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Professional Growth Orientation and Collaboration: Mediating Roles in Science Teacher Professional Learning

Abstract

This study addresses current dilemmas surrounding features of effective teacher professional development (PD). Using a theoretical framework that conceptualizes the complexity of teacher learning, this study investigates the interconnections among teachers' professional backgrounds, purposes for developing professionally, teaching contexts, engagement and participation in PD, and PD outcomes. Drawing upon the experiences of 16 case study teachers participating in a multi-year, multi-site environmental science literacy PD, this research uses a variety of data sources to better understand how teachers applied the concepts and practices from their PD program to the classroom context. Our analysis identified three forms of classroom implementation: *Integrated* incorporated practices across the curriculum, *Focused* attended closely to one interest area, and *Consistent* involved authentic instruction of the curriculum as designed. Findings suggest that teachers who demonstrated *Integrated* implementation were more likely to come to PD with a general desire for professional growth and engage collaboratively with colleagues. Implications include a deeper understanding of teacher learning to inform the design of effective PD.

In the last decade, research on teacher professional development (PD) reached what was termed a consensus on key features of highly-effective programs (Hill, Beisiegel, & Jacob, 2013). Studies drawing upon national samples identified program characteristics resulting in significant increases in teachers' knowledge and skills as well as their application to classroom practice (Garet, Porter, Desimone, Birman, & Yoon, 2001; Penuel, Fishman, Yamaguchi, & Gallagher, 2007). Several reports synthesized these features into a vision for effective PD that is situated in classroom practice, focused on student learning, embedded within professional learning communities, and sustained over time (Whitcomb, Borko, & Liston, 2009). Others emphasized the importance of active learning, collective participation, and connection to the larger change process (Desimone, 2011; Hawley & Valli, 2007).

However, this vision has recently been challenged by rigorous studies finding little long-term increase in teacher or student knowledge from PD adhering to these key design principles (Wilson, 2013). Notably, two Institute of Education Sciences and U.S. Department of Education-funded studies on early reading and middle school mathematics PD failed to demonstrate sustained change in teachers' knowledge or student achievement. The first study showed significant increases in teacher knowledge immediately following the PD, but this effect disappeared one year later; the second found no increase in teacher or student knowledge as a result of the PD (Garet et al., 2008; Garet et al., 2011). These, as well as other high-profile and disappointing results have called into question the consensus on effective PD as well as the use of district funds for these efforts (e.g., Arens et al., 2012; Bos & Sinicrope, 2012).

This study addresses the present dilemma in professional development research by expanding the frame of analysis to include not only the PD program features and outcomes, but also the learners themselves. In this study, we sought to understand the ways in which teachers participating in multi-year, multi-site science PD incorporated the principles and practices from PD into their individual classrooms. In our analysis, we used a theoretical framework that is based on Opfer and Pedder's (2011) understanding of teacher professional learning as inherently complex and situated in nature. Opfer and Pedder (2011) explain:

> We believe that teacher learning must be conceptualized as a complex system rather than as an event … Complex systems thinking assumes that there are various dynamics at work in social behavior and these interact and combine in different ways such that even the simplest decisions can have multiple causal pathways (p. 378).

Opfer and Pedder (2011) argue that to understand teacher learning beyond the process-product paradigm, research needs to address reciprocal influences in three subsystems, *the teacher, the school,* and *the learning activity.*

This study examines these three interrelated subsystems using research conducted with 16 secondary science teachers participating in a multi-year PD program at four sites across the United States. The stated goal of the PD was to connect educators with research scientists in an effort to build ecological literacy using a learning progressions approach. In particular, the PD focused on developing teachers' understanding and use of eight key pedagogies for learning progressions, incorporated into curricular units and into their science classrooms in general. Complexity theory argues that there are multiple causal pathways for social behavior; in

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this study we aimed to unpack one type of interaction among the teacher, the school, and the learning activity by exploring what teachers' brought to and took from an extended PD experience. In doing so, we also intended to expand the scope of PD research to include not only program features and outcomes but also a deeper understanding of the learners themselves.

