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Todd Campbell[a], Rebecca Zuwallack[b], Max Longhurst[c], Brett E. Shelton[d] & Paul G. Wolf[e]

[a] Curriculum and Instruction, University of Connecticut, Storrs, CT, USA

[b] STEM Education, University of Massachusetts Dartmouth, Dartmouth, MA, USA

[c] Teacher Education and Leadership, Utah State University, Logan, UT, USA

[d] Educational Technology, Boise State University, Boise, ID, USA

[e] Biology, Utah State University, Logan, UT, USA

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An Examination of the Changes in Science Teaching Orientations and Technology-Enhanced Tools for Student Learning in the Context of Professional Development

Todd Campbell[a*], Rebecca Zuwallack[b], Max Longhurst[c], Brett E. Shelton[d] and Paul G. Wolf[e]
[a]*Curriculum and Instruction, University of Connecticut, Storrs, CT, USA;* [b]*STEM Education, University of Massachusetts Dartmouth, Dartmouth, MA, USA;* [c]*Teacher Education and Leadership, Utah State University, Logan, UT, USA;* [d]*Educational Technology, Boise State University, Boise, ID, USA;* [e]*Biology, Utah State University, Logan, UT, USA*

This research examines how science teaching orientations and beliefs about technology-enhanced tools change over time in professional development (PD). The primary data sources for this study came from learning journals of 8 eighth grade science teachers at the beginning and conclusion of a year of PD. Based on the analysis completed, Information Transmission (IT) and Struggling with Standards-Based Reform (SSBR) profiles were found at the beginning of the PD, while SSBR and Standards-Based Reform (SBR) profiles were identified at the conclusion of PD. All profiles exhibited Vision I beliefs about the goals and purposes for science education, while only the SBR profile exhibited Vision II goals and purposes for science teaching. The IT profile demonstrated naïve or unrevealed beliefs about the nature of science, while the SSBR and SBR profiles had more sophisticated beliefs in this area. The IT profile was grounded in more teacher-centered beliefs about science teaching and learning as the other two profiles revealed more student-centered beliefs. While no beliefs about technology-enhanced tools were found for the IT profile, these were found for the other two profiles. Our findings suggest promising implications for (a) Roberts' Vision II as a central support for reform efforts, (b) situating technology-enhanced tools within the beliefs about science teaching and learning dimension of science teaching orientations, and (c) revealing how teacher orientations develop as a result of PD.

Keywords: *Teacher orientation; Technology-enhanced tools; Science literacy*

*Corresponding author. Curriculum and Instruction, University of Connecticut, Storrs, CT, USA. Email: todd.campbell@uconn.edu

Introduction

Developing understandings about teaching in science is no simple task, given the complex and unending array of factors that are consistently shaping the instruction that teachers provide. Pedagogical content knowledge (PCK) is one framework that is used consistently for disentangling this complexity. PCK 'includes knowledge of how particular subject matter topics, problems, and issues can be organized, represented, and adapted to the diverse interests and abilities of learners, and then presented for instruction' (Magnusson, Krajcik, & Borko, 1999, p. 96). But, as researchers have noted (e.g. Anderson & Smith, 1987; Friedrichsen, Van Driel, & Abell, 2011; Magnusson et al., 1999), PCK is shaped by myriad influences, including teachers' knowledge and beliefs about the purposes and goals for teaching science. In examining influences that shape PCK, researchers have conceptualized teacher orientations as a construct that serves as a filter through which teacher knowledge is grounded, developed, and subsequently manifested in the instruction experienced by students. Whereas science teacher orientations have been framed in several ways, Friedrichsen et al. (2011) proposed three dimensions of science teacher orientations to better understand the roots of the 'what' and 'how' of teachers planning and instruction: 'beliefs about the goals and purposes of science teaching, beliefs about the nature of science, and beliefs about science teaching and learning' (p. 373).

Technology is another important modern aspect of science teaching and learning. Technology becomes important to teaching because of the ways in which technology is shaping or reshaping lives and society. This can be seen as Ito et al. (2008) reveal how technology is potentially transforming students' lives as social networking, online gaming, iPods, and mobile phones are found as fixtures of youth culture. Further, the transformative role of technology on society can be seen affecting how information is accessed and influences intelligence. Glassman and Kang (2012) suggested that fluid, crystal, and cultural intelligence is changing in what they understand as open source intelligence. Additionally, and more salient to science teaching and learning, technology transforms science practices (Sabelli, 2006). For example, Hey, Tansley, and Tolle (2009) describe these transformations in the context of the recent emergence of new fields such as computational and data-intensive sciences. Given the pervasive influence of technology on society, as well as the potential benefits of leveraging technology to teach science, some education researchers have connected PCK and teachers' technological pedagogical content knowledge (TPACK) (Koehler & Mishra, 2005). TPACK is conceptualized as an extension of Shulman's (1986) PCK as it more explicitly considers technology as another type of knowledge that teachers possess and that can shape, and be shaped by, teachers' content and pedagogical knowledge. If one accepts that technology is another type of knowledge, consequently then, consistent with the PCK framework, TPACK would be necessarily shaped by, while shaping, teacher orientations. This is especially true if, like others have proposed (e.g. Crippen, 2012; Koehler & Mishra, 2005; Niess, 2005), technology represents another realm of science teacher knowledge.

Through a review of literature connected to a careful articulation of teacher orientations as a construct, Friedrichsen et al. (2011) identified a series of important and needed areas of research. These include investigating science teacher orientations and other components of PCK and how the development of PCK associated with curriculum interventions of professional development (PD) influences science teaching orientations. Friedrichsen et al. (2011) also noted the need for researchers using science teaching orientations to be explicit in how each of these constructs is defined so that the definitions used can be situated in the literature. This research attended to many of these recommendations by revisiting and extending our previous research (Campbell, Longhurst, Duffy, Wolf, & Shelton, 2013) as we examined orientations and technology-enhanced tools for student learning in relation to a standards vision of science literacy (American Association for the Advancement of Science [AAAS], 1989; National Research Council [NRC], 1996, 2011). In comparison with Campbell et al. (2013), this research is characterized as 'revisiting' because past emergent science teacher orientations and technology-enhanced tool profiles were re-examined with respect to their conceptualization both in connection with other literature and the emergent findings. Additionally, this represents an extension to our past research, because previously we focused exclusively on teachers at the beginning of a science literacy/technology-enhanced tools PD project. After one year of this same PD, this research seeks to examine (un)predicted changes in science teacher orientations during curriculum innovation, or in the case of this research, PD. Given this focus, the primary goal of this study was to investigate the following two facets of science teaching and learning: (1) how teachers' orientations for teaching science, which include beliefs about technology-enhanced tools, aligned or misaligned with the science literacy framework outlined in this research over time, and (2) how teachers' beliefs and knowledge of technology-enhanced tools for student learning in science shape and are shaped by science teacher orientations over time. The guiding research question is: *How do science teacher orientations, which include beliefs about technology-enhanced tools for student learning, shift over time as a result of a year of PD?*

Theoretical Background

Science Teacher Orientations and Technology

Putnam and Borko (1997) explain how

> teachers, like students, interpret experiences through the filters of their existing knowledge and beliefs. A teacher's knowledge and beliefs—about learning, teaching, and subject matter—thus, are critically important determinants of how that teacher teaches. (p. 1228)

Avraamidou (2013), in research examining science teacher orientations aligned to Friedrichsen et al.'s (2011), emphasized the importance of teacher orientations by considering them in ways consistent with Pajares (1992) with respect to the importance of beliefs that shape science instruction. More specifically, Avraamidou (2013) recognized that 'clusters of beliefs around a particular situation form attitudes, and attitudes become action agendas that guide decisions and behavior' (p. 4). In this research, as previously (Campbell et al., 2013), we have adopted the following three dimensions of science teacher orientations proposed by Friedrichsen et al. (2011): 'beliefs about the goals and purposes of science teaching, beliefs about the nature of science, and beliefs about science teaching and learning' (p. 373). Each of these dimensions is briefly described next.

Beliefs about the goals and purposes of science teaching. This dimension of teacher orientation considers the function of science education. Roberts (2007) considered the functions and goals of science teaching in terms of 'knowledge of' and 'knowledge for' or Vision I and Vision II, respectively. As described by Roberts (2007),

> Vision I gives meaning to SL [science literacy] by looking inward at the canon of orthodox natural science, that is, the products and processes of science itself. At the extreme, this approach envisions literacy (or, perhaps, thorough *knowledgeability*) within science. (p. 2)

There is wide agreement that most of the documents and assessments of the US standards movement of the last 20 years focus on Vision I (Bybee, Fensham, & Laurie, 2009; Bybee, McCrae, & Laurie, 2009; Osborne, 2007). Conversely, 'knowledge for' is described by Roberts (2007) as

> Vision II derives its meaning from the character of situations with a scientific component, situations that students are likely to encounter as citizens … in which considerations other than science have an important place at the table … 'science for specific social purposes'. (pp. 2–3)

Sadler and Zeidler (2009) describe Vision II as progressive science education concerned with citizens' understanding of science, humanistic science education, and context-based science teaching (e.g. science–technology–society (S–T–S) and socioscientific issues instruction). While discussing whether Vision I and Vision II is 'most appropriate' is beyond the scope of our current research (see Roberts, 2007), considering how science teaching orientations shape and are shaped by PCK, understanding whether teachers place a premium on 'knowledge of' or 'knowledge for' or on a combination of the two, helped unpack one facet of their filters for pedagogical and curriculum decisions.

