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Confusion Over Models: Exploring Discourse in a STEM Professional Development

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Abstract

For 2 weeks in the summer of 2018, K-12 science, technology, engineering, and mathematics (STEM) teachers ($n = 40$) attended a professional development (PD) that included four sessions focused on computer science modeling with follow-up academic year sessions; however, overall, the teachers did not incorporate or utilize *modeling* means or how as the instructors intended. The purpose of the study is to examine why this occurred, and the authors looked at the teachers' modeling discourse. Using two theories to connect to practice (terministic screens, and schema theory), the authors collected data via the surveys, interviews, and email reflections. The authors analyzed the results via coding to explore participants' concept of *models* and the potential difficulties of implementing computer modeling in their classrooms. Findings show that the term *model* was interpreted differently by the PD's faculty team and participants. Further, the authors found that the majority of presenters held differing theories of models than the participants. Participant concepts of models did improve slightly after the PD, but lingering model concepts caused confusion with the anticipated PD results. Conclusions include five general modeling concepts which are presented and explained. Implications are provided showcasing articulated keys for delivering PD that assists in eliminating discursive and theoretical issues. Included are considerations for STEM teacher educators, PD providers, and K-12 teachers. The main study limitations include mixed K-12 teaching participants, distance between participants, a self-selected population, and non-generalizable findings based on qualitative work. Future directions are outlined.

Keywords

Teacher Education, Computer Modeling, Professional development, Computer science education, STEM, Schema theory, Terministic screen, K-12 teacher, Models, Human communication

At the end of 2018, the second author reflected on the summer's professional development (PD) for K-12 science, technology, engineering, and/or mathematics (STEM) teachers. One goal of the PD was to assist K-12 teachers to use computer science modeling in their classrooms. Combined with a state-wide initiative mandating computer science in K-12 district classrooms by the 2022 to 2023 school year (https://edu.wyoming.gov/wp-content/uploads/2022/04/2022-WDE-Statutory-Changes-in-Computer-Science-Education.pdf), she believed these PD sessions would be well received, and that teachers would be able to begin integrating computer science in their classrooms once they finished the experience. However, she reflected:

> I didn't have many teachers reach out for modeling and/or computer science support this year, and that is worrisome to me. I emailed the group several times, and I expected the teachers to ask questions or bounce ideas off me (or someone from Robotics, Applied Mathematics, Physics, & Engineering Design (RAMPED) project team, but instead, it was almost silent on our end for help extensions even after we reached out and offered to even go into the classrooms.

The authors reflected together and identified the problem: Why were the PD modeling results different than expected in relation to teaching modeling in K-12 settings? Specifically, the authors explored this problem, and they wanted to find reasons for why the teachers did not incorporate modeling into their classrooms. The purpose of this qualitative