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Understanding teacher instructional change: the case of integrating NGSS and stewardship in professional development

Kathryn N. Hayesa, Mele Wheatonb and Deborah Tuckerc

aDepartment of Educational Leadership, California State University, East Bay, Hayward, CA, USA; bGraduate School of Education, Stanford University, Palo Alto, CA, USA; cIndependent science education consultant

ABSTRACT
The environmental education (EE) field has encountered persistent challenges in fostering the integration of EE practices in public schools, a challenge that may be addressed through integration of EE with the Next Generation Science Standards (NGSS) in the United States. In addition to the potential for fostering EE, the integration of EE and NGSS may provide a unique set of conditions for understanding how and why teachers shift their practice to incorporate more EE in their classrooms. Using a mixed methodology research design, this study examines the outcomes and processes of a professional development institute that integrated NGSS and student-driven environmental stewardship. This study provides evidence that integrating NGSS Science and Engineering Practices with stewardship may help infuse EE into classrooms. The research also contributes to theoretical understanding of the processes by which professional development shapes teacher change within an organizational context. Specifically, teacher instructional change was predicated on a shift in their beliefs that stewardship was possible in a standards and accountability-based educational context. The requisite shift in beliefs came about through the expectations and supportive resources provided by the professional development, teacher observation of student engagement, and the justification NGSS integration provided for stewardship activities.

Introduction
As our society faces increasingly complex decisions regarding sustainability, incorporating environmental education (EE) in public school curriculum becomes ever more critical. The growing international trend toward standards systems that focus on the practices of science provides an unprecedented opportunity for such incorporation of EE (Ai-xin 2016; DeBoer 2011). That is, standards systems that include student engagement in scientific experimentation and reasoning (hereafter referred to as practice-inclusive science education) may create a fertile ground for including EE. The Next Generation Science Standards (NGSS) in the United States are an example of such a practice-inclusive science education approach (NRC 2013). Amongst the 14 US states that have officially adopted the NGSS and the other US states and nations that have adopted similar standards, there is a push for science education reform. This push infuses funding, professional development, and opportunities to incorporate new ways of teaching science that include the Science and Engineering Practices (NGSS SE Practices)
and sense-making around scientific phenomena. These, in turn, encourage the project-based learning approaches and real-world problem solving that environmental education does so well.

Although science is not always the best subject-marriage for environmental education (Ashley 2000), it nonetheless provides an important space for the infusion of EE in public schools (Shepardson and Harbor 2004). On one hand, there is friction between some aspects of EE and science education, such as different perceptions of the role of social and environmental values (Birdsall 2013). On the other, research suggests that an environmental approach to science education can increase the relevance of science to students’ lives and motivate students to be effective producers and consumers of science (Birdsall 2013; Gough 2008). In addition, EE and science education share some similar features. Problem-solving, critical thinking, and reasoning skills are important aspects of EE as well as science education. While EE has many different components, we subscribe to the commonly recognized idea that EE endeavors to increase environmental conceptual understanding, attitudes, awareness, skills, and participation (Hollweg et al. 2011; UNESCO 1977).

Moreover, the integration of EE and NGSS in professional development (PD) may provide a unique set of conditions for both fostering and understanding shifts in teacher practice. Teacher instructional practice is remarkably resistant to reform, whether in science or environmental education (Cuban 2013). A growing body of research is attending to the factors that underlie teacher shifts in instructional practices, including policy levers (Hayes and Trexler 2016), personal history and beliefs (Coburn 2004), and observing student engagement (Fishman et al. 2003). This area of theoretical and empirical work may provide an essential lens for understanding how and why some teachers incorporate more EE into their teaching.

Given the current widespread adoption of NGSS and similar standards, and a push to incorporate more EE in schools, there is a critical need to understand the ways in which practice-inclusive science education and environmental stewardship can mutually support each other in shaping teacher thinking and instructional practice. Moreover, EE scholarship could benefit from an application of teacher change theories from the educational implementation and reform literature, with the purpose of understanding the unique drivers of teacher change in an EE context. Finally, there is a need for empirical evidence to inform teacher change theory.

To address these needs, this mixed methodology study examined the extent to which an in-service teacher PD institute, focused on incorporating NGSS SE Practices into student-driven environmental stewardship activities, resulted in enactment of targeted classroom instructional practices. We then explored the processes which shaped how and why teachers enacted these changes, with the goal of contributing to theory building regarding teacher change. In sum, this study provides evidence regarding the benefit of using practice-inclusive science education to help infuse EE into classrooms, as well as contributing to a growing body of literature regarding the role of teacher learning and organizational conditions in shaping teacher instructional change.

**Theoretical framework: instructional change**

Much of the PD literature is based on a linear conceptualization of teacher change along a continuum: from PD, to change in teacher knowledge, to change in practices (Desimone 2009; Fishman et al. 2003). Such a linear conceptualization has been problematized by some scholars, who claim that teacher change is predicated on iterative processes involving experimenting with instruction, reflection, and evaluating student learning and engagement (Clarke and Hollingsworth 2002; Perry and Lewis 2009).

In order to understand the processes which shape how teachers enact stewardship practices in their classroom, we draw on a model described by Clarke and Hollingsworth (2002). This model has been used as an element of PD research in prior EE studies (Dymant et al. 2014), but has yet to be used as a robust tool of analysis in an EE context. Clarke and Hollingsworth (2002) proposed that rather than a linear process, teacher change rests on interconnections between external sources of information, professional experimentation, teacher knowledge and beliefs, and student actions and outcomes (Figure 1).

This model provides a starting place from which to ask questions regarding the specific mechanisms and processes which shape teacher change in practice. Teachers go through an iterative process of
learning new ways of teaching, experimenting with new practices, and observing student reactions. They interpret all of these elements through the lens of their knowledge and beliefs, with a potential for change in each domain (Clarke and Hollingsworth 2002; Coburn 2004). The role of teacher belief in the overall change process is receiving growing attention, particularly in EE literature. Alignment of teacher beliefs with reform pedagogies may be instrumental to teacher change, but beliefs also tend to be very stable and difficult to change (Ernst 2007; Luft 2001). Teacher observation of student response may also play a particularly pivotal role in teacher change, mediated by teacher beliefs about students (Fishman et al. 2003; Jeanpierre, Oberhauser, and Freeman 2005). Student responses can include student enjoyment or engagement (affective) as well as student learning or performance (cognitive).