Literature Review

We draw upon two distinct bodies of knowledge to inform this study. The first includes impact studies of science-related PD and examines PD outcomes such as curriculum implementation and student achievement. The second body of research focuses on teacher learning; this literature illustrates teacher learning as an active, collaborative, and situated process. While these two bodies of literature are often separated, we see them as inherently interconnected. This study builds upon the understanding that it is not only program features that shape PD outcomes, but also the active role played by the learners themselves.

PD as Influencing Practice and Achievement

Over the last decade, a number of research studies have identified and quantified PD outcomes, both in an attempt to illustrate their value as well as justify time and money devoted to these efforts (Arens et al., 2012). In science in particular, these studies have clearly demonstrated the positive impact of PD on both teacher practice as well as student achievement. Supovitz and Turner's (2000) study of PD focused on concrete science tasks found that teachers' increased participation in PD influenced their use of inquiry-based practices as well as the development of their classroom culture. Desimone, Porter, Garet, Yoon, & Birman (2002), in their analysis of science and mathematics PD across US five states, likewise found that PD focused on specific instructional practices increased the use of those same practices in the classroom. Jeanpierre, Oberhauser, and Freeman (2005) studied a two-week PD institute that engaged teachers in the full scientific inquiry process. Through a mixed-methods analysis, they found that teachers' first-hand experience with inquiry led to the use of those same inquiry practices in the classroom setting. And Penuel, Gallagher, and Moorthy (2011) found, in their comparison of three earth science-related PD interventions, that the most effective programs provided teachers with the immersive experiences and explicit instruction for translating practices back to the classroom.

A second set of studies has looked at the effect of PD programs on student achievement. For instance, Johnson, Kahle, and Fargo's (2007) analysis of whole-school PD using the *Discovery* schools initiative indicated significantly higher student scores on the *Discovery* Inquiry Test in Science, as compared with scores from a non-participating school. Likewise, Doppelt et al's (2009) study showed that those teachers who participated in a series of ongoing curriculum reform workshops had student achievement one standard deviation higher than those who did not participate. Taken together, these impact studies indicate that PD can and does have an effect on both teacher practice as well as subsequent student performance. Certain features of PD, including active learning, specific content focus, and collaboration can lead to classroom pedagogy more carefully aligned with research-based practices and guiding curriculum standards.

Teacher as Learner

While this first body of research demonstrates the impact of PD on teachers, classrooms, and students, a second set of foundational research illustrates the central role of the teachers themselves in their own learning. Contrary to the process-product paradigm, which conceptualized a top-down, linear connection between PD, teacher learning, and curricular implementation (Shulman, 1986), this approach acknowledges teaching as a lifelong-learning profession and views teachers as coming with prior experiences, expectations, and beliefs that shape how they filter and construct new understandings throughout their careers (e.g., Darling-Hammond & Sykes, 1999; Huberman, 1989). Extant research has demonstrated time and again that teachers are not passive recipients of new information, but rather active players in constructing professional knowledge and understandings. Borko, Davinroy, Bliem, and Cumbo (2000) argued that PD efforts are interpreted through both personal and situational factors such as available resources, beliefs about teaching and learning, and personal lives. Allen and Penuel (2015) found that teachers' perceptions of coherence influence their appropriation of PD. Brickhouse (1990) and Luft (2001) have demonstrated the role of beliefs in facilitating the use of science practices. Hanuscin, Rebello, and Sinha (2012) highlighted the importance of understanding teachers' ideas and perceptions of teacher leadership in promoting effective leadership skills and dispositions. Rinke (2008; 2014) found that personal orientations toward the profession mediate teachers' professional growth.

There is also an accepted understanding that teacher learning can be enhanced by collaborative interaction within a professional learning community. Previous research has found that collaborative settings can foster not only teacher learning, but also teacher effectiveness and student achievement. Thompson, Windschitl, and Braagen (2013) demonstrated the differential learning of science educators based on their participation within communities. Likewise, Day, Sammons, Stobart, Kington, and Gu (2007) found collaboration as one key element for facilitating long-term teacher effectiveness. Finally, emerging evidence indicates that strong instructional collaborations can facilitate student achievement school-wide, based on value-added modeling (Ronfeldt, Farmer, & Loeb, 2014). As a whole, these studies illustrate that it is not only PD programs that influence practice, but also the background, participation, and collaboration of the teachers themselves. These studies enhance PD outcomes research by highlighting the role of the learners in the learning process.