Beliefs about the nature of science. Lederman (1998) describes the nature of science as 'the epistemological underpinnings of the activities of science' and along with others (e.g. McComas, 2004) has, over time, identified specific important aspects that belong within the realm of the nature of science (e.g. the tentativeness of scientific knowledge and science as necessarily theory-laden). When considering this dimension of science teachers' beliefs, we have focused on considerations of epistemology (i.e. the nature of knowledge and ways of knowing) and ontology (i.e. perceptions about reality) as a helpful vantage point (Campbell et al., 2013). We considered the range of beliefs teachers might hold about science as extending from naïve realism, where science knowledge is seen as an 'objective' absolute truth mirroring reality and is directly accessible to human senses, to a more sophisticated belief about science as a tentative and evolving truth constructed as human explanations of natural phenomena (Kang & Wallace, 2005). In this more sophisticated belief of science knowledge, human explanations are understood as constructions that rely on multiple theories, coordinated with data derived from variable approaches to scientific inquiry.

Beliefs about science teaching and learning. Friedrichsen et al. (2011) describe the final dimension of teacher orientation as the ways in which teachers conceptualize science teaching and learning. This considers the roles of teachers and learners, as well as how they believe students learn science. And, it includes ways in which teachers can interest students in science and make it understandable. Luft and Roehrig (2007) used an open-ended survey to identify categories of beliefs about science teaching and learning when examining teachers' beliefs about science teaching and learning. The following are Luft and Roehrig's (2007) categories adopted for this research, but an additional category, supportive, is also included that we created and added based on a perceived need to help better characterize beliefs we recognized within this research:

- Traditional: Focus on information, transmission, structure, or sources.
- Instructive: Focus on providing experiences, teacher focus, or teacher decision.
- Transitional: Focus of teacher/student relationships, subjective decisions, or affective response.
- (Supportive: Focus on teaching ways to communicate, summative feedback from teacher or self, creating opportunities for knowledge development.)
- Responsive: Focus on collaboration, feedback, or knowledge development.
- Reform-based: Focus on mediating student knowledge or interactions.

The traditional and instructive categories of beliefs were connected with a view of science as rules or facts, the transitional category with the view of science as being consistent, connected, and objective, and the (supportive), responsive and reform-based categories with a view of science as a dynamic structure in a social and cultural context (Luft & Roehrig, 2007).

Technology and science teacher orientations. To organize our identification of technology beliefs, like in our previous research (Campbell et al., 2013), we adopted Kim, Hannafin, and Bryan's (2007) framework for technology-enhanced tools for student learning in science because we considered it to be compatible with a standards view of science literacy (AAAS, 1989; NRC, 1996, 2011). This is a three-dimension framework articulated as: tools supportive of mindful investigation of driving questions, tools serving as metacognitive scaffolds for building and revising scientific understanding, and tools supportive of collaborative construction of scientific knowledge. It should be noted that Kim et al. (2007) originally proposed this framework for inquiry learning tools, but we adapted these designations for identifying tools that play a significant role in science literacy. The dimensions are described in detail with our adaptations in Table 1.

More details about how the technology-enhanced tools framework was used in examining teacher beliefs are shared in the methodology, but first our conceptualization of science literacy that guided the development of the PD serving as a context for curriculum innovation, for this research, and for shaping the teacher orientation profiles is shared in Table 2. Note: This science literacy conceptualization was developed by Campbell et al. (2013) and as such is shared more concisely here.

Literature Review

Teachers' Beliefs and Science Teacher Orientations

For several decades, researchers have recognized the important role teachers' beliefs play in shaping instruction. While other factors, such as the social environment, resources, and formal training, play a role in shaping instruction, beliefs have been recognized as the primary factor influencing teacher behavior (Gill & Hoffman, 2009; Pajares, 1992; Speer, 2005; Talbot & Campbell, in press; Thompson, 1992).

Table 1. Categories of technology-enhanced tools for student learning in science

Categories	Description
Tools supportive of mindful investigation of driving questions	These tools are supportive of students' identification, exploration, location of resources, and development of problem solutions as a centrally important focus in science learning targeting science literacy (e.g. Linn, Davis, & Bell, 2004)
Tools serving as metacognitive scaffolds for building and revising scientific understanding	These tools help students better understand the strategies of thinking and learning processes that are inherently part of science literacy, specifically the epistemology of science (e.g. understanding how theoretical foundations are coordinated with evidences in the development of arguments) (e.g. Quintana et al., 2004)
Tools supportive of collaborative construction of scientific knowledge	The potential of these tools resides in the dialectic affordance of social interaction. They allow students to interact with students who are inherently more or less knowledgeable in supporting the co-construction of knowledge (e.g. Hmelo-Silver, 2003)

Note: As previously described in Campbell et al. (2013).

Table 2. Science literacy conceptualization (Campbell et al., 2013)

Categories	Description
Epistemology	Epistemology is a metacognitive understanding of the theory and practices surrounding science knowledge that specifically focuses on how these facets of science are coordinated in the construction of knowledge
Theoretical foundations	Theoretical foundations refer to the canonical knowledge of science that is traditionally and currently seen as a central target of the enterprise of science. Foundations are the well-established theories and concepts in science that are generalizable and supportive of explaining a wide range of natural phenomenon in and across disciplines (e.g. plate tectonics, evolutionary biology, and atomic molecular theory)
Practices	Practices refer to the general term describing 'a set of sensible actions that are both performed by members of a community and that evolve over time' (Berland, 2011, p. 627). In science education, practices have occasionally been described in more narrow terms such as exclusive skills, science processes, or scientific inquiry. Here, practices are described more broadly and in alignment with the newest NRC (2011) standards framework. Berland (2011) describes practices as the habits of mind and processes undertaken by communities of scientists as they work to develop explanations and arguments for explaining natural phenomena and/or leverage science for making informed decisions as citizens

More specifically, beliefs play a central role in shaping teachers' thinking, motivation, and intentions (Clark & Peterson, 1986; Czerniak & Lumpe, 1995) and, along with teacher knowledge, beliefs guide actions and decision-making (Kagan, 1992).

More specific to science teaching and learning, researchers over the past several decades have investigated teachers' beliefs about students, learning, teaching, and the nature of science to determine how these beliefs shape instruction or support/inhibit science education reform efforts (Brickhouse, 1990; Cronin-Jones, 1991; Gallager, 1991; Pilitsis & Duncan, 2012; Wallace & Kang, 2004). Additionally, researchers, especially those interested in science teacher PD, have sought to understand the role of interventions as mechanisms for affecting beliefs. But, as Tatto and Coupland (2003) point out, in general, little progress has been made in this area.

More recent studies, like Pilitsis and Duncan (2012), have investigated how pre-service science teachers' beliefs change overtime as a result of a science teaching methods course intervention and in response to specific activities within the course. This specific study found clusters of responses that demonstrated the mutability of pre-service teachers' beliefs in response to course experiences (Pilitsis & Duncan, 2012). Additional research has investigated university factors that shaped pre-service elementary teachers' science teaching orientations (Avraamidou, 2013). This research demonstrated how certain experiences in university coursework (e.g. inquiry-based investigations, contemporary theoretical discussions, and outdoors field study) were critical in shaping reformed focused science teacher orientations (Avraamidou, 2013).

With respect to investigations of in-service teachers' science teacher orientations, less research is found in the literature, especially research investigating the role of interventions in shaping science teacher orientations. But, research like that of Da-Silva, Mellado, Ruiz, and Porlan (2007) and Campbell et al. (2013) has offered some insight into how certain features of science teacher orientations support one another. As an example, Da-Silva et al. (2007) observed how secondary science teacher's' conceptions of science teaching and learning characterized as a content-centered model were rooted in coherent naïve beliefs about the nature of science. In sum, the literature on beliefs and science teacher orientations points to the importance of understanding how beliefs shape instruction and how interventions shape beliefs, especially as more reformed oriented practices are sought. But as noted, much room exists for additional investigations into in-service science teacher orientations, especially with respect to how these are shaped by PD targeting reformed instruction.