Yet although Clarke and Hollingsworth (2002) propose the model, they noted that empirical work is needed to understand the processes that guide change in particular contexts. In addition, they provided little theoretical detail as to the role of external incentives for change. Literature in organizational theory provides some guidance in this regard, suggesting that various ‘institutional logics’ structure the choices available to teachers in their practice (Scott 2014). These logics include policies, such as accountability and NGSS, and context, such as the degree of parent involvement and nature of student behavior. Teachers draw on their previous experiences, beliefs, and professional norms in ‘making sense’ of the prevailing institutional logics and the reform pedagogies (Coburn 2004; Spillane, Reiser, and Reimer 2002). For example, teachers may resist or embrace change depending on whether they perceive congruence across standards and professional development (Allen and Penuel 2015). Teachers may also resist if they do not feel consulted or if the new reforms do not align with their beliefs (Coburn 2004). Conversely, if the reform aligns with teacher beliefs, requiring teachers to try a particular strategy (such as an inquiry project) can promote teacher shifts in practice (Clarke and Hollingsworth 2002; Jeanpierre, Oberhauser, and Freeman 2005; Luft 2001). Such sensemaking processes, particularly in regards to current educational policies of standardization and testing, likely shape teacher implementation of EE (Stevenson 2007).

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**Figure 1.** Model of the iterative processes that shape teacher change, proposed by Clarke and Hollingsworth (2002) (reprinted with permission).
Effective professional development: previous research

The often-cited study of the Eisenhower subject-matter professional development program identified core features of effective PD that enhanced teacher knowledge and skills and resulted in changes in teacher practice (Desimone 2009; Garet et al. 2001). The study demonstrated that content focus, active learning, coherence, extensive duration, and collective participation are more likely to effect change in practice. These general approaches have been confirmed in other analyses (Darling-Hammond and Richardson 2009). However, research on how these approaches translate into specific PD strategies, and their role in science and environmental education instructional change, is less clear.

Research is mixed regarding the role of PD in shifting teacher classroom practice in both EE and science education, with indications that personal and contextual factors may mediate the influence of PD. Some programs, especially when the PD is extensive, have been shown to help teachers successfully translate strategies (often inquiry-based teaching) into their classrooms, resulting in a substantive difference before and after participation (Luft 2001; Penuel et al. 2007; Shepardson and Harbor 2004; Supovitz and Turner 2000). Moreover, when PD provides specific techniques and practice in integrating the innovation into classroom curriculum, teachers may incorporate the reform practice to a greater depth (Penuel et al. 2007; Shepardson and Harbor 2004).

However, other studies indicate less-than-optimal transfer from PD into classroom use (e.g. Wade 1996). This may be partially due to teachers’ pre-existing beliefs; for example, in a qualitative case study, Harlow (2014) found that teachers only changed their practice in areas they identified as ‘deficit’ before entering the training. Other studies implicate personal or contextual factors in limiting PD transfer, including the newness of the teacher (Luft 2001) or difficulty with students (Wee et al. 2007). Still others touch on the role of policy in teacher learning. For example, Dyment et al. (2014) found that ‘bridging’ between the Australian standards and sustainability principles influenced teacher uptake of sustainability ideas. Yet with few exceptions (e.g. Allen and Penuel 2015), science and EE PD studies leave the ‘external source of stimulus’ (Clarke and Hollingsworth 2002), including policy and organizational context, underdeveloped.

Regarding the integration of science and EE, there are a few calls for PD focused on both environmental education and inquiry/science practices (Forbes and Zint 2010; Shepardson and Harbor 2004). Researchers have also suggested that EE PD include project-based learning (such as stewardship projects) and opportunities for critique and reflection (Ernst 2007; Wade 1996). Both of these suggestions resonate with NGSS SE Practices, which represent a new way of approaching science education that move beyond ‘cook-book’ type labs, and toward engaging students in the investigation activities and sense-making necessary to understand the development of scientific knowledge (Hayes, Lee, DiStefano, O’Connor and Seitz, 2016; NRC 2013).

Methods

Research design

The EE literature is underdeveloped in terms of evaluating the complex relationship between PD and teacher practice, and in characterizing the contextual factors and teacher traits that shape instructional change. In order to address this need, we used an explanatory sequential mixed methods research design (Creswell and Plano Clark 2011), which allowed us to both quantitatively measure change over time in teaching practices, and to qualitatively elucidate the nature and reasons for the changes. We asked the following questions:

1. To what extent do teachers enact targeted classroom instructional practices after engaging in a 4-month, intensive NGSS/stewardship integration PD?

2. What are the processes which shaped teacher change in enacting NGSS and stewardship in their classroom practice?
Setting

In spring of 2015, the California Environmental Education Foundation (CEEF)\textsuperscript{1} conducted a teacher professional development institute (Institute) in the greater Los Angeles area, consisting of three 8-hour days spaced out over 4.5 months. The Institute concentrated specifically on integrating NGSS SE Practices (NRC 2013) with stewardship activities. NGSS SE Practices include (summarized) (1) Asking questions, (2) Developing and using models, (3) Carrying out investigations, (4) Analyzing data, (5) Computational thinking, (6) Constructing explanations, (7) Engaging in argument, and (8) Communicating information. Environmental stewardship was defined broadly as informed, responsible action on behalf of the environment and future generations, with an emphasis on involving students in the decision-making processes. In addition to the three days in person, the Institute provided follow-up individual coaching from the Los Angeles-based Coordinator of the California Regional Environmental Education Community (CREEC) Network. CEEF provided a stipend to the teachers for attending the Institute and for completing the required environmental stewardship project.

The Institute was developed as a hands-on, participatory learning experience. The 5E Model (Bybee 1997) was employed as a framework, and teachers played the role of the learner in research-based EE activities selected from Project WET, Project Learning Tree, and Project Aquatic WILD. The chosen activities represented topics selected by teachers in a statewide survey conducted by CEEF. Prior to an activity, content specialists provided information and tools on water resource management, water conservation, water quality, renewable and non-renewable energy sources, and environmental stewardship. After the activities, teachers gathered in grade-level cohorts to (1) discuss the accuracy of their content preconceptions that had been shared before the activity, (2) suggest alternative procedural steps with the goal of enhancing student understanding, and (3) discuss ways to adapt the activity to include a stewardship component.