Program Background

This research was conducted as part of a National Science Foundation-funded Math-Science Partnership project (Culturally Relevant Ecology, Learning Progressions and Environmental Literacy, herein referred to as the Pathways Project). The focus was on teaching "coupled human-ecosystem interactions in the context of socio-ecological systems as a framework to promote place-based learning and environmental literacy" (Pathways to Environmental Literacy, 2014). The project connected scientists in the Long-Term Ecological Research (LTER) network with middle school and high school science teachers with the goal of developing the teachers' own environmental science literacy and their use of learning progressions in their classroom practice.

The PD program spanned a five-year period at four LTER sites across the United States, including East Coast, Great Lakes, Mountain, and West Coast regions. The vast majority of teachers participated at one site for multiple years. Altogether, the PD reached a total of 250 science teachers and over 70,000 students in 22 K-12 school districts. The project developed and disseminated three instructional units, termed teaching experiments or TEs: 1) Carbon Cycling, 2) Water Pathways and Quality, and 3) Biodiversity. Teachers participated in school-year sessions and summer workshops. Some teachers were involved in ecological or educational research as Research Experiences for Teachers (RET) fellows and others served as part- or full-time Teachers-In-Residence (TIR). All were supported through explicit instruction, conceptual development, material resources and in-school assistance for implementing the TEs in their classrooms. They were also encouraged to collaborate with other PD participants, PD providers, and teachers at their school sites.

Further, participating teachers were introduced to the concept of key pedagogies as an application of the learning progressions research. Learning progressions are models of learning that describe pathways by which students develop increasingly sophisticated understandings of a particular concept until they ultimately master the curricular goal (Duschl, Schweingruber, & Schouse, 2008). Most learning progression approaches describe a series of levels in student sophistication, represent actual student performances, and span an extended period of time (Schneider & Plasman, 2011). The Pathway Project's key pedagogies are widely recognized as effective teaching practices that project educators identified as productive for applying insights from learning progressions to the classroom. Eight specific key pedagogies work together to support teachers in fostering student development of more sophisticated understandings, thus progressing on pathways to environmental science literacy: (1) Big Ideas; (2) Planning; (3) Formative Assessment; (4) Attending to Ideas; (5) Inquiry; (6) Reasoning; (7) Local Context; (8) Citizen Practices. A brief description of each of these key pedagogies is provided in Table 1.

Methodology

The purpose of this study is to articulate the relationships between teachers' initial intentions for engaging in the PD, how they engaged in the PD workshops, and their later implementation practices. The questions addressed include, (1) What were the case study teachers' professional backgrounds and purposes for engaging in PD, teaching contexts, participation, and forms of engagement in PD (i.e., What did they bring to the PD)?; (2) To what extent and in what ways did the 16 case study teachers implement key pedagogy in their classrooms (i.e., What did they take from the PD)?; and (3) What relationship, if any, existed among the teacher, the school, the learning activity, and teachers' implementation practices?

We addressed these research questions using a multiple case study design in which we sought to understand the background, teaching context, PD participation, and classroom implementation for 16 selected middle school and high school science teachers (Merriam, 1998; Yin, 2003). The qualitative case study method was chosen in an effort to explore potential connections among as well as outcomes from the teacher, the school, and the learning activity, as laid out in our theoretical framework (Opfer & Pedder, 2011). We recruited teachers who project staff considered exemplary: teachers who had regularly attended professional development meetings and had thoughtfully implemented Pathways curricular units in previous years. These case study teachers constituted approximately 10% of the 160 teachers who participated in the larger Pathways project during 2012-2013. They included four teachers from each of the four PD sites: East Coast, Great Lakes, Mountain, and West Coast. They also included an equal number of middle school and high school teachers. Additional demographic information for each of the case study teachers is provided in Table 2. For the full group of participating teachers, data were collected through an annual survey, whereas for the case study teachers, data were collected through four in-person interviews, two written reflections, curriculum feedback forms, administrator interviews, and classroom observations. We sought to understand the ways in which each case study teacher began PD, participated in PD, and implemented PD in their own classrooms.