Teachers' Technology Use

While there is evidence to suggest that technology is playing an increased role in teachers' in- and out-of-school experiences (Wang, Hsu, Campbell, Coster, & Longhurst, under review), Bell, Maeng, and Binns (2013) report that, more generally, teachers use technology for administrative purposes or to support traditional instruction. Several researchers have attributed teachers' inability to move beyond using technology for administrative purposes or supporting traditional instruction to teachers' lack of confidence with technology (Lussier, Gomez, Hurst, & Hendrick, 2007; Mumtaz, 2000; Zhao & Cziko, 2001) or lack of support in the form of PD (Baylor & Ritchie, 2002; Ping Lim & Sing Chai, 2008). Instances can be found where technology-enhanced tools like scientific visualizations show promise in supporting teachers' adoption of reformed instruction practices (Varma, Husic, & Linn, 2008). And, research exists to document the positive teacher and student outcomes that emerge when teachers are supported with ongoing PD focused on new technologies aligned with reformed instruction (Bell et al., 2013; Lussier et al., 2007; Quintana et al., 2004). But, Tamin, Bernard, Borokhovski, Abrami, and Schmid (2011) found that the effectiveness of the technology interventions depended on the teacher's goals and pedagogy, among other things. As Lawless and Pellegrino (2007) conducted a review of the literature focused on supporting teachers' integration of technology in their instruction, they described how their review provided only limited insight into the types of pedagogical changes teachers made when integrating technology into instruction or the impacts technology-focused PD had on teacher development.

So, just as a research base does exist for beginning to understand teachers' beliefs as they relate to science teacher orientations, a literature base exists to document the importance of technology/reformed instruction-focused PD. And while there exists space for contributing to the beliefs/science teacher orientation literature regarding how interventions shape belief orientations, space also exists in the literature focused on teachers' technology use for better understanding how technology/reformed instruction-focused PD interventions shape teachers' development. As such, this current research is focused on contributing to the literature base in both of these areas.

Methods

Participants

Data for this study came from a group of 8 eighth grade science teachers. These eight teachers took part in our previous research investigating science teacher orientations and technology-enhanced tools for student learning at the beginning of PD (Campbell et al., 2013). Since the last study, these teachers participated in a year of PD, which is described in detail in a subsequent section. All participants had an undergraduate science major, although they had a range of classroom teaching experience from 1 to 20 years.

The sample population of participants taught eighth grade science in a school district in a metropolitan area of the western USA that has 67,000 students in 86 schools. The eighth grade student population of approximately 5,000 is served by 18 junior high schools. Similar to most western states, the state where the study was completed had a majority of white population, with a Hispanic population with the highest minority prevalence (US Census Bureau, 2000). Previously (Campbell et al., 2013), we acknowledged, based on the teacher, student, and school demographics, that there are similarities and differences in these and other demographics when comparing the eight participant teachers in this study and other eighth grade teachers both in the state and nationally. But, the research team believed that identified teacher orientations, the interactions identified between coalescing dimension of teacher orientations, and how technology 'sits' within orientations could offer important insights in general, and in connection with curriculum innovation described next more specifically.

Context

This research took place over a one-year period with data collection at the beginning and end of a year of a two-year PD project for the participants. The two-year PD is part of a larger five-year National Science Foundation-funded research project (Award Number 1020086), whereby three cohorts of participants experience a two-year PD cycle over the life of the project (2010–2015). More details about the PD is described here, so that what we considered something comparable with 'curriculum innovation' (Friedrichsen et al., 2011), in our case PD with embedded curriculum supports, is clearly articulated, especially since we are investigating the potential it has for causing (un)predicted changes in science teacher orientations.

We have chosen a description of the PD framed by our orientations to science teacher PD, because like Park Rogers et al. (2010) who believe science teacher PD orientations have 'implications for those designing and implementing PD for science teachers' (p. 309), we believe our orientation also has implications for the impact of the PD in terms of influencing science teaching orientations and subsequently classroom instruction. The goal of our project is to enhance teacher and student learning by tapping the enormous potential of technologies as cognitive tools for engaging students in scientific inquiry (Campbell, Wang, Hsu, Duffy, & Wolf, 2010). To accomplish this goal, we use educative curriculum (Davis & Krajcik, 2005) as the base of the PD experience for participants, so that each year teachers are supported with curriculum and PD. In total, four (seven- to nine-day) curriculum modules were developed with a commitment to our science literacy framework. During the initial summer workshop, teachers were introduced to the first module. This introduction to the curriculum came in a learner/teacher sequence, so that participants first experienced the curriculum from a 'learner hat' perspective, before they were asked to consider the curriculum from a 'teacher hat' perspective. In experiencing the curriculum as a learner, the participants engaged in the entire nine days of the module(s); modules that were developed in alignment with Slater, Slater, and Shaner's (2008) backward faded scaffolding inquiry, so that participants and subsequently students experience three experiments with increasing levels of independence. During the 'learner hat' experiences, the project leadership team instructed the participants by modeling reformed teaching practices such as encouraging students to make predictions, estimations and hypotheses and devising means for testing them (Piburn et al., 2000). During the 'teacher hat' experiences of the PD, participants spent time analyzing student work to identify different levels of sophistication in student thinking and creating an instructional guide that included logistical, as well as intentional teaching moves they believed were important as they considered each instructional day of the module. Additionally, as part of the 'teacher hat' experience, participants co-planned lessons that targeted compatible new literacies (e.g. identifying questions, locating information, evaluating information, synthesizing information to answer questions, and communicating answers to others; Leu, Kinzer, Coiro, & Cammack, 2004, p. 1572) and science literacy outcomes emphasized in the project. This same PD model was enacted in an abbreviated fashion during a three-day winter workshop as module 2 was introduced. And, this sequence and PD model were again enacted during the summer of 2011 for module 3, followed by a three-day winter workshop that took place in November 2012 for Module 4, after the data included and reported in this research were collected. Table 3 highlights the content of each of the modules and offers additional information about the curriculum focus for each.

In describing the science teacher PD orientation, Park Rogers et al. (2010) identified five different orientations. Of these, an amalgam of the following three might best describe the PD model we believe provides the context for this research, while none are accurate and fully descriptive in and of themselves:

Table 3. PD curriculum module foci

Modules	Curriculum/State standards focus (Utah State Office of Education Core Curriculum)	Nature of module
1	*Objectives*: Analyze human influence on the capacity of an environment to sustain living things	Students use Google Sites to sample plant and insect species at or near their school (Campbell, Longhurst, Duffy, Wolf, & Nagy, 2012)
	Objective: Investigate the application of forces that act on objects and the resulting motion	Beginning with ramps, students investigate the variables that influence the amount of force required to move an object
3	*Objective*: Generalize the dependent relationships between organisms and their environment	Using a web browser-based simulation, students investigate the dependent relations between organisms and abiotic factors in their environment (Duffy, Wolf, Barrow, Longhurst, & Campbell, 2013)
4	*Objectives*: Describe the chemical and physical properties of various substances. Observe and evaluate evidence of chemical and physical change. Investigate and measure the effects of increasing or decreasing the amount of energy in a physical or chemical change, and relate the kind of energy added to the motion of the particles. Identify the observable features of chemical reactions	Using an online game, student attention is focused on the nature of changes in matter. This is followed by students investigating the changes in temperature as a substance goes through phase changes before students finally investigate variables that impact reaction rates of chemical reactions.

Note: Each module used a three-iteration-adapted Scaffolding Inquiry Approach (Slater et al., 2008).

- Science content-driven. Professional developers try to help teachers learn new science content and laboratory techniques to enhance teachers' understanding of selected concepts.
- Pedagogy-driven. Professional developers encourage a particular inquiry-based instructional model and/or strategies (e.g. whiteboarding, science notebooks, questioning strategies, and cooperative learning groups) that will help teachers to help students learn.
- Curriculum material-driven. Professional developers guide participating teachers through lessons and units from nationally or locally developed and tested curriculum materials to help teachers learn to use those materials in their classes (Park Rogers et al., 2010, p. 316).

In our project, science content was targeted as modules that were developed by the leadership team. To target science content within these modules, participants took on the role of student learners to complete authentic scaffolding investigations with the support of science researcher project team leaders. This was seen as a mechanism for helping teachers learn new content, so the science content-driven orientation is descriptive in this limited regard. There was a focus on pedagogy, but this was embedded in the curriculum materials in a way that helped encourage a particular inquiry-based instructional model, while also helping teachers use the curriculum materials. In our orientation and project, we are testing whether providing and expecting some level of fidelity with limited and strategically placed curriculum throughout the eighth grade will lead to improved science teaching and learning beyond these selected curriculums. So, as alluded to already, the curriculum material-driven orientation also falls short in describing this particular context. Therefore, perhaps a hybridized science content–pedagogy–curriculum material-driven orientation describes the PD model approach, but this still may come up short as the primary goal of the project is to improve teaching and learning beyond the four curriculum modules provided as supports throughout the PD.