Over the course of the Institute, each teacher facilitated the selection, development, and implementation of a class stewardship project which focused on one of the Institute-introduced aspects of caring for the environment and incorporated select SE Practices. Teachers were provided with a handbook to guide them through each stage of the students’ planning, implementation, and evaluation of a stewardship project.\textsuperscript{2} In addition, teachers were given access to on-line National Geographic interactive mapping platforms and citizen science networks to share with their students. Teachers were required to photo-document their project.

The Institute staff provided a variety of supporting resources. During the Institute days, experts from the Jane Goodall Institute, the National Geographic Society, and the Project Learning Tree Green Schools program provided specific examples of environmental stewardship. In addition, a pedagogy consultant from K-12 Alliance/WestEd presented on connections between the NGSS SE Practices and environmental stewardship. This consultant was also available to teachers in person at Day 1 and 2 of the Institute and by email throughout the Institute to discuss any questions specific to their classroom needs. At the Institute, teachers shared successes and challenges they experienced, allowing each participant to receive constructive solutions to school-site challenges from other Institute participants.

Participants

CEEF selected 28 teachers\textsuperscript{3} from urban schools located in the greater Los Angeles area to participate in the Institute. Teachers volunteered for the PD, and were admitted if they met the following criteria: K-12 LAUSD teacher, written permission from the principal, appropriate credential, and statement of interest. Teachers ranged in the grade levels from elementary to high school. Although the fact that teachers volunteered may appear to be a limitation, we believe it represents an important opportunity for studying teacher change. In many contexts, science PD (and certainly EE PD) is voluntary. Yet volunteering does not necessarily mean that the new ideas will be implemented in practice (Coburn 2004). Moreover, research demonstrates that creating a cadre of volunteers who are ‘bought in’ to a particular reform supports spread of reform practices (Spillane and Kim 2012). Thus, studying the mechanisms which shape teacher enactment of practices learned in a voluntary PD experience is pertinent.
To facilitate the mixed-methods design, we selected two samples (Table 1). Sample 1 included all teachers who participated in the CEEF Institute, for the purpose of collecting survey data. The teachers primarily served in low income, high minority population schools (Table 2). Their years of teaching experience ranged from 2 to 34, with an average of 13.5; seven majored in a natural science as an undergraduate. Sample 2 was a sub-sample of the participating teachers selected for interviews, consisting of 10 teachers who signed up on Day 1, on a first-come, first-serve basis, with the understanding that the researchers needed four high school, two middle school, and four elementary teachers who were willing to participate in two 15-min telephone interviews, and receive an extra stipend for their time. The purposive selection of participants at each grade band was guided by findings from the analysis of the pre-surveys, which indicated significant differences in responses across subject areas and grade levels (Creswell and Plano Clark 2011). The years of experience of the Sample 2 teachers ranged from 8 to 25, with an average of 14.7.

**Instrumentation**

In accordance with our research design, we conducted a pre-survey, followed by two interviews with each sample 2 teacher, capped by written reflections and a post-survey. Teachers completed pre-surveys on Day 1 of the Institute (January) and post-surveys on Day 3 (May). These surveys consisted of two quantitative scales, the Science Instructional Practices + Stewardship survey (SIPS + Stewardship) (Hayes, et al. 2016), and the Belief Alignment Scale, adapted from Schultz (2002). Interviews were conducted between Institute days.

**SIPS + Stewardship**

This instrument is a modified version of the SIPS instrument created by Hayes, et al. (2016) to examine shifts in NGSS and other science instructional practices. We used subscales from the instrument that correspond with particular NGSS and stewardship practices advocated by CEEF (Table 3). Teachers were asked to respond to the prompt: ‘How often do your students do each of the following in the class(es) in which you will be conducting CEEF projects: Never, Rarely (a few times a year), Sometimes (once or twice a month), Often (once or twice a week), Daily or almost daily.’

**Belief alignment scale**

The belief alignment scale was developed by the first author as part of a large NSF-funded professional development project. The format of this measure was drawn from work by Aron, Aron, and Smollan (1992), who used overlapping circles in an instrument to measure the degree of interpersonal relationship; and the work of Schultz (2002) who used overlapping circles to demonstrate the relationship between self and nature. Beliefs are defined as a ‘system that includes our values and attitudes, plus our personal knowledge, experiences, opinions, prejudices, morals, and other interpretive perceptions of the social world’ (Saldaña 2013, 111). As a driver of action, they play a key role in motivating particular instructional practices (Luft 2001). Content validity was established through a review of the literature and examination by two researchers. Ecological and face validity were bolstered through collaboration with the project director regarding item wording, and a review of the items by 25 teachers (Desimone and Le Floch 2004). The final instrument was reviewed by three teachers for wording and relevance. Factor analysis of the instrument revealed a bifurcation along the lines of belief alignment ($\alpha = 0.920$) and belief-practice alignment ($\alpha = 0.944$).

**Table 1. Grade level and gender of sampled teachers.**

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Elementary</th>
<th>MS and HS science</th>
<th>MS and HS non-science</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample 1 (surveys)</td>
<td>27</td>
<td>6</td>
<td>15</td>
<td>5</td>
<td>19</td>
</tr>
<tr>
<td>Sample 2 (interviews)</td>
<td>10</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>8</td>
</tr>
</tbody>
</table>
In the measure, teachers considered a statement of educational philosophy (Table 4) and then answered two questions in which they selected a pair of overlapping circles, from completely overlapped (5) to completely separated (1) (total of eight questions). The first asked, ‘Please indicate the figure that best represents the overlap between your present educational philosophy and the above statement’ (belief alignment). The second asked, ‘Please indicate the figure that best represents the overlap between your current teaching or site practices and the above statement’ (belief-practice alignment).

**Interview protocol**

Teachers in sample 2 were interviewed twice (15–20 minutes per interview), once between Day 1 and 2 of the institute, and once between Day 2 and 3. We developed a structured interview protocol based on the research questions and pre-survey results. The protocol focused on reported changes in the teachers’ instructional practice during the Institute and any features of the Institute that may have impacted those changes. Teachers were additionally asked whether they perceived any advantages to integrating NGSS SE Practices with environmental stewardship.
Day 3 reflections
At the end of the last day of the Institute, all participating teachers wrote 1–2 page reflections regarding effective ways to incorporate NGSS SE Practices in stewardship, advantages and disadvantages to integration, and students’ reaction to the environmental stewardship project.