Table 1. Key Pedagogy Descriptions

Key Pedagogy	Description
Big Ideas	Focus on big ideas in the field of study, supported by LP.
Planning	Plan instruction based on student understanding of topic in LP context.
Formative Assessment	Develop and use LP-based formative assessments to guide instruction.
Attending to Ideas	Carefully attend and respond to students' thinking guided by LP.
Inquiry	Guide students in inquiry with authentic events and experiences.
Reasoning	Engage students in increasingly complex principle- and evidence-based accounts.
Local Context	Link to real problems anchored in students' culture and place.
Citizen Practices	Support engagement in science-based citizenship decision-making practices.

Data Sources

Diverse types of data were collected starting with the summer PD and continuing through an entire school year, providing multiple, overlapping windows to understand case study teachers' experience in and application of the Pathways PD. For the purposes of this analysis, we focused specifically on those data sources that would illuminate key elements of our theoretical framework (for full sources and alignment see Table 3). Starting from a foundation of teacher, school, learning activity, and outcomes, we identified five specific categories with aligned data sources: (1) Professional Background and Purpose for PD Participation; (2) Teaching Context; (3) Participation and Engagement in PD; (4) Implementation Characteristics; and (5) Implementation Extent. Together, these categories were intended to respond to the research questions through teachers' background and experiences, implementation practices, and connections between the two. We collaboratively constructed definitions and indicators for each of the five categories, in an effort to clarify constructs, train coders, and promote consistency throughout the coding process.

To better understand these five elements, we used the following data sources: (1) A teacher information dataset assembled by PD leaders at each site containing basic demographic information, PD participation dates, and grades and subjects taught; (2) Teacher interviews conducted at four points across the study school year, focusing on teachers' professional backgrounds, purposes for participating in PD, experiences in PD, and implementation practices in their classrooms; (3) Teacher written reflections completed twice during the school year, targeting implementation practices as well as the influence of PD on those practices; (4) An on-line teacher survey, completed by all participating teachers at the end of the school year, providing a quantitative lens on teachers' understanding of learning progressions, use of key pedagogies and TEs in the classroom, and overall influence of PD; (5) Teacher Feedback Forms, specific to Carbon, Water, and Biodiversity topics, inquiring into specific aspects of the TEs implemented and modifications made.

Data Analysis

Data analysis was conducted as a multistage and iterative procedure, guided by the processes of first exploring and describing, then ordering and explaining suggested by Miles and Huberman (1994). After all relevant data were gathered, we as researchers then independently conducted a round of open coding to identify emergent patterns and themes not included in the original framework. The initial round was followed by a second coding cycle across the five identified categories of interest, merging framework codes with emergent themes. A third coding sequence followed, this one applying the earlier identified codes across individual case study teachers. The authors of this paper, each of whom holds a Ph.D. and has extensive expertise and experience conducting education research using qualitative research methodologies, performed all coding. Each round of coding was initially completed individually by each of the three researchers. Results were then compared and discrepancies were resolved through discussion, coming to consensus when needed. Descriptions and examples for each of the codes applied are provided in Table 4.

These three coding cycles resulted in the classification of case study teachers into three groups based on the synthesis of their implementation characteristics and extent. In this characterization, *Integrated* teachers applied multiple key pedagogies broadly across their teaching, *Focused* teachers attended carefully to one particular area or key pedagogy of interest, and *Consistent* teachers put their efforts primarily into the careful implementation of the TE curricular unit. We then used these classifications to develop matrices comparing teachers' type of classroom implementation with other factors of interest. When looking across implementation category, school context, and level of participation, we saw little connection. However, when looking across implementation category, purpose, and engagement in PD, we saw clear patterns. These cross-case matrices ultimately led to the development of the findings of this study.