Data Collection

The data collection took place at the beginning and end of the first year of PD during the two-week summer workshops in 2011 and 2012. The primary data sources for this study were drawn from learning journals. Learning journals were completed throughout the two eighty-hour/two-week summer PD sessions, where it took participants between 10 and 15 minutes to complete each entry. During the two-week PD sessions, each participant completed a learning journal throughout the workshops that were intended to prompt reflection and synthesis of what they were learning. Additionally, these journal prompts were crafted with this research in mind to elicit participant responses capable of offering insight into their beliefs related to science teaching and learning including technology. Prompts were used throughout each workshop day, with more coming at the end of the day, generally. In total, 12 journal entries were completed and collected electronically at the beginning of the PD (Summer, 2011) and 13 journal entries were completed and collected electronically at the conclusion (Summer, 2012). Example prompts were 'What is the instructional purpose for using technology as a part of your instruction? Provide examples of how you use technology for different purposes during your classroom instruction', 'Please consider where you were the first day of last year's summer workshop in comparison to where you are now. How have your ideas about teaching science as inquiry/reformed teaching and integrating technology into science instruction changed?', and 'What do you feel is important for students to know and understand about 'science' as they engage in this module?'

Data Analysis

Our analysis was completed in four stages and was derived from Groenewald's (2004) phase strategy for explicating data. In the first stage of our analysis, we used the following questions to identify 'units of meaning' that could be used in constructing teacher orientation profiles at the beginning and conclusions of a year of PD:

(1) What are the dimensions of teacher orientation that can be identified (i.e. beliefs about: the goals and purposes of science teaching, the nature of science, and science teaching and learning)?
(2) What are the beliefs about technology-enhanced tools that can be identified (i.e. beliefs about: tools supportive of mindful investigation of driving questions, tools serving as metacognitive scaffolds for building and revising scientific understanding, and tools supportive of collaborative construction of scientific knowledge)?

'Units of meaning' were statements identified in the participants' learning journals that were thought to reveal teachers' beliefs about orientation or technology-enhanced tools' dimensions. At this stage the analysis was across all participants, with 'units of meaning' as the focus.

The second stage of our analysis involved clustering 'units of meaning' and was completed at the participant level, so that the science teacher orientation component of the profiles was created for each participant. In this stage, 'units of meaning' were reviewed to elicit their essence within the context of the phenomenon (Groenewald, 2004), so that grouping the 'units of meaning' could form themes. As an example, when building the profile of *Participant X*, all units of meaning thought to reveal the participant's beliefs about the nature of science, as just one dimension, were clustered so that a theme was developed that could be used as the nature of science component of the participants' science teacher orientation. Themes were developed for each dimension of orientations to complete the profiles for each participant. It should be noted here that for the most part, when considering the dimension, beliefs about science teaching and learning, participants in our previous research (Campbell et al., 2013) and this research did not fit cleanly into one of the categories; instead teachers generally exhibited articulations that fit into two neighboring categories. Examples of this occurred as a teacher exhibiting beliefs about science teaching and learning characterized as Supportive also exhibited some beliefs aligned with the transitional characterization. As this happened, the characterization that was found most often was used. Further, while 'units of meaning' for each of the technology-enhanced tools were also themed, because we elected to transparently locate the emergent themes into the beliefs about science teaching and learning science teacher orientation dimension, at this stage these were located within these orientation dimensions. We included technology-enhanced tools into the beliefs about science teaching and learning dimensions because of how Friedrichsen et al. (2011) describe this final dimension of teacher orientation as '[c]onceptions of science teaching and learning, including . . . how to teach it in ways that make science attractive and comprehensible' (p. 370).

In the third stage of analysis, all science teacher orientation profiles created for each participant were re-examined so that categories of profiles could be created. Considering what patterns of interactions between the dimensions of orientations allowed for categorizing similar participant profiles within the same group, such that the final categories of profiles were judged to reveal salient patterns of how interactions between the dimensions of science teacher orientations converged. Through this process, and by considering the convergence of teacher orientations in the context of our science literacy framework (Table 2), the three profiles were named and judged sufficient to describe the trends present within the data. Tables 4–6 in the findings section, shared next, offer examples of how the three stages of analysis came together to inform the three profiles created. Within these tables, stage 1 can be seen as an example of 'units of meaning' shared. Stage 2 of the analysis can be seen as the themes for the 'units of meaning' created in this stage which are included in [brackets] within each profile, and stage 3 can be seen as each profile shown as representative of multiple participants at different stages of the research (e.g. the Information Transmission (IT) profile was characterized by 7/8 participants at the beginning of the PD). In each of the first three stages two raters were involved in all phases of analysis to ensure that multiple perspectives were available to challenge emergent findings. This occurred as the researchers met weekly to discuss the results of the qualitative coding of the 'units of meaning'. After all units of meaning were identified, the researchers met to develop themes for each orientation dimension, individual

Table 4. Information transmission teacher orientation profile exemplars

Teacher orientation dimension	Exemplar participant 'unit of meaning'
Beliefs about the goals and purposes of science teaching	I feel once we have given students some of the specific background (i.e. vocabulary terms), then students will be able to foster the true meaning behind this information given ['Knowledge of'/ Vision I focused on the canon of orthodox natural science, that is, the products and processes of science itself]
Beliefs about the nature of science	I don't like to publicly share my research questions because I feel like I have to get the 'right' answer so I was pretty scared [Naïve or unrevealed beliefs focused on the 'right answer']
Beliefs about science teaching and learning (including an example of each of the technology-enhanced tools for student learning in science dimensions)	Currently I teach a unit with demonstrations, mini labs etc. throughout the unit. I then end the unit with a cumulative 'cookie cutter' lab in which the students are supposed to experience and relate back to what we just learned. I have done this for 5 years [Traditional: Focus on information, transmission, structure, or sources] *Beliefs about technology-enhanced tools supportive of mindful investigation of driving questions* [none identified] *Beliefs about technology-enhanced tools serving as metacognitive scaffolds for building and revising scientific understanding* [none identified] *Beliefs about technology-enhanced tools supportive of collaborative construction of scientific knowledge* [none identified]

Table 5. SSBR teacher orientation profile exemplars

Teacher orientation dimension	Exemplar participant 'unit of meaning'
Beliefs about the goals and purposes of science teaching	I want my students to be able to do is be able to fill out the experimental outline for a inquiry-based project with their own ideas, hypothesis, procedures, and conclusion. It is important for students to be able to produce a product of a experimental work on their own and have ownership of their data and ideas. ['Knowledge of'/Vision I focused on the canon of orthodox natural science, that is, the products and processes of science itself]
Beliefs about the nature of science	Experiments are meant to be built on and communicated with peers. Research is used to validate or invalidate what was done in class to what is also done already. [More sophisticated beliefs about the nature of science connected to the evolving and tentative nature of science and the empirical nature of science]
Beliefs about science teaching and learning (including an example of each of the technology-enhanced tools for student learning in science dimensions)	They should be able to collaborate together effectively . . . they should be able to use Google Docs to express what they have learned [Supportive: Focus on teaching ways to communicate, summative feedback from teacher or self, creating opportunities for knowledge development] *Beliefs about technology-enhanced tools supportive of mindful investigation of driving questions*—They [students] can use the technology that they are familiar with to research and find information that is relevant to their project and perhaps to themselves *Beliefs about technology-enhanced tools serving as metacognitive scaffolds for building and revising scientific understanding*—ICTs are used to help facilitate and organize their experimental design [this was done through template prompts offered to students building websites] *Beliefs about technology-enhanced tools supportive of collaborative construction of scientific knowledge*—Google docs is probably the most useful way of creating documents that can be easily shared and collaborated anywhere. I have had students collaborate on a writing project or lab report from home