Analysis
Quantitative analysis
Survey data were first analyzed descriptively to establish teacher practices and belief alignment before and after the Institute, including mean differences across subject area and grade level. Because the small N will not support multi-variate parametric analyses, we used a t-test to determine the significance of difference between pre and post.

Qualitative analysis
Using Dedoose software, the research team first coded the interviews and reflections with a set of a priori categories derived from the literature and research questions. These included teacher references to NGSS SE Practices and stewardship and any ‘attributions’ as to why they incorporated NGSS and stewardship into their teaching practices. In keeping with Miles and Huberman’s (1994) guidelines, we allowed for emergent codes both as subcodes of larger a priori categories (e.g. types of stewardship) and as independent codes. The interviews and reflections were designed to allow the processes teachers underwent to arise naturally from teacher statements.

Two researchers coded the data. They each coded one interview, compared and discussed the codes, then separately coded another interview, which was subsequently compared. Once coding reached a satisfactory level of similarity (90% agreement on mid-level codes), the researchers then split the remaining interviews to code (Miles and Huberman 1994). In order to increase trustworthiness, we triangulated across multiple sources of data, including survey data, interviews, and reflections. We also performed member-checks with the project director several times over the course of data analysis and writing. We checked alternative theoretical interpretations throughout the coding process to verify findings.

Results
RQ1: To what extent do teachers enact targeted classroom instructional practices after engaging in a 4-month, intensive NGSS/stewardship integration PD?

Results from the pre and post SIPS + Stewardship survey demonstrated that teachers on average reported significant and substantive shifts in their practices over the course of the Institute. T-tests of the difference in mean pre to post showed significant differences for all subscales except Traditional

Table 4. Philosophies to which teachers were asked to respond.

<table>
<thead>
<tr>
<th>Philosophy</th>
<th>Philosophy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Student centered learning</td>
<td>The role of teachers should be shifted from being the source of knowledge to a facilitator of learning. This requires consistently involving students in asking questions and making decisions about their investigations and stewardship projects</td>
</tr>
<tr>
<td>2. Environmental literacy</td>
<td>Environmental literacy, including understanding of concepts and issues, cognitive skills, and stewardship strategies, is key to a student’s well-rounded education. It must be taught at every grade level to ensure they become responsible stewards of the environment.</td>
</tr>
<tr>
<td>3. Education for sustainability</td>
<td>An important aim of education is to empower students to take positive action toward an environmentally sustainable future (i.e. ensure that we have and will continue to have, the water, materials, and resources for human and environmental health)</td>
</tr>
<tr>
<td>4. Environmental action competence</td>
<td>Students need to be actively involved in educational activities that demonstrate the relationship between their actions and environmental effects, positive (stewardship) and negative (e.g. pollution)</td>
</tr>
</tbody>
</table>
Instruction (Table 5). Although teachers initially rated themselves lowest on Stewardship integration, Data collection and analysis (NGSS SE Practices 3, 4 and 5), and Reasoning, explanation and argumentation (NGSS SE Practices 6 and 7), these subscales also exhibited the greatest gains pre to post (0.91, 0.75, and 0.96 standard deviations difference, respectively) (Figure 2). The lack of change in traditional instruction is consistent with the fact that traditional pedagogies were not the target of the CEEF Institute, and that teachers are fairly routine and consistent in their use of traditional instruction.

RQ2. What are the processes which shaped teacher change in enacting NGSS and stewardship in their classroom practice?

The processes which shaped teacher enactment of the targeted practices were examined in light of our theoretical framework regarding teacher change (Clarke and Hollingsworth 2002). The processes that emerged from this analysis are portrayed in Figure 3, specifying the roles of teacher beliefs, learning opportunities, professional experimentation, reflection on student outcomes, and sensemaking regarding the external context in the change process. Evidence of each of these aspects follows. Evidence of the first process is supported by quantitative data, the remaining processes emerged from qualitative data analysis.

Process 1: changes in teachers’ beliefs

Initial belief alignment. Analysis of the pre-belief alignment scale indicated that the average overlap between teacher beliefs and the stated CEEF philosophy was fairly high for all philosophy statements (mean 4.08 out of 5.00, Table 6). In other words, teachers came into the Institute with beliefs that were already fairly aligned with CEEF philosophies, likely due to the fact that they volunteered. They agreed with the inherent value of student-centered learning (philosophy 1), environmental literacy (philosophy 2), education for sustainability (philosophy 3), and environmental action competence (philosophy 4). However, teacher conceptualization of their ability to carry out these philosophies in their practice (practice-belief alignment) was considerably lower on average (the overlap between philosophy and practice had a mean of 3.00). The significant difference between average belief alignment and practice-belief alignment for each philosophy ($t = 4.99, p < 0.001$) indicates that teachers perceived that (a) they were unable to carry out their beliefs in practice; or (b) their school did not prioritize these philosophies.

Final belief alignment. A comparison of pre to post belief alignment demonstrated that teachers’ initially high belief alignment did not change significantly (although the average increased slightly, 4.08–4.22). Thus, teachers started out well aligned to CEEF philosophies – and remained aligned. Yet an examination of pre to post changes in belief-practice alignment with the CEEF philosophies shows an interesting change (Figure 4). Each changed positively on average, between 0.17 and 0.65 of a standard deviation. There was a significant difference pre to post ($p < 0.05$) for education for sustainability (philosophy 3) and action competence (philosophy 4).