Table 2. Demographic Profiles of the Participating Teachers

Teacher	Gender	Ethnicity	First Language	Childhood SES
Ms. M	Female	Asian	Filipino	Middle Class
Ms. P	Female	White	English	Middle Class
Ms. R	Female	White	English	Middle Class
Ms. F	Female	White	English	Borderline Poverty
Ms. Z	Female	White	English	Middle Class
Ms. E	Female	White	English	Lower Middle Class
Ms. T	Female	White	English	Middle Class
Ms. S	Female	White	English	Borderline Poverty
Ms. V	Female	White	English	Middle Class
Ms. L	Female	White	English	Middle Class
Mr. B	Male	White	English	Middle Class
Mr. D	Male	White	English	Middle Class
Mr. G	Male	White	English	Lower Middle Class
Mr. A	Male	Indian	Tamil	Middle Class
Mr. K	Male	White	English	Lower Middle Class
Mr. J	Male	White	English	Middle Class

Findings

Our case study analysis revealed a strong connection between individual teacher characteristics and key pedagogy implementation approaches. Initially, we set out to understand what patterns existed among elements of teacher learning, that is the teacher, the school, and the learning activity, and our three categories of key pedagogy implementation. Perhaps owing to the individual-level, rather than school- or district-level focus of this PD, we found no clear relationship linking school or learning activity features to key pedagogy implementation. However,

Table 3. Data Sources and Alignment

Framework Element	Data Category	Data Source(s)
The Teacher	1a. Professional Background	Teacher Information Dataset Teacher Interviews
The Teacher	1b. Purpose for PD Participation	Teacher Interviews
The School	2. Teaching Context	Teacher Information Dataset Teacher Interviews
The Learning Activity	3a. Participation in PD	Teacher Information Dataset
The Learning Activity	3b.Engagement in PD	Teacher Interviews
Outcomes	4. Implementation Characteristics	Teacher Written Reflections Teacher Interviews Teacher Feedback Form Teacher Survey
Outcomes	5. Implementation Extent	Teacher Survey Teacher Feedback Form

there was a clear connection between teacher characteristics, specifically teachers' purpose for participating in PD and teachers' active collaboration during PD, and their key pedagogy implementation.

Table 5 profiles the 16 case study teachers, organized by key pedagogy implementation classification. This table highlights school features, such as teaching assignment, school culture, and student population. The data presented here underscore the notion that teachers implementing key pedagogies in Integrated, Focused, and Consistent forms taught in a variety of school contexts, with no clear patterns present. Likewise, the table incorporates data on teacher participation in the learning activity, including PD site by region, workshop participation, and TE focus. Here again, no clear connections exist between type or level of participation in the learning activity and key pedagogy implementation. Integrated, Focused, and Consistent teachers were found across all four PD sites and among low, moderate, and high levels of teacher participation.

In contrast, Table 6 profiles the same teachers alongside data indicating their stated purposes for participation in PD and their engagement in PD. The purposes for participation in PD were based on teachers' responses to interview questions, with a particular focus on their past professional development experiences and their stated reasons for joining the Pathways project. Codes indicate what they hoped to get out of the learning experience for themselves and/or their students. Teachers' engagement in PD was also gauged from their interviews, focusing on their descriptions of interactions with fellow participants, site leaders, teachers-in-residence, and other colleagues. Technical engagement primarily focused on the resources and knowledge needed for authentic implementation of the TE unit, conceptual engagement centered on understanding and using the key pedagogies, and collaborative engagement involved practice-based knowledge sharing and critical reflection among educators.

Integrated Implementation

The results in Table 6 clearly show that all but one of the nine teachers who implemented key pedagogies into their classrooms in an Integrated fashion, that is comprehensively across the curriculum, came to the PD experience with an expressed goal of growing professionally. Rather than mentioning specific content or practices they hoped to gain, these teachers expressed an openness to continual learning and growth as well as a desire to maintain excitement about the profession. For example, in one of her interviews, Ms. Z described her reasons for participating in the Pathways PD:

> I love learning new things. I absolutely love being able to add to what I know, to find out the latest research. I love being part of the science community. I really like to push myself and to grow and to learn more.

She expressed a similar sentiment in another interview when describing her own development as a positive example for her students, noting, "I love being able to share with the students what I have learned over the summer. They can see that I am a student like them, that I'm always wanting to learn, that I'm always wanting to grow."

In addition, seven of the nine teachers who took an Integrated implementation approach engaged in PD in a collaborative manner, sharing ideas and discussing practice with fellow educators. Ms. Z for example, in describing her experience in the PD, stated, "They have been wonderful bonding times to be with other teachers and to meet other scientists and colleagues. I look forward to them every summer." These patterns make a clear case for the role of teachers' purpose and engagement in PD in their later implementation practices.