Table 6. SBR teacher orientation profile exemplars

Teacher orientation dimension	Exemplar participant 'unit of meaning'
Beliefs about the goals and purposes of science teaching	[E]veryone should have a sound understanding of science so they can make informed personal and policy decisions. ['Knowledge for'/Vision II focused science for specific social purposes]. I expect students to learn science thinking methods, how to communicate with logic and science reasoning ['Knowledge of'/Vision I focused on the canon of orthodox natural science, that is, the products and processes of science itself]
Beliefs about the nature of science	I want them [students] to understand that science is a way of thinking and problem solving. It's a method that they can use ... to help them solve problems ... to be able to scrutinize information and use logic to come to conclusions. [More sophisticated beliefs about the nature of science connected to the evolving and tentative nature of science and the empirical nature of science]
Beliefs about science teaching and learning (including an example of each of the technology-enhanced tools for student learning in science dimensions)	I will help them refine by asking questions that challenge their work and make them go back and improve the pieces that need it. My goal is to not to solve the problems but critique them in a way that they can go back and fix it themselves. For example, for the question that isn't detailed enough I would ask, 'What plants? What do you mean by 'colonization'? Is there a way you could make it more specific?' [Reform-based: Focus on mediating student knowledge or interactions] *Beliefs about technology-enhanced tools supportive of mindful investigation of driving questions*—I feel like technology is used best when students can use it to virtually collect data and then present it with ICTs *Beliefs about technology-enhanced tools serving as metacognitive scaffolds for building and revising scientific understanding*—The real power of using ICT comes in the organization and creativity that it allows students to have when expressing what they have learned *Beliefs about technology-enhanced tools supportive of collaborative construction of scientific knowledge*—[Using ICTs], they can collaborate easier and share their work nearly without boundaries

participant teacher orientation profiles, and categories of orientations. If disagreements arose at any of these stages, the researchers revisited the original 'unit of meaning' identified in the data source to discuss and seek consensus of interpretation before finalizing the 'unit of meaning'. Additionally, the entire learning journal for each participant was revisited after individual profiles were created to recheck the profiles before they were aggregated into the categories of profiles. This was done first at the beginning of the PD, as well as at the conclusions of the PD, to examine how the teacher orientations changed over time, especially with respect to how facets of teacher orientations (e.g. goals of teaching science and beliefs about technology-enhanced tools) converged to shape the emergent orientations.

Findings

In response to the research question, the findings reveal the teacher profiles that represent the convergence of teacher orientation dimensions and beliefs about technology-enhanced tools for learning science over time. Within each profile, the dimensions of teacher orientations that were identified both at the beginning and conclusion of one year of PD are shared as applicable (e.g. no dimension of teacher orientations identified at the conclusion of PD was shared within the IT profile, since it was not seen as descriptive of participants at the conclusion of PD). And, a close examination of the (mis)alignment of the dimensions within each profile is presented to offer insight into the similarities and differences across profiles as they changed over time. Additionally within each profile, beliefs about technology-enhanced tools for student learning dimensions, at the beginning and conclusion of PD, are identified, again as applicable. As revealed earlier, all of this was done for the primary purpose of understanding how science teacher orientations shift over time as a result of a year of PD.

IT Teacher Orientation Profile (Profile 1)

This profile aligns with the 'More Traditional Teacher Orientation Profile' that was developed previously (Campbell et al., 2013) and characterized all but one of the participants (7/8 participants) at the beginning of PD. It has been renamed here to help mitigate any confusion that may have been caused by similar names for beliefs about science teaching and learning and profiles used previously. In this orientation (Table 4), only beliefs consistent with 'knowledge of' or Vision I (Roberts, 2007) goals and purposes for science teaching were found for all participants at the beginning of the PD. The following are examples of 'units of meanings' for 'knowledge of'/Vision I beliefs informing this profile:

- I feel once we have given students some of the specific background, i.e. vocabulary terms, then students will be able to foster the true meaning behind this information given.
- There is a lot of material to get through and this particular method [teaching science as inquiry] takes a long time.

Additionally, when considering 'knowledge of'/Vision I beliefs of participants in this profile found exclusively at the beginning of PD, all participants espoused beliefs about the goals or purposes of science teaching, but with more emphasis placed on 'the canon of orthodox natural science, that is, the products', while little to no emphasis was placed on the 'processes of science itself' (Roberts, 2007, p. 2), even though both are considered within this conception of goals or purposes of science. In addition to the quotes already offered exemplifying this theme, another example of this can be seen in the following participant quote informing Profile 1:

> I like to do a lot of reading with my students, have them do questions in the book or on a worksheet, go through a vocab challenge and then do activities or a lab to pull things together, do a review and then test.

When considering participants' beliefs about the nature of science within this profile, participants exhibited naïve or 'unrevealed' beliefs about the nature of science. Specifically within this dimension, naïve beliefs about the nature of science focused on getting the 'right answers'. This less sophisticated conception of the nature of science was identified exclusively at the beginning of the PD for 2/7 participants within this profile and was thought to reveal a view of the nature of science associated with natural realism. Examples of learning journal statements leading to the establishment of this theme are as follows:

Right Answer

- Yesterday, as a teacher, I was feeling anxious again (geez, that happens a lot!) because I'm so concerned about doing everything right.
- I don't like to publicly share my research questions because I feel like I have to get the 'right' answer so I was pretty scared.

With respect to 'unrevealed' beliefs about the nature of science, this theme was assigned to participants in cases where statements from learning journals could not be found to characterize the participants' beliefs about the nature of science, which was the case for 5/7 participants in this profile at the beginning of PD.

Lastly, within the teacher orientation dimensions, participants' beliefs about science teaching and learning that informed this profile were Luft and Roehrig's (2007) traditional, instructional, and transitional categories. The following are examples of participant articulations representative of 'units of meaning' within each theme, along with the number of participants articulating ideas that were characterized using the theme at the beginning of PD:

Traditional (4/7 participants within this profile at the beginning of PD)

> I like to do a lot of reading with my students, have them do questions in the book or on a worksheet, go through a vocab challenge and then do activities or a lab to pull things together, do a review and then test.

Instructive (2/7 participants within this profile at the beginning of PD)

> I guess I am just used to step-by-step things and I need to get away from that. But at the same time I don't want to keep giving my students step-by-step things and I want them to be comfortable with what I am trying to do, too.

Transitional (1/7 participants within this profile at the beginning of PD)

> I think some students will really take into it [technology-enhanced tools used in teaching science] while others will hate it at the beginning and then come around to it later.

Unsurprisingly, because technology-enhanced tools for science learning were originally conceptualized as tools for student-centered/inquiry learning environments (Kim et al., 2007) and the IT profile described here is predominately descriptive of a teacher-centered learning environment, no beliefs about technology-enhanced tools for science learning were found for this profile. See Table 4 as it reveals the amalgamation of how each of these dimensions coalesced to create this profile.

Struggling with Standards-Based Reform Teacher Orientation Profile (Profile 2)

This profile characterized the orientation of 1/8 of the participants at the beginning of PD and 7/8 of the participants at the conclusion of a year of PD (Table 5). It should be noted that the participant characterized with this profile at the beginning of PD was the only participant not characterized by this profile at the conclusion of the PD. In this orientation, all participants held beliefs consistent with 'knowledge of'/Vision I goals and purposes for science teaching, with the exception of one participant at the end of the PD, who was found hinting to 'knowledge for'/Vision II goals and purposes. The following is an example of 'units of meaning' for the dominant 'knowledge of'/Vision I goals and purposes found:

> The final product I want my students to be able to do is be able to fill out the experimental outline for a inquiry-based project with their own ideas, hypothesis, procedures, and conclusion. It is important for students to be able to produce a product of a experimental work on their own and have ownership of their data and ideas.

In this profile, unlike in Profile 1, the participants were found articulating more holistic 'knowledge of'/Vision I goals or purposes that demonstrated a commitment to both products (canonical knowledge) and processes of science. This is exemplified in the previous exemplar unit of meaning and in the following participant quote informing Profile 2:

> Students learn to tie new information to the data they collected and connect the two sets of information in a cohesive way that they can articulate in their journals.

With respect to the beliefs about the nature of science dimension of teacher orientations, participants informing this profile exhibited more sophisticated (5/7 participants within this profile at the conclusion of PD) or 'unrevealed' beliefs (1 participant at the beginning of PD and 2/7 participants within this profile at the conclusion of PD) about the nature of science. For those revealing more sophisticated beliefs, this was connected to understanding the empirical nature of science. The following is an example articulation of this more sophisticated belief about the nature of science theme:

> Students learn to tie new information to the data they collected and connect the two sets of information in a cohesive way that they can articulate . . .

Similar to what was found with respect to the beliefs about the nature of science, while occurring less frequently, the 'unrevealed' beliefs theme was assigned to participants in cases where statements from learning journals could not be found to characterize the participants' beliefs about the nature of science. This was the case for the one participant characterized by this profile at the beginning of PD and for 2/7 participants within this profile at the conclusion of PD.

The beliefs about science teaching and learning supporting this profile were transitional, supportive, and responsive. The following are examples of 'units of meanings' within each of these themes, along with the number of participants articulating ideas that were characterized using the theme at the beginning and conclusion of PD:

Transitional (0/1 participant within this profile before PD and 1/7 participants within this profile after PD)

> I have given up absolute control of what the kids are doing every minute ... I have found that when I do that they are more engaged because they are so into it but because I have given them a level of trust which they like. Junior high students really want to be treated like they are grown up.

Supportive (0/1 participant within this profile before PD and 2/7 participants within this profile after PD)

> I am learning the importance of students being able to communicate results and also being able to communicate about their learning.