To summarize, teachers came into the Institute with beliefs that were highly aligned to CEEF philosophies, but felt their classroom and site practices were not as aligned. They left the institute with their

<table>
<thead>
<tr>
<th>Factor name</th>
<th>Mean pre</th>
<th>SD pre</th>
<th>Mean post</th>
<th>SD post</th>
<th>t-statistic</th>
<th>Cohen’s d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Stewardship integration</td>
<td>2.75</td>
<td>1.01</td>
<td>3.54</td>
<td>0.74</td>
<td>−4.63***</td>
<td>0.91</td>
</tr>
<tr>
<td>2. Data collection and analysis</td>
<td>3.14</td>
<td>0.78</td>
<td>3.69</td>
<td>0.68</td>
<td>−3.29*</td>
<td>0.75</td>
</tr>
<tr>
<td>3. Reasoning, explanation and argumentation</td>
<td>3.42</td>
<td>0.80</td>
<td>4.14</td>
<td>0.70</td>
<td>−4.39***</td>
<td>0.96</td>
</tr>
<tr>
<td>4. Discourse and communication</td>
<td>3.63</td>
<td>0.74</td>
<td>4.10</td>
<td>0.59</td>
<td>−3.38***</td>
<td>0.70</td>
</tr>
<tr>
<td>5. Prior knowledge</td>
<td>3.88</td>
<td>0.90</td>
<td>4.41</td>
<td>0.55</td>
<td>−3.50***</td>
<td>0.71</td>
</tr>
<tr>
<td>6. Traditional instruction</td>
<td>3.84</td>
<td>0.63</td>
<td>3.96</td>
<td>0.47</td>
<td>−0.83</td>
<td>0.13</td>
</tr>
</tbody>
</table>

Notes: SD in parentheses. The t-test indicates whether there was a significant difference pre to post ($N = 27$). Cohen’s $d$ is the effect size – the difference in SD’s from pre-to-post. ($N = 27$).

"$p < 0.01$; ""$p < 0.001$"
beliefs still highly aligned, AND feeling that their classroom and site practices were more aligned (also evidenced by the SIPS + Stewardship survey increases).
To further understand the processes that supported teacher reconsideration of their practices, we analyzed interview and reflection data. Four process themes emerged that both corresponded to Clarke and Hollingworth’s (2002) model and also complicated it (Figure 3). These additional processes included the role of CEEF in facilitating teacher learning, the role of CEEF in requiring enactment, teacher observations of student reaction, and teacher sensemaking regarding policy.

Table 6. Mean pre and post alignment between CEEF philosophies and teacher beliefs and practices.

<table>
<thead>
<tr>
<th>Philosophy name (number in parenthesis)</th>
<th>Belief alignment</th>
<th>Practice/belief alignment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean pre</td>
<td>Mean post</td>
</tr>
<tr>
<td>Student-centered (1)</td>
<td>3.86 (1.09)</td>
<td>3.81 (1.03)</td>
</tr>
<tr>
<td>Environmental literacy (2)</td>
<td>3.96 (1.22)</td>
<td>4.15 (1.00)</td>
</tr>
<tr>
<td>Sustainability (3)</td>
<td>4.14 (1.13)</td>
<td>4.46 (0.81)</td>
</tr>
<tr>
<td>Environmental effects (4)</td>
<td>4.36 (0.96)</td>
<td>4.44 (0.85)</td>
</tr>
<tr>
<td>Overall mean belief overlap</td>
<td>4.08 (0.99)</td>
<td>4.22 (0.86)</td>
</tr>
</tbody>
</table>

Notes: SD in parentheses. The t-test indicates whether there was a significant difference pre to post (N = 27). *p < 0.05.

Figure 4. The change over time (pre to post) in the averages of belief alignment and belief-practice alignments from teacher surveys.

To further understand the processes that supported teacher reconsideration of their practices, we analyzed interview and reflection data. Four process themes emerged that both corresponded to Clarke and Hollingworth’s (2002) model and also complicated it (Figure 3). These additional processes included the role of CEEF in facilitating teacher learning, the role of CEEF in requiring enactment, teacher observations of student reaction, and teacher sensemaking regarding policy.
**Process 2: learning opportunities from the external domain**

Eight of the ten interviewed teachers discussed how their prior conceptions about teaching changed as they incorporated new information about pedagogies and pedagogical materials, in three general areas: **strategies, tools, and activities for student-centered teaching, standards, and environmental impacts**.

In regards to strategies, tools, and activities for student-centered teaching, examples ranged from teachers simply being exposed to a useful website like National Geographic (Liz) to trying new activities such as water sampling (Carlos, Liz), to learning strategies that may ultimately transform their teaching. As an example of the latter, Janet, an elementary school teacher, discussed how she incorporated what she learned about the 5E lesson plan, which she first heard about during the Institute.

> It seems more of a process to me, than a lesson plan that begins in one place and ends in another place … So I think it’s prompting me to rethink how I approach lessons.

Several other teachers discussed new ways of understanding their pedagogies, often focused on incorporating a more problem-based approach to teaching. For example, Jeremy (middle school teacher) said,

> I loved it [one of the presentations] because it got me thinking, and I would have to say that was one of the more direct impacts. So for example, when I am teaching my Geometry class, I am now making it into a real problem that they’ve got to solve. They are not getting a diagram, they have to make the diagram … figure out a whole bunch of things that I don’t think I would have done before.

These teachers, and several others, all talked specifically about changes in their thinking (‘rethink,’ ‘got me thinking’) about their teaching that were sparked by experiences in CEEF, which subsequently led them to move their practice to a more student-centered approach.

Several of the teachers had not had much training regarding NGSS and appreciated the exposure to the standards. As Jeremy noted, ‘I have been floating around to various schools throughout the years, I haven’t had any training. So the symposium was particularly valuable.’ Moreover, NGSS was presented in a way that emphasized the standards’ support for student collaborative work. As Lara, an elementary teacher, described, ‘In seeing the NGSS standards and the ability to apply across the curriculum … the NGSS standards have a lot to do with collaboration, communication, so I think those are really integrated into our stewardship project.’

Finally, teachers discussed how the Institute re-inspired them regarding the need to address environmental impacts, which they subsequently brought to their students. As Karina said, ‘That was so impactful to me … that particular slide [a comparison of Sierra snowpack under drought and non-drought conditions]. The snow packs … In fact, we’re using that slide on our presentation on Thursday to the students. It was so impactful to just introduce to the kids to water and how important water is.’ Teachers gained the inspiration and the tools they needed to introduce environmental problem solving to the students. Liz, a high school science teacher described, ‘Seeing the demonstration … it was very effective … It induced me to go out and take water samples and have UCLA help me test them.’

**Process 3: expectations for classroom enactment**

Although only four out of the ten interviewed teachers discussed the importance of the CEEF Institute’s strong expectation for completing a stewardship project, their comments provided important insight into the details by which the change process unfolded. Despite high belief alignment, several of the teachers either lacked the confidence or the motivation to get over the hurdle of planning and completing a stewardship project on their own; the Institute approach provided needed external motivation. For example, Karina said,

> That [the expectation] forced me to really commit to this. That really helped. In talking to the Tree People contact [Local CREEC Coordinator] … it was like, ‘You’re right on target!’ So it made me feel more confident in what I was doing and that I could more easily go ahead doing this.