Focused Implementation

While the number of case study teachers in the remaining categories are far fewer, these data also suggest potential patterns. Those teachers who took a Focused implementation approach, targeting one specific type of key pedagogy in their classroom, tended to come into the PD with a specific goal in mind such as building students' understanding of evidence-based reasoning or environmental issues. Not surprisingly, at different times they reported initial purposes and their later implementation focused on similar ideas and practices. Mr. D for example, saw the most useful PD experiences as ones that explicitly demonstrated activities to be used in the classroom. Mr. G stated, "[PD workshops are] best if they're a little bit hands on and if it's something that teachers can easily turn around and maybe even use the next day." He initially chose to join the Pathways Project because he wanted his students to become more independent with labs. He explained, "It's very important that they can do [labs] not necessarily with me holding their hands and giving them direction after direction." Coming from a goal of making science more hands-on, Mr. G then implemented those same active learning practices into his classroom. In one reflection he wrote:

> The Pathways Project has helped me create an environment in which science is much more of an active process. Students need to be able to work

Table 4. Code Descriptions and Examples

Data Category	Data Code	Code Description	Example
Professional Background and Purpose for PD	Scientific Ideas	Teacher focus is on incorporating scientific ideas	"We bring in the articles, and have them discuss and deliberate and you know talk about science in their world."
	Student Ideas	Teacher focus is on working with student ideas	"It's really [about] listening to where students are in terms of their discourse and the language that they are using to explain something."
	Evidence-Based Reasoning	Teacher focus is on engaging students in evidence-based reasoning	"[Students] need to understand how to reason logically and scientifically based on evidence."
	Environmental Issues	Teacher focus is on incorporating local environmental issues	"[I am] always working in environmental issues, especially my area of interest is human impact."
	Professional Growth	Teacher focus is on their own professional growth	"Every time I go I learn something and it helps me grow as a teacher."
Teaching Context	Independent	Teachers at the school generally work independently	"There are not that many teachers in my department."
	Collaborative	Teachers at the school generally work collaboratively	"Our focus is on collaboration. We meet once a week every morning, every Thursday morning—talk teaching strategies, assessment criteria, really focus on student learning."
	High-Need	School has Title 1 status	N/A
	Resourced	School does not have Title 1 status.	N/A
Participation and Engagement in PD	Collaborative	Teacher PD focus is on collaboration opportunities	"One reason I actually did the professional development was because I knew they would be there and I really like working with teachers from other schools."
	Technical	Teacher PD focus is on acquiring resources for implementing the TE	"Knowing that there's a place that I can just borrow equipment is awesome."
	Conceptual	Teacher PD focus is on learning about LPTSs	"I would like to better - learn to better take students initial understanding and figure out a way to develop that to the next learning progression or level."
Implementation Characteristics	Scientific ideas	Teacher focus is on student development of scientific ideas	"I want to try to tie more curriculum topics to understanding science concepts and how understanding these topics can help students to be less intimidated by scientific issues.
	Evidence-based reasoning	Teacher focus is on student development of evidence based reasoning	"I feel like I've stressed the evidence based reasoning throughout my teaching."
	Local environmental understandings	Teacher focus is on student development of local environmental understandings	"I wanted the students to really take into account their personal attachment to the Bay and how they view this resource."
	Teacher Professional growth	Teacher focus is on their own professional growth	"The project has tremendously helped me in my teaching strategies. It has changed the way I impart information to students."
Implementation Extent	TE Curriculum-Focused	Teacher is focused on implementing the TE as an independent unit	"I taught carbon TE during the last quarter"
	LPTS-Focused	Teacher focus is on implementing a specific LPTS	"I used more inquiry activities than I have in the past"
	Application-Focused	Teacher focus is on applying the LPTSs broadly in their teaching	"Because of my participation in pathways I have incorporated many small lessons or strings of lessons in many parts of my curriculum."
Implementation Overall (Synthesis of Characteristics and Extent)	Integrated	Teacher synthesizes multiple areas and applies broadly to teaching	Synthesis category: No specific quotes
	Focused	Teacher targets one specific area of interest	Synthesis category: No specific quotes
	Consistent	Teacher implements TE coherent with curriculum design	Synthesis category: No specific quotes