Responsive (0/1 participant within this profile before PD and 4/7 participants within this profile after PD)

> Rather than confining their group project to school only or library only setting, they can access their projects wherever there is a computer to contribute without having to be in each other's presence.

Within the beliefs about science teaching and learning, the beliefs about technology-enhanced tools for student learning in science in all three dimensions were found with some participants expressing these in each dimension and others only expressing them in one or two dimensions. More specifically, for the one participant informing the construction of this profile at the beginning of PD, technology-enhanced supportive of collaborative construction of knowledge was found. For the 7 participants informing this profile at the conclusion of PD, 5/7 participants revealed beliefs about all three dimensions, while the other 2/7 participants within this profile revealed beliefs about two dimensions. The following are examples of teachers' journal entries coded for each dimension, along with the number of participants articulating beliefs that characterized with each theme after PD: Tools support of

Mindful investigation of driving questions (0/1 participant in this profile at the beginning of PD and 6/7 participants in this profile at the conclusion of PD)

> I feel like technology is used best when students can use it to virtually collect data and then present it with ICTs.

Metacognitive scaffolds for building and revising scientific understanding (0/1 participant in this profile at the beginning of PD and 7/7 participants in this profile at the conclusion of PD)

> Students can also see in real time how charts and graphs change as data is put into a data table.

Collaborative construction of scientific knowledge (1/1 participant in this profile at the beginning of PD and 6/7 participants in this profile at the conclusion of PD)

> It [technology-Google Docs specifically] is also a way for them to organize data that they collect in other class investigations and a way to communicate or collaborate with their work groups or with me [the teacher].

Finally, within the collaborative construction of knowledge dimension, when it was revealed, in most cases it was limited to collaborative communication of knowledge instead of construction. This profile is further illuminated in Table 5.

Standards-Based Reform Teacher Orientation Profile (Profile 3)

This profile aligns with the 'Reformed-Based Teacher Orientation Profile' that was developed previously, not as one that was found to characterize any of the participants at the beginning of PD (Campbell et al., 2013), but as one that was considered 'as a future target for how teacher orientations and technology-enhanced tools for student learning can coalesce to support science literacy' (p. 32). While this profile was not found characterizing any participants at the beginning of the PD, it was found capable of characterizing one participant at the conclusion of a year of PD. This is the same participant who was characterized by Struggling with Standards-Based Reform (SSBR) Teacher Orientation Profile at the beginning of the PD, the only one not characterized by the IT profile. In this orientation, the participant held beliefs consistent with 'knowledge of'/Vision I of Profile 2 with a more holistic commitment to both products (canonical knowledge) and processes of science. Additionally, this profile was also characterized with 'knowledge for'/Vision II goals and purposes for science teaching. The following is an example articulation of the 'knowledge for'/Vision II belief, while additional examples of Vision I and Vision II articulations are found in Table 6:

> I want them [students] to understand that science is a way of thinking and problem solving. It's a method that they can use not just in science class, but to help them solve problems.

With respect to beliefs about the nature of science, the participant exhibited more sophisticated beliefs about the nature of science dealing primarily with ideas of understanding science as a way of thinking and problem-solving and tentative as evidenced in beliefs espoused about working with students to refine their ideas through investigations. The following is one example articulation exemplifying this, while another is found in Table 6 as well:

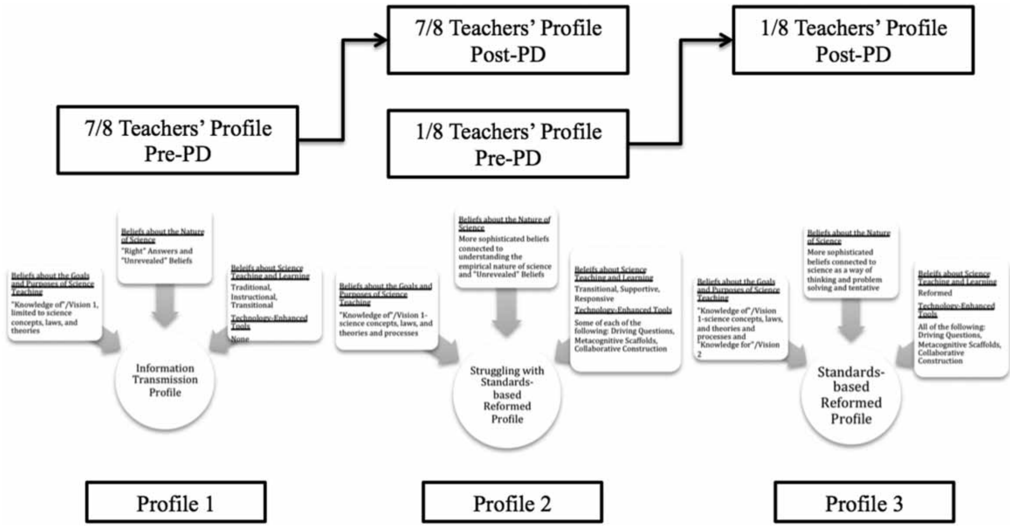

Figure 1. Pre- to post-PD teacher profile shifts. Note: The shifts for participants are accurately depicted in the figure such that the one teacher who started pre-PD at Profile 2 was the same teacher who found post-PD at Profile 3. Likewise, the seven teachers who started pro-PD at Profile 1 were the same teachers who found Post-PD at Profile 2

> [S]cience is a process. It is not just finding the word that goes in the blank. It is a process of trying to gain knowledge through research and experimentation.

And finally, within the teacher orientation dimension concerned with beliefs about science teaching and learning, the participant was characterized by the reformed category described by Luft and Roehrig (2007) as focusing on mediating student knowledge or interactions. This can be seen in the following as well as in Table 6:

> I . . . challenge their work and make them go back and improve the pieces that need it . . . to . . . critique them in a way that they can go back and fix it themselves.

Additionally, within the reformed category of beliefs about science teaching and learning, all beliefs about technology-enhanced tools for student learning in science were found. In addition to the 'units of meaning' already shared, Table 6 reveals 'units of meaning' exemplifying the themes developed for this profile as well as the composite amalgam for the profile.

Finally, Figure 1 offers a representation of the different science teacher orientation profiles identified and how these profiles and the dimensions within these profiles shifted over time.

Discussion

Below we discuss the teacher profiles that represent the convergence of teacher orientation dimensions and beliefs about technology-enhanced tools for learning science over time. Within each profile, the dimensions of teacher orientations that were identified both at the beginning and conclusion of one year of PD are discussed as applicable. And, within each profile, beliefs about technology-enhanced tools for student learning dimensions, at the beginning and conclusion of PD, are discussed, again as applicable.

IT Teacher Orientation Profile (Profile 1)

When comparing our conceptualizations of orientations with what others have proposed, Profile 1, exclusively characterizing 7/8 participants at the beginning of PD and no participants at the conclusion of PD, was aligned with Friedrichsen's (2002) 'teacher-centered' grouping. As revealed in the findings section, this profile was built around 'knowledge of'/Vision I goals and purposes of science teaching with more emphasis placed on concepts or with little to no emphasis placed on the practices of science. At the conclusion of PD, especially in Profiles 2 and 3, the participants were found articulating more holistic 'knowledge of'/Vision I goals or purposes that demonstrated a commitment to both products (canonical knowledge) and processes of science. We believe that the difference in the 'knowledge of'/ Vision I goals or purposes is also something that should be considered in relation to other dimensions of science teacher orientations and as such revisit this further as we discuss the coalescence of the different teacher orientation dimensions both within this profile and the others.

With respect to those 'units of meaning' we could identify, they were more connected to naïve beliefs about the nature of science grounded in 'right answers' in what seemed more aligned to Kang and Wallace's (2005) description of less sophisticated conceptions of the nature of science as 'objective' absolute truth. When considering the 'unrevealed' beliefs found in Profile 1, it could be that the learning journal prompts did not effectively elicit participants' beliefs about the nature of science, even though a wide range of prompts were used. But, as we examined participants' learning journals after a year of PD, the instances of 'unrevealed' beliefs declined noticeably from characterizing seven participants at the beginning of PD, to characterizing only two participants at the end of one year of PD, suggesting that our finding in this area at the beginning of PD may be more indicative of what Lederman (1999) revealed as he found that the level of reflection on the nature of science is 'not automatic' (p. 917). Further, Duschl (1990) and Lederman (1992) describe how when these beliefs are revealed, in many cases they are less satisfying than what is expected (Duschl, 1990; Lederman, 1992). In our previous research (Campbell et al., 2013), we considered two scenarios for understanding these 'unrevealed' beliefs: (1) validated in past research (Duschl, 1990; Lederman, 1992) suggesting that teachers' beliefs about the nature of science are misaligned with the science literacy framework (Table 2) (Duschl, 1990; Lederman, 1992) or (2) the 'unrevealed' theme leaves the possibility of a more sophisticated conception of the nature of science. But, even in the event of a participant harboring an 'unrevealed' sophisticated conception this could be conceived as problematic if these remain 'unrevealed' in the classrooms and are not intentionally targeted in science instruction (Ackerson, Abd-El-Khalick, & Lederman, 2000).