It is noteworthy that it was the combination of the expectation and the supportive resources (external consultants she could call) that boosted her confidence and her ability ‘to commit.’ Supportive resources included other Institute teachers, who were encouraged during the Institute to problem solve
together. Several of the interviewed teachers worked in collaboration with partner teachers in carrying out stewardship projects, finding the collaboration particularly valuable. As Lara described, ‘having the opportunity to collaborate with my colleagues of similar class or grade level has been incredible. I think that was a good opportunity for all of us and especially for our students.’

In other cases, the motivation stemmed from a sense of responsibility or accountability to the Institute. Carlos described it as, ‘I’ve always been an environmental activist … [but] I’m more sensitive to the issues and want to do a good job and be responsible to the [Institute].’ Likely the high belief alignment reported earlier in this paper contributed to Carlos’ sense of responsibility. Tapping into such values may be a key motivator for change in environmental education efforts.

Other teachers needed external motivation to overcome perceived barriers. Marguerite described how the Institute’s expectations helped her overcome a hurdle related to workload: ‘The most significant feature is the willingness to actually do the project because it’s a HUGE amount of work and I don’t know if I would have done it without the CEEF institute.’ Likewise, Lara spoke about lacking resources at her school that support stewardship, then stated, ‘I think the features that most impacted was just getting into the mode of doing the projects and thinking outside of the box.’

Process 4: observation of student excitement, engagement, and environmental stance

One of the most prominent aspects of the change process described by teachers (9 of the 10 teacher interviewees) was witnessing the excitement, engagement, and environmental stance of their students. Such student responses motivated them to overcome barriers to completing a stewardship project. One quote from a middle school teacher provides a sense of the multifaceted ways in which this happened. When asked if there was a key component or experience that lead to the success of their students’ project, Karina replied,

We went to this workshop and we knew we actually had to do something, but actually starting it, and seeing the kids’ excitement to do it …. For me, I was very gung-ho to do it, but [my partner teacher] was a little leery because she was afraid to take time away from the math, and once she actually got into it, the kids! The kids actually want to start a Water Conservation Club on campus … That was their idea, not ours. So I think leading to the success of the students is the one, willingness to do it and getting over the fear of ‘It’s a huge project’ … [and] now the kids are wanting to take it and run with it.

Karina eloquently articulated how being incentivized to do the stewardship project (‘we had to do something’) and then engaging in the stewardship (‘actually starting it’) allowed her to see her students’ excitement. Witnessing student ownership helped her overcome barriers, including the ‘leeriness’ of partner teachers and the ‘hugeness’ of the project.

Others described similar experiences regarding how student reaction made the hard work of stewardship ‘worthwhile.’ Lara stated,

I think that the big impact was … having the students really get more involved, have them understand it more, and have them be a part of the solution, which was amazing … as they were able to take ownership of the project. It was a lot of work, but completely worthwhile. I think the students will never forget the experience and that they were part of something big.

As in the example of Karina, Lara not only referenced the students’ engagement, but also their environmental responsibility. This was a common theme among teachers who discussed this process. As demonstrated in their belief alignment, many of these teachers were already committed to environmental stewardship, but the Institute provided incentives and tools for them to try it in the classroom. Subsequently, witnessing student reaction ‘compensated’ for the amount of work. Several more teachers talked about how the process made students ‘better environmental citizens’ or ‘more responsible members of the community.’

Process 5: sensemaking regarding the policy context

This theme concerns how teachers made decisions about their curriculum in the context of a variety of pressures, including testing, standards, and other district mandates, few of which focused on environmental education. We highlight two prominent and iterative themes: (1) the legitimization afforded by
integrating standards and stewardship in an age of standards and testing; and (2) the role of stewardship in helping to authenticate the standards.

The first theme, experienced by six out of ten teacher interviewees, concerned the ways that NGSS legitimized teachers’ incorporation of stewardship in their teaching. Accountability to standardized tests was an important arbiter of practices for several teachers, although their perceptions differed. On one hand, some teachers felt tremendous pressure from accountability in trying to implement EE. As Karina described:

We have the tests that are coming up and a lot of teachers are freaking out about this new test … they feel they have to put everything else on the backburner because they feel they have to get this done … What are my priorities? Do I do what the District tells me or do I do what I really want to do, which is my environmental project?

On the other hand, Carlos believed that students would do better on the test after participating in stewardship: ‘There are advantages. I believe the students do better on their tests when [environmental stewardship] is integrated into their curriculum.’ Because of accountability pressures, integrating stewardship with NGSS standards facilitated carrying out the stewardship in practice. Marguerite stated: ‘We’re very focused on the standards, so that the students can pass whatever tests they’re going to throw at us. So if we don’t integrate the standards, people are just going to ignore whatever it is … But the standards are good. They’re reasonable.’

Even when teachers did not talk about accountability pressure, the melding of the NGSS standards and stewardship provided an external justification for them to bring their beliefs into practice. As Lara wrote in her reflections, ‘The advantage of incorporating these new standards is that we now have much more liberty to justify our environmental stewardship project by demonstrating the integration and application of these standards.’ In a similar statement, a high school teacher (Liz) noted how stewardship allowed her to tie it all together – what they are required to teach (the standards) with what they want to teach (the environment).

We were hired to teach the Common Core standards and the NGSS, but by involving that in the environmental stewardship projects, you’re kind of hitting that all at once. So for example, students are required to read information, come up with ideas, and provide evidence, but are also supposed to work in groups. With the stewardship project, they are able to do that. It kind of all ties in nicely together.

These teachers all used words such as ‘connected,’ ‘tied together,’ and ‘integration.’ Such a conceptualization corresponds to growing evidence that coherence is a key element of successful reform (Honig and Hatch 2004).

Coherence may play such a salient role because of the demands placed on teachers’ time. Karina, a middle school teacher commented that incorporating NGSS and CCSS together with stewardship addressed this common barrier.

The biggest hurdle is getting over the idea that you have limited time to teach the way you want. Stewardship projects are the cornerstone of a NGSS and CCSS. It encompasses BOTH extremely well if implemented correctly and student driven. They will learn more from a Stewardship project than any handout in class.