Table 5. Teacher School and Learning Activity Profiles by Overall Implementation Classification

Teacher		School			Learning Activity		
Teacher	Implementation	Level	Culture	Students	PD Site	#Workshops TIR/RET	TE(s) Taught
Ms. M	Integrated	High	Independent	Resourced	East Coast	12	Biodiversity
Ms. P	Integrated	High	Collaborative	Resourced	East Coast	4	Water Biodiversity
Ms. R	Integrated	High	Collaborative	High-Need	Great Lakes	11	Biodiversity
Ms. F	Integrated	High	Collaborative	High-Need	Great Lakes	14 RET	Biodiversity
Ms. Z	Integrated	Middle	Independent	High-Need	West Coast	3	Biodiversity
Ms. E	Integrated	Middle	Independent	High-Need	West Coast	3	Carbon Water
Ms. T	Integrated	Middle	Collaborative	Resourced	Mountain	2	Carbon Water
Ms. S	Integrated	Middle	Independent	Resourced	Mountain	3	Carbon
Ms. V	Integrated	High	Independent	Resourced	Mountain	1 TIR / RET	Water
Ms. L	Focused	Middle	Independent	High-Need	West Coast	3	Carbon Water
Mr. B	Focused	High	Independent	Resourced	East Coast	7 RET	Biodiversity
Mr. D	Focused	Middle	Collaborative	High-Need	Great Lakes	15	Water
Mr. G	Focused	High	Collaborative	High-Need	Great Lakes	8 RET	Carbon
Mr. A	Consistent	High	Independent	Resourced	East Coast	11 RET	Carbon Water
Mr. K	Consistent	Middle	Independent	High-Need	West Coast	3	Water Biodiversity
Mr. J	Consistent	Middle	Collaborative	Resourced	Mountain	1 TIR	Water

> independently and not be spoon-fed answers. These workshops have given me some ideas on how to guide students through activities, but not necessarily give them the answers.

In addition to this apparent pattern, it is also worthy of mention that fewer of the Focused teachers engaged collaboratively, as compared with their Integrated counterparts.

Consistent Implementation

Finally, those teachers who took a Consistent approach to curriculum implementation, concentrating primarily on teaching the original TE as designed, did not characterize themselves as wanting to grow as professionals in a general sense. Instead, they described engaging in the PD in the hopes of obtaining and gaining familiarity with curricular supports. Mr. A for example, hoped that the Pathways Project would provide additional curriculum materials, "I just want to know if there are any teaching experiments part one, part two. If they can come up with a simple project that make the students apply the concepts they learned." Although one of the Consistent teachers worked collaboratively, all three exhibited a Technical engagement in which the interaction largely focused on the mechanics of implementing the TE in the classroom setting. Mr. A for example, described working with his colleagues in a very technical capacity during the PD:

> They were very useful. And not only like material support, but when you have an adult in the class who knows the content, more than what I know. And when kids asked me questions and I couldn't answer, they would interject and answer the question.

However, despite these apparent patterns, the numbers of case study teachers in the Focused and Consistent categories were quite low, so further investigation is needed to solidify these findings into clear patterns and themes.

Table 6. Profiles of Teachers' Purpose for PD Participation and Engagement in PD by Implementation Classification.

Teacher	Implementation	Purpose for PD	Engagement in PD
Ms. M	Integrated	**Professional Growth**	**Collaborative**
Ms. P	Integrated	**Professional Growth**	Technical
Ms. R	Integrated	**Professional Growth**	Technical
Ms. F	Integrated	**Professional Growth**	**Collaborative** & Conceptual
Ms. Z	Integrated	**Professional Growth**	**Collaborative** & Technical
Ms. E	Integrated	**Professional Growth**	**Collaborative** & Conceptual
Ms. T	Integrated	**Professional Growth** Evidence & Environmental	**Collaborative** & Technical
Ms. S	Integrated	**Professional Growth** Scientific Ideas & Environmental	**Collaborative** & Conceptual
Ms. V	Integrated	Student Ideas & Evidence-Based Reasoning	**Collaborative** & Technical
Ms. L	Focused	Environmental Issues	Technical
Mr. B	Focused	Professional Growth	Technical
Mr. D	Focused	Evidence-Based Reasoning	Technical Conceptual
Mr. G	Focused	Evidence-Based Reasoning & Environmental Issues	Collaborative & Conceptual
Mr. A	Consistent	Scientific Ideas	Technical
Mr. K	Consistent	Environmental Issues	Collaborative & Technical
Mr. J	Consistent	Evidence-Based Reasoning & Environmental Issues	Technical