In this profile, when we considered participants' beliefs about science teaching and learning, these beliefs were characterized across the spectrum of traditional, instructive, and transitional categories (Luft & Roehrig, 2007). That is, the beliefs were judged as misaligned with the science literacy framework developed in this current research (Table 2), since they primarily focused on IT or providing experiences where teacher focus and decisions were more often seen guiding instruction (Luft & Roehrig, 2007).

Collectively, as we consider how these different dimensions of teacher orientations push or pull on one another, the teacher-centered focus of Profile 1 is most prominent. Something that made sense as it is shaped by naïve conceptions of the nature of science concerned with 'right answers' instead of more sophisticated concerns associated, among others things, with the tentativeness of scientific knowledge. Additionally, the naïve nature of science conceptualization was also found supported in Profile 1 by traditional, instructive, and transitional beliefs about science teaching and learning. And, these findings align with what Da-Silva et al. (2007) observed when they found secondary science teachers' conceptions of science teaching and learning characterized as a content-centered model, they also noted how this content-centered model was rooted in coherent naïve views of the nature of science. In this sense, Profile 1 seems best described as an amalgam of compatible beliefs. An example of this might come as 'a more naive epistemological and ontological belief of science might continue to isolate and prioritize the normative knowledge of a scientific discipline' (Campbell et al., 2013, p. 7) exclusively seen as 'knowledge of'/Vision I goals for science teaching. This is evidenced as one of our participants at the beginning of the PD, characterized by this profile, shared her typical instructional planning and teaching strategy:

> Traditionally I like to do a lot of reading with my students, have them do questions in the book or on a worksheet, go through a vocab challenge and then do activities or a lab to pull things together, do a review and then test.

In this example, the traditional belief about science teaching and learning focused on information and transmission seems to settle cohesively among the other beliefs (i.e. the nature of science and purposes of science teaching). Additionally, while 'knowledge of'/Vision I goals and purposes of science teaching were identified this was revealed at the beginning of PD when, as we noted earlier, this belief was centered on the products of science instead of both products and processes in concert. Given this, there also seems to be some cohesion between the traditionally focused belief about science teaching and learning where information and transmission are prioritized in concert with the products or canonical knowledge of science.

Finally, within this profile, no beliefs about technology-enhanced tools for student learning in science were found. This also made sense given that our dimensions of technology-enhanced tools for student learning in science were derived from Kim et al.'s (2007) originally proposed framework for inquiry learning tools, tools not typically prioritized in teacher-centered classrooms. Bell et al. (2013) report that teachers generally use technology for administrative purposes or to support traditional instruction. While it is difficult to speak to the extent to which the teachers at the beginning of PD, who helped shape the characterization of this profile, were using technology for administrative or traditional instruction, our findings did suggest, like Bell et al. (2013), that technology was not being used to support reformed instruction. And, these findings seemed to at least align with other research (e.g. Baylor & Ritchie, 2002; Ping Lim, & Sing Chai, 2008), in that no technology tools were identified that were being integrated in science instruction in reformed ways at the beginning of the PD, which was when these teachers had not received PD support that others have found is needed.

SSBR Teacher Orientation Profile (Profile 2)

When comparing our conceptualizations of Profile 2, and subsequently Profile 3 described next, with orientations Friedrichsen (2002) proposed, these are more aligned with the orientation category based on reform efforts and associated curriculum projects. Additionally, at the beginning of PD, all participants informed this profile was best characterized by Profile 1 (i.e. the IT teacher orientation profile) (7/8 participants). So, at the conclusion of a year of PD, participants informing this profile went from having naïve or 'unrevealed' nature of science beliefs to more sophisticated beliefs about this nature of science, with the exception of two participants who still had 'unrevealed' beliefs at the conclusion of the PD. This should be noted as there were some participants at the conclusion of the PD where nature of science articulations could not be found, the 'unrevealed' theme for beliefs about the nature of science remained in this profile, similar to what was found in Profile 1. In some ways this made sense given that this profile was considered one that depicted teachers SSBR.

Beliefs about science teaching and learning in Profile 2 moved from traditional, instructive, and transitional beliefs prior to PD to supportive and responsive categories after a year of PD. This meant that at the extremes, these participants' beliefs about science teaching and learning went from focusing on information and transmission to focusing on collaboration, feedback, and knowledge development. And, within the beliefs about science teaching and learning, technology-enhanced tool beliefs from each of the three dimensions were found, at least to some extent for all participants, indicating that beliefs about the value of reformed framed technologies were also developing alongside these more reformed efforts beliefs. The fact that these technology-enhanced tools were found more visible in this profile at a time when a more reformed aligned set of beliefs were also identified seems to suggest, like Varma et al. (2008), that these technology tools are playing some role in supporting a more reformed science teacher orientation, at least in comparison with the IT profile. But, with the exception of one participant found hinting at 'knowledge for'/Vision II beliefs about the goals and purposes of science teaching, the beliefs about goals and purposes of science teaching were primarily focused on 'knowledge of'/Vision I beliefs.

What separated Profile 2 from Profile 1, or the majority of participants' profiles at the end of a year of PD from the majority of profiles at the beginning of PD, as revealed earlier in the discussion of the beliefs about the goals and purposes of science teaching, was Profile 2's more holistic focus on 'the canon of orthodox natural science, that is, the products and processes' (Roberts, 2007, p. 2) in comparison with Profile 1's more dominant focus on the canons or normative knowledge of science. And, Profile 2 was different from Profile 1 with respect to their beliefs about the nature of science and the beliefs about science teaching and learning, which included beliefs about technology-enhanced tools for student learning in science. So, cohesion seemed to exist between the dimensions of Profile 2, with respect to the beliefs about the nature of science that were more sophisticated and tied to the empirical nature of science and a more holistic conception of 'knowledge of'/Vision I beliefs about the goals and purposes of science teaching. This also seemed supportive or supported by technology-enhanced tool beliefs.

Standards-Based Reform Teacher Orientation Profiles (Profile 3)

This profile was not informed by themes emerging from participants at the beginning of PD, since no participant themes were available to help characterize/build this profile. But, after a year of PD, we identified one participant who aligned with our early conceptions of how the three dimensions of science teacher orientations might come together. This helped us flesh out the nuances of what previously was only an idealized profile (Campbell et al., 2013). At the beginning of PD, this participant suggested his own struggles with teaching science as inquiry as a central focus of Standards-Based Reform (SBR):

> My biggest gains came from learning how to teach using inquiry. I didn't really do inquiry before . . . and now I do it often. I had always been taught that inquiry was the thing I should be striving for, but I had never seen it in action or had anyone explain to me how to implement it.

And, this participant also previously shared how he struggled with integrating technology into his instruction:

> I . . . use technology, but have never done so in such an integrated way. For a long time I have been trying to imagine my ideal classroom but have been struggling how to put all of the pieces together in an effective way. (Campbell et al., 2013, p. 12)

But, at the conclusion of a year of PD, he espoused more sophisticated beliefs about the nature of science dealing primarily with ideas of understanding science as a way of thinking and problem-solving, as well as tentative as evidenced in his beliefs about working with students to refine their ideas through investigations. The participant, and subsequently the profile, was also characterized as having reformed beliefs about science teaching and learning that were focused on mediating student knowledge or interactions. Within these beliefs about science teaching and learning, beliefs about all three dimensions of technology-enhanced tools were found, whereas in the past only the collaborative purposes of technology-enhanced tools for learning science were found at the beginning of PD, when this participant informed the development of Profile 2. Additionally, as with Profile 2 at the conclusion of a year of PD, even the 'knowledge of'/Vision I beliefs were characterized as prioritizing products and processes of science instead of just focusing on products or normative knowledge in isolation, which was characteristic of Profile 1.

What separated Profile 3 from Profile 2, both of which were mainly found at the conclusion of a year of PD, is that it seemed most connected to the beliefs about the goals and purposes of science teaching where Profile 3 espoused both 'knowledge of'/Vision I and 'knowledge for'/Vision II beliefs about the goals and purposes of science teaching and the beliefs about technology-enhanced tools. While the beliefs about the goals and purposes of science teaching may seem trivial on the surface, some have suggested that also prioritizing 'knowledge for'/Vision II beliefs might require teachers to reconsider positions of power in relation to their students (Melville, 2013), because, in the context of complex societal issues, learners are expected to 'develop a sense of having something to say about these issues and to see themselves as legitimate participants in social dialogues, particularly those that involve science' (Sadler, 2009, pp. 12–21). And, in the context of these issues science teachers find themselves working to position their own students to 'approach decisions in an open unbiased way, respecting and acknowledging different perspectives, views, beliefs, and other ways of knowing' (National Science Teachers Association, 2010, p. 3). So, as Vision II has teachers considering how to help students 'use scientific knowledge to handle complex issues—to be an informed citizen' (Melville, 2013, p. 2), it could be that this can play an important role in influencing teachers so that they move away from beliefs about science teaching and learning that focus on information and transmission, as in Profile 1, found most often at the beginning of PD, toward beliefs focused on mediating student knowledge, like that found in Profile 3.