In the second sensemaking process, teachers recognized that the integration of stewardship with NGSS SE Practices resulted in opportunities for deep learning in science (eight out of ten teachers). For example, Marguerite spoke articulately of how stewardship helped the NGSS SE Practices ‘come to life.’

So when you have standards like that, they tend to be abstract … But if you use the framework of environmental stewardship and figure out how to teach the standards … then you can make the NGSS SE Practices come alive for the kids. You’ve got to have something real at the core.

This teacher indicated that stewardship provided authentic activity, ‘something real’ to place at the instructional core of teaching science.

These teachers were ‘making sense’ of how and why to do stewardship in the context of their work. The integration of NGSS provided a key pathway for them to justify bringing stewardship into their curriculum.
Illustrating the change process with one case

A final quotation from Janet provides an example which demonstrates how four of the five change processes were linked together in one case. Although the shift in instructional practice in this quotation pertains primarily to teaching science, Janet also notes that she is incorporating the environment into her science education.

I have incorporated more science into the curriculum and I am trying to utilize the 5E lesson plan; I think that the lesson plan is very different from the traditional lesson plan …… So I think it’s prompting me to rethink how I approach lessons, and what it did for me is gave me permission to start thinking things in the environment to be legitimate in science instruction … I’m being told at the [Institute] that this is legitimate. However, coming back to my school it feels like I’m really still not totally comfortable at my school site because I’m always afraid, just because of the power structure, that it’s not enough. It’s not enough of a rationale … Especially in terms of the core curriculum of English and Language Arts, which gets the most attention. But I could see and could tell that when I presented it to my students that they were just so excited that we’re going to be doing science, that this is the way to go.

In this example, Janet first says that she has shifted her practice (Shifts in practice: ‘incorporated more science’; ‘things in the environment were legitimate’) based on exposure to a new pedagogical strategy (Process 2: ‘5E lesson plan’), which caused her to shift her thinking (Shift in beliefs regarding practices: ‘rethink how I approach lessons’). She then reflects on how the Institute legitimized using the environment to teach science, although she still feels a lot of pressure around what she is supposed to be teaching (Process 5: ‘it’s not enough of a rationale’). Then she continues in her reflection, focusing on her students (Process 4: ‘they were just so excited’). She finalized by stating, ‘this is the way to go,’ implying that the entire sequence has helped her shift her belief state regarding enacting environmental education.

Discussion

These results demonstrate a reported increase in incorporation of stewardship and NGSS SE Practices over the course of participation in the four month Institute. The quantitative changes in SIPS + Stewardship survey pre to post were surprisingly substantive. From a low initial starting point, teachers showed the greatest gains in subscales pertaining to NGSS SE Practices, as well as integrating stewardship (a gain of between 0.70 and 0.96 standard deviations; \( p < 0.01 \) [Cohen’s \( d \)]. Many PD efforts demonstrate much smaller effect sizes in relation to shifts in practice (e.g. Harlow 2014; Jeanpierre, Oberhauser, and Freeman 2005; Penuel et al. 2007; Supovitz and Turner 2000). Although such a reported shift is positive for the Institute providers, the findings of interest emerge from the second research question, exploring the processes which shaped teacher change.

We framed our study with Clarke and Hollingsworth’s (2002) theory that teacher change happens through an iterative process between original beliefs, learning new strategies, enacting new practices, and observing student reactions. In order to test and refine this theory in an environmental education context, we first measured teacher initial belief alignment, which demonstrated a relatively high alignment between teacher beliefs and Institute philosophies. In other words, teachers were coming in to the Institute predisposed towards the ideas that would be presented, likely due to the selection process. The important role of previous belief alignment in facilitating uptake of new practices reflects an on-going discussion in both the overall PD literature and EE literature (Ernst 2007; Harlow 2014; Luft 2001), and begs the question as to how to proceed when beliefs are not aligned.

That said, addressing such a question is beyond the scope of this study. Instead, we focus on an equally important barrier, teachers’ perception of what is possible in practice. In that regard, teachers indicated an initial low overlap between Institute philosophies and their classroom or site practices, signifying that they felt unable to carry even their highly aligned beliefs into practice. By the end of the Institute, teachers not only demonstrated significant change in their practices on the SIPS + Stewardship survey; they also showed significant change in the overlap between Institute philosophies and practice. In other words, their practice came more into alignment with their beliefs.
Our qualitative analysis explored the additional processes by which this happened. Although Clarke and Hollingsworth’s (2002) model substantively contributed to our understanding of teacher change, our results also gave rise to additional mechanisms that refine and complement their framework. In the second process, teachers referenced the important role the Institute played as a source of new information that helped change their conceptions about teaching and that exposed them to additional pedagogical tools and environmental issues. The important role of new ideas to complement existing expertise has been documented elsewhere (Luft 2001), as has the role of environmental literacy in fostering EE instructional practice (Ernst 2007). In this case, teachers may have been especially receptive to learning new strategies that helped them carry their beliefs out in practice. They appreciated being re-inspired regarding environmental issues and appreciated resources to help their students understand.

In the third process, some teachers noted that CEEF’s strong expectation that the teachers complete a stewardship project was an important motivator for changing their practice. This process reflects PD research regarding the importance of trying out strategies in practice (Guskey 2002). Although not explicitly referenced in the Clarke and Hollingsworth (2002) model, our findings in this area point to the need for ‘high expectations, high scaffolds’ learning experiences to support teacher change. The scaffolds in the present study included the learning facilitated by the Institute, the availability of expert consultants, and discussion with other teachers. High expectations/high scaffolds are a mantra of K-12 teaching (e.g. Lutz, Guthrie, and Davis 2006), however such an approach is rarely, if ever, discussed in PD literature. Such expectations may give an important nudge to teachers who lack the impetus to change or who face institutional barriers (Coburn 2004; Luft 2001). The central role belief alignment played in teachers’ receptivity to these expectations contributes to the scholarly debate regarding the role of voluntariness in teacher instructional change (Coburn 2004).

In the fourth process, many teachers discussed how observing positive student reaction motivated them to enact the hard work of a stewardship project, a process noted in PD literature (Fishman et al. 2003; Jeangepierre, Oberhauser, and Freeman 2005) and literature regarding EE instructional practices (Winther, Volk, and Shrock 2002). Teachers observed engaged learning as students implemented their projects, and they were excited that students took a more thoughtful stance about their environment. Again, teachers’ appreciation of students’ affective learning was likely enhanced by pre-existing belief structures that align with environmental education; in turn student response provided teachers with motivation to enact their beliefs (Guskey 2002). Moreover, the Institute focus on stewardship – an active, contextualized learning experience – rather than simply integrating EE content into science, may have played a role in student engagement, influencing teacher shifts in practice (Wade 1996).