Discussion

In this study, we set out to understand science teacher learning in one particular PD program through characterizing teachers' background and purpose for participating in PD, their teaching context, and their participation and engagement in PD. Building upon an understanding that PD can influence teacher practice (e.g., Desimone, Porter, Garet, Kwang, & Birman, 2002; Supovitz & Turner, 2000) and that teachers are active agents in their own learning (e.g., Borko et al., 2000; Thompson et al., 2013), we found that teachers' purpose for participating in PD and engagement in PD were influential for that classroom practice. We found that case study teachers implemented the PD in three general ways and that the majority of teachers who adopted an Integrated approach tended toward a Professional Growth orientation and Collaborative engagement in the PD program. While these findings in no way serve as a sole explanation for teacher learning in the Pathways Project, they nonetheless highlight an important dynamic in teacher professional growth: the role of teachers' own perspectives and engagement in the learning process.

In doing so, these findings extend Opfer and Pedder's (2011) model by introducing two features that help to mediate the core interaction between teacher, school, and learning activity. This study suggests a revised model of teacher learning that incorporates Opfer and Pedder's (2011) original notion of teacher, school, and learning activity. The revised model fleshes out these connections by adding purpose and engagement to the interconnections among these factors, working together toward teacher learning that exhibits key pedagogy implementation across classroom practice. Our case studies suggest that teachers who came to PD with the purpose of professional growth and engaged collaboratively during PD exhibited an integrated form of teacher learning. While these are certainly not the only factors at play in this complex dynamic, they are two features that emerged prominently in this data set as mediating the teacher learning process.

These findings also suggest important implications for PD research as well as practice.

Psychologist Carol Dweck (1999) introduced what is now the prominent theory of mindset, arguing that the most successful learners adopt a *growth mindset* and "believe they can develop their intelligence over time" (Dweck, 2010, p. 16). This underlying belief in one's own effort leads to greater openness to challenge, risk-taking, and resilience in the face of initial failure. Dweck argues that development emerges from a "love of learning" (Dweck, 2010, p. 20), rather than from any inherent talent or ability. Application of Dweck's mindset model to teacher professional growth suggests first that those teachers who already possess a growth mindset may be more open to new learning experiences and more inclined to accept the challenge of applying novel practices to their classroom. It further suggests that, in practice, teacher PD should be designed with growth mindset in mind, incorporating goal-setting, documentation of progress, and a culture of risk-taking to foster a growth mindset among teacher learners (Dweck, 2010).

These findings further extend the already extensive body of knowledge on teacher collaboration to a new context, that of science teacher implementation of key pedagogies. The Pathways Project fostered collaboration by design and one-half of the case study teachers reported engaging in professional collaboration in either Technical or Conceptual ways. Present research demonstrates the role of collaboration in classroom practice, long-term effectiveness, and student learning (e.g., Day et al., 2007; Ronfeldt et al., 2014; Thompson et al., 2013). This study suggests that collaboration also plays a role in mediating key pedagogy implementation. Although the consensus on effective PD practices may be still in question, this study suggests that collaboration remains one influential feature and continues to be an important feature of PD programs (Wilson, 2013).

The current dilemma around features of effective PD requires extensive and large-scale investigation before it is resolved. The scope and sample size of this study are not sufficient to fully address this dilemma and the findings need replication among larger samples of teachers. Findings would also be strengthened with a connection to student achievement data (Fishman, Marx, Best, & Tal, 2003). Given these limitations, this study nonetheless draws from the experiences of 16 case study participants in a national multi-year, multi-site science PD program and identifies the ways in which professional growth orientations and collaboration link PD with classroom implementation. In doing so, this study makes the case for the role of not only program features, but also the learners themselves as engaged agents in the learning process.

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