Review of Educational Research*, 76(4), 607–651.
- Denzin, N. K., & Lincoln, Y. S. (2011). Introduction: The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 1–19). Thousand Oaks, CA: Sage.
- Eick, C. J. (2009). Tailoring national standards to early science teacher identities: Building on personal histories to support beginning practice. *Journal of Science Teacher Education*, 20, 135–156.
- Eick, C. J., & Reed, C. J. (2002). What makes an inquiry-oriented science teacher? The influence of learning histories on student teacher role identity and practice. *Science Education*, 86, 401–416.
- Frykholm, J. (2004). Teachers' tolerance for discomfort: Implications for curricular reform in mathematics. *Journal of Curriculum and Supervision*, 19(2), 125–149.
- Fusco, D. (2001). Creating relevant science through urban planning and gardening. *Journal of Research in Science Teaching*, 38(8), 860–877.
- Geijsel, F., & Meijers, F. (2005). Identity learning: The core process of educational change. *Educational Studies*, 3(4), 419–430.
- Griffith, G., & Scharmann, L. (2008). Initial impacts of no child left behind on elementary science education. *Journal of Elementary Science Education*, 20, 35–48.
- Hatcher, J. A., Bringle, R. G., & Muthiah, R. (2004). Designing effective reflection: What matters to service-learning? *Michigan Journal of Community Service Learning*, 11(1), 38–46.
- Holland, D. C., Lachicotte, W. J., Skinner, D., & Cain, C. (1998). *Identity and agency in cultural worlds*. Cambridge, MA: Harvard University Press.
- Holstein, J. A., & Gubrium, J. F. (2011). The constructionist analytics of interpretive practice. In N. K. Denzin & Y. S. Lincoln (Eds.), *The Sage handbook of qualitative research* (pp. 341–357). Thousand Oaks, CA: Sage.
- Hurd, P. D. (2002). Modernizing science education. *Journal of Research in Science Teaching*, 39, 3–9.
- Jung, M. L., & Tonso, K. L. (2006). Elementary preservice teachers learning to teach science in science museums and nature centers: A novel program's impact on science knowledge, science pedagogy, and confidence teaching. *Journal of Elementary Science Education*, 18, 15–31.
- Katz, P., McGinnis, J. R., Riedinger, K., Marbach-Ad, G., & Dai, A. (2012). The influence of informal science education experiences on the development of two beginning teachers' science classroom teaching identity. *Journal of Science Teacher Education*, 24(8), 1357–1379.
- King, D., & Ritchie, S. M. (2012). Learning science through real-world contexts. In B. J. Fraser, K. G. Tobin, & C. J. McRobbie (Eds.), *Second international handbook of science education* (Vol. 1, pp. 69–79). Dordrecht: Springer.

- Lave, J., & Wenger, E. (1991). *Situated learning: Legitimate peripheral participation*. Cambridge, MA: Cambridge University Press.
- Leander, K. M., Phillips, N. C., & Headrick Taylor, K. (2010). The changing social spaces of learning: Mapping new mobilities. *Review of Research in Education*, 34, 329–394.
- Luehmann, A. L. (2007). Identity development as a lens to science teacher preparation. *Science Education*, 91, 822–839.
- Mays, N., & Pope, C. (1995). Rigour and qualitative research. *British Medical Journal*, 311, 109–112.
- Minner, D. D., Levy, A. J., & Century, J. (2010). Inquiry-based science instruction: What is it and does it matter? Results from a research synthesis years 1984–2002. *Journal of Research in Science Teaching*, 47(4), 474–496.
- National Council for Accreditation of Teacher Education. (2008). *Unit standards in effect 2008*. Retrieved from <http://www.ncate.org/Standards/UnitStandards/UnitStandardsinEffect2008/tabid/476/Default.aspx>
- National Research Council. (1996). *National science education standards*. Washington, DC: National Academy Press.
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, DC: National Academies Press.
- National Research Council. (2013). *Next generation science standards: For states, by states*. Washington, DC: National Academy Press.
- Patton, M. Q. (2002). *Qualitative research and evaluation methods* (3rd ed.). Thousand Oaks, CA: Sage Publications.
- Polkinghorne, D. E. (1995). Narrative configuration in qualitative analysis. In R. Wisniewski & J. A. Hatch (Eds.), *Life history and narrative*. Washington, DC: Falmer.
- Price, J. F., & McNeil, K. L. (2013). Toward a lived science curriculum in intersecting figured worlds an exploration of individual meanings in science education. *Journal of Research in Science Teaching*, 50(5), 501–525.
- Reynolds, J. A., & Ahern-Dodson, J. (2010). Promoting science literacy through research service-learning—An emerging pedagogy with significant benefits for students, faculty, universities, and communities. *Journal of College Science Teaching*, 39(6), 24–29.
- Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York: Basic Books.
- Settlage, J., Southerland, S. A., Smith, L. K., & Ceglie, R. (2009). Constructing a doubt-free teaching self: Self-efficacy, teacher identity, and science instruction within diverse settings. *Journal of Research in Science Teaching*, 46, 102–125.
- Sfard, A., & Prusak, A. (2005). Telling identities: In search of an analytic tool for investigating learning as culturally shaped activity. *Educational Researcher*, 34(4), 14–22.
- Smagorinsky, P., Cook, L. S., Moore, C., Jackson, A. Y., & Fry, P. G. (2004). Tensions in learning to teach: Accommodation and the development of a teacher identity. *Journal of Teacher Education*, 55(1), 8–24.
- Spencer, B. H., Cox-Petersen, A. M., & Crawford, T. (2005). Assessing the impact of service-learning on preservice teachers in an after-school program. *Teacher Education Quarterly*, 32(4), 119–135.
- Timošičuk, I., & Ugaste, A. (2010). Student teachers' professional identity. *Teaching and Teacher Education*, 26, 1563–1570.
- Wallace, C. S. (2013). Promoting shifts in preservice science teachers' thinking through teaching and action research in informal science settings. *Journal of Science Teacher Education*, 24, 811–832.
- Wenger, E. (1998). *Communities of practice: Learning, meaning, and identity*. Cambridge: Cambridge University Press.
- Wilson, R. E., & Kittleson, J. (2012). The role of struggle in pre-service elementary teachers' experiences as students and approaches to facilitating science learning. *Research in Science Education*, 42(4), 709–728.
- Windschitl, M. (2006). Why we can't talk to one another about science education reform. *The Phi Delta Kappan*, 87(5), 348–355.
- Wolcott, H. F. (2001). *Writing up qualitative research* (2nd ed.). Thousand Oaks, CA: Sage.