Finally, we found that the external domain of policy and organizational context, although under-specified in Clarke and Hollingsworth’s (2002) model, played a pivotal role. To understand why, we drew upon sensemaking theory (Spillane, Reiser, and Reimer 2002) to examine how teachers thought about stewardship in relationship to the requirements of their work. Teachers felt under pressure from testing in some contexts, and in others simply felt a ‘responsibility’ to implement the standards. Teachers discussed how the substantive incorporation of NGSS in the Institute fostered their ability to address common barriers to including environmental education in instruction – the heavy emphasis on a set of prescribed standards and related tests, and lack of time (Ernst 2007; Stevenson 2007). Here teachers’ sensemaking of the integration of standards and stewardship allowed them to carry their beliefs out in practice, contributing to the significant shift in the alignment between belief and practice that was demonstrated in the quantitative data. We conjecture that such alignment may only be possible due to NGSS’ science-practice inclusive nature, and may not have occurred in the context of prior standards which focused on discrete factual content. Alignment with teacher internal beliefs and with external requirements created a space within which teachers could do this work (Darling-Hammond and Richardson 2009). This is a particularly important finding given the reduction of space for environmental education in schools guided by high stakes assessment (Stevenson 2007).
**Theoretical implications**

Environmental Education scholarship engages in a continual struggle to understand how and why teachers incorporate EE practices into their teaching. We contribute to this dialogue by applying Clarke and Hollingsworth’s (2002) theory to understand the processes that shaped quantitatively demonstrated instructional change. In so doing, we also tested and refined Clarke and Hollingsworth’s (2002) theory in an EE context, applying sensemaking theory to understand a key emergent element of teacher behavior. Refinements include: (1) the pivotal role of external expectations for enactment, in combination with aligned beliefs (without aligned beliefs the expectations might have backfired); (2) the notion that supporting teacher change may require high expectations together with high scaffolds; and (3) the idea that sensemaking plays a critical role in shaping how PD can change teacher practice. Together, these existent and emergent theoretical lenses afford a powerful tool for understanding how and why teachers incorporate environmental education into their practice.

**Implications for practice**

This study provides a window into the processes by which teachers take up and enact stewardship in the context of standards and testing. The results demonstrate the power of programs that infuse relevant pedagogical and environmental knowledge, strategies and tools; hold teachers to high expectations and simultaneously provide high support; and provide opportunities for teachers to reflect on student learning (Fishman et al. 2003). Moreover, PD that clearly integrates environmental education strategies with state standards (more than just stating that it meets particular standards) can foster a process by which teachers make sense of how to implement the EE in the context of competing demands. Perhaps most importantly, we found that teachers had aligned beliefs but did not know how to translate them into their teaching practice in light of the complex barriers to change. An infusion of knowledge was not enough. It took iterative process with enactment, observation, and sensemaking within their teaching context.

Stewardship has great potential for fostering student learning due to its relationship to project-based, real world contexts. Yet there has been consistent struggle among environmental educators to find ways to infuse stewardship into curriculum. This may be a window of opportunity. As the NGSS and similar standards are implemented around the world, an increasing number of teachers will look to professional development opportunities for ways to incorporate these new standards into their instruction. Participating in a long-term PD focused on integrating standards and stewardship, with built-in incentives and support, may help teachers incorporate more environmental education.

**Limitations**

It must be noted that the teachers participating in this program were paid volunteers. Thus their belief alignment was likely considerably higher than the general population, which may have affected their motivation to change (Fishman et al. 2003). Yet, it is perhaps because of these limitations that these teachers represent a great opportunity for studying teacher change. Much of science and EE PD is voluntary; and thus studying the mechanisms which shape teacher enactment of practices learned in a voluntary PD experience is pertinent. That said, additional research is needed to understand how processes of teacher change differ when PD is mandatory or teacher beliefs are not as highly aligned.

Another limitation is that we did not adequately capture the role of teacher collaboration, which is demonstrated as a key driving process in the literature (Darling-Hammond and Richardson 2009). Finally, not all states (or countries) are adopting NGSS or NGSS-like standards. Although this research may not be directly applicable in such states in terms of the specific NGSS SE practices, the results may nonetheless be useful in conceptualizing teacher change in complex organizational contexts.
Notes

1. CEEF (California Environmental Education Foundation) is a 501 (c) (3) non-profit foundation established at the recommendation of the Environmental Education Task Force Steering Committee in 2003. CEEF’s mission is to promote environmental literacy and stewardship by identifying and coordinating efforts that support the highest standards of practice and by increasing the flow of resources to those efforts. The organization has agreed to share its participation in the research publically (http://www.caeefoundation.org).

2. This handbook was adapted from guidelines that were developed by the K-12 Alliance.

3. One teacher missed the last Institute day, thus the final sample is 27.

4. All teacher names are pseudonyms.

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Notes on contributors

Kathryn Hayes, PhD, is an assistant professor in the Department of Educational Leadership at California State University, East Bay. She serves as a Co-PI for the Science Partnership, which oversees several grant-funded science education professional development projects. Her research focuses on the organizational capacity needed to support urban science education reform, as well as the role of institutional processes in mediating how reforms translate into teacher instructional shifts. Her recent publications have appeared in Teaching and Teacher Education (2016), Journal of School Leadership (2016), Environmental Education Researcher (2016), and International Journal of Science Education (2016).

Mele Wheaton, PhD is a research scholar in the Graduate School of Education at Stanford University. Her research interests include environmental education, informal science education, and nature-based tourism. As lead on a variety of projects, she has studied behavior change in ecotourists, environmental identity and action in students, and professional development in environmental educators.

Deborah L. Tucker, EdD, is currently an independent science education consultant. Her career as a science educator includes experience as a professional developer, assessment developer, evaluator, project manager, state science supervisor, and middle school science teacher. She served as the Bay Area Regional Director for the National Science Foundation-supported State Systemic Initiative in California. Prior to finishing her doctorate, she served as the science consultant at the California Department of Education. Her doctoral research focused on science professional development and the efficacy of those who provide it.

References