And, when considering the differences between Profiles 2 and 3 with respect to beliefs about technology-enhanced tools, all dimensions were found present in Profile 3, while only some of all three dimensions were found present in Profile 2. Put more succinctly, statements were found within Profile 2 across all dimensions, but generally only one to two dimensions were found for each participant. And, for the one teacher who was representative of Profile 3 at the end of one year of PD where statements for all three dimensions of technology-enhanced tools were found, when he was representative of Profile 2 at the beginning of PD, his statements were only found for one dimension (i.e. tools supportive of collaborative construction of scientific knowledge). Whether shifts in other dimensions of science teacher orientations were pushing or pulling on technology-enhanced tool dimensions or vice versa, it is interesting to note that when the dimensions identified in Profile 3, the SBR teacher orientation profile, seemed supportive of one another in ways aligned with our science literacy conceptualization (Table 2), these previously identified important dimensions of technology (Kim et al., 2007) were also found. This is a point that seems much more important as these finding are compared with findings from Profile 1. In Profile 1, for the most part, each dimension of the science teacher orientation was misaligned with our science literacy framework and no beliefs about technology-enhanced tools for student learning in science were found.

Conclusion and Implications

Borko and Putnam (1996) describe orientations and their importance in research focused on science teaching in the following:

> An orientation represents a general way of viewing or conceptualizing science teaching. The significance of this component is that these knowledge and beliefs serve as a 'conceptual map' that guides instructional decisions about issues such as daily objectives, the content of student assignments, the use of textbooks and other curricular materials, and the evaluation of student learning. (p. 97)

This research continued to build on our previous work (Campbell et al., 2013) in an attempt to better understand how dimensions of beliefs converge as lens for conceptualizing science teaching over time. The main focus of this research was concerned with changes in teacher beliefs over time within three dimensions that others like us have argued are central to science teacher orientations (Friedrichsen et al., 2011). Additionally, beliefs about technology-enhanced tools for student learning in science (Kim et al., 2007) were considered, especially concerned with where these might 'sit' within science teacher orientations. As importantly, we considered how different dimensions of teacher orientations found seemed to push or pull on each other (e.g. how naïve conceptions of the nature of science found in Profile 1 at the beginning of PD influenced or were influenced by the 'knowledge of'/Vision I goals and purposes of science teaching relegated to normative knowledge without a focus on science processes). Our findings revealed three complex profiles or 'conceptual maps' that were related to what was revealed previously (Campbell et al., 2013); but instead of an idealized Profile 3 most aligned to our science literacy framework as was presented previously, we were able to identify one participant at the conclusion of a year of PD who could help us more thoroughly illuminate the nuances of this important profile. And, as we considered the two other profiles (i.e. Profiles 1 and 2), we were able to provide more specifics about how different beliefs were manifested, especially in relation to beliefs across different dimensions. And, through this close examination of the amalgamation of the different dimensions of science teacher orientations in these three profiles, this research has added to the limited insights available in the literature regarding the impacts of technology-focused PD on teacher development that Lawless and Pellegrino (2007) recognized.

Among the most salient findings we believe were revealed, (a) considering how 'knowledge for'/Vision II goals and purposes for teaching science might push or pull on other beliefs within profiles and over time, (b) situating and examining technology-enhanced tool beliefs within the beliefs about science teaching and learning dimension within profiles and over time, and (c) considering the impact of a year of PD, representative of what Friedrichsen et al. (2011) referred to as 'curriculum interventions', stand out as three findings that potentially hold important implications and warrant our recommendation for future research investigations. Our concern for how 'knowledge for'/Vision II goals and purposes for teaching science might push or pull on other beliefs emerged as only our Profile 3 included these goals and purposes of science teaching that were concerned with 'situations in which science has a role, such as decision-making about socioscientific issues' (Roberts, 2007, 9). As we considered others' concern for Vision II, especially related to issues of power (Melville, 2013) as students are expected to 'see themselves as legitimate participants in social dialogues' (Sadler, 2009, p. 13), it makes sense that seeing this as a goal or purpose of science teaching might support or be supported by a convergence of more sophisticated beliefs about the nature of science accompanied by cohesive beliefs about the need to mediate aspects of students learning. Conversely, it makes sense that the absence of these types of goals in Profile 1, found exclusively at the beginning of PD, left open a clear path for prioritizing IT in a profile grounded on naïve conceptions of the nature of science. It also left us questioning whether the absence of 'knowledge for'/Vision II goals forming a tripartite of beliefs with more sophisticated views of the nature of science and a focus on collaboration, feedback, and knowledge development might provide enough internal strife or friction, especially rooted in power still residing mainly with the teacher, to bring about struggles in enacting more reformed teaching as seen in Profile 2, still found for the majority of participants after a year of PD. More research in this area whereby classroom observations are completed to examine consistent instructional behaviors that can be cataloged and used in concert with in-depth participant interviews to connect beliefs to instruction or PCK in ways similar to what Speer (2005) suggests might offer more insight in the influence of Vision II beliefs. While future research is needed to more fully understand the role of beliefs about 'knowledge for'/Vision II goals in pushing or pulling on other dimensions of science teacher orientations, given the strong case Roberts (2007) and others (e.g. Feinstein, 2011; Sadler & Zeidler, 2009) have made for the importance of Vision II and the potential promise it offers in supporting Profile 3, it seems important for professional developers to begin to ensure that Vision II also becomes central to the work they do with teachers.

As we considered technology-enhanced tools for student learning in science, we believed these were sufficiently locatable within the beliefs about science teaching and learning dimension of science teaching orientations. This was especially true for the purposes of this research, since Friedrichsen et al. (2011) described this dimension of science teacher orientation as ' the ways of representing and formulating the subject that make it comprehensible to others', and this aligned with the role we saw technology playing more broadly for teachers. Additionally with respect to technology-enhanced tools, we found that as teachers shifted from Profiles 1 through 3, from less to more alignment with our science literacy conceptualization toward the SBR profile over time, more beliefs about technology in each dimension were found. This seemed to suggest that technology can play an important complementary role for teachers by either playing a role in initiating reform aligned change or in supporting this type of change. This has implications for research as it suggests a need for future investigations into whether technology plays a role in mediating science teacher orientation belief changes or if technology-enhanced tools instead are mediated by these science teacher orientation beliefs, something that could inform the work of future professional developers and has already been investigated to some extent by Varma et al. (2008). This subsequently has implications for practice, since much research already exists documenting the benefits of teachers leveraging technology-enhanced tools in instruction (e.g. Hoffman, Wu, Krajcik, & Soloway, 2003; Linn, Clark, & Slotta, 2003).

Most importantly given our research focus, by completing research before and at the conclusion of a year of PD, we were well positioned to examine the changes in teacher orientations that occur during what we considered 'curriculum interventions' (Friedrichsen et al., 2011) or a year of PD experienced by our participants. Through this, we were afforded a window into how teacher knowledge developed as a result of PD, something that Lawless and Pelligrino (2007) identified was needed in the technology-focused PD literature. This is seen in Figure 1 as changes in the different science teacher orientation profiles and dimensions within the profiles shifted when comparing participant profiles identified at the beginning of PD with those found at the end of a year of PD. Through this study, at the beginning of PD, we found that dimensions of teacher orientations that are seen guiding instructional decisions were mainly 'out-of-step' with respect to the science literacy framework (Table 2) of most recent national standards documents. This is especially evident in Profile 1, the IT profile, which was descriptive of most of the participants in this study at the beginning of PD. At the conclusion of PD, a year later however, we found that as teachers were supported with curriculum resources and PD, the dimensions of teacher orientations were found shifting in complimentary ways to support science literacy framework-grounded instruction. This could be seen as an initial step found in Profile 2 for most participants and even more aligned in Profile 3 for one of the participants after a year of PD.

Finally, as with our previous research (Campbell et al., 2013), these findings are interrelated with the work of others examining science teacher orientations, PCK, and technology-enhanced tools for student learning in science. We submit them here to add to the current literature, while also exposing them for further scrutiny. We expect to revisit this research in the future as our funded PD continues, and as we continue to examine science teacher orientations in the context of PCK. To this end, our immediate future plans involve close study of how teacher orientations can be found influencing the instruction teachers provide, documented with paired classroom observations, teacher interviews, and classroom artifacts, to support student science learning.

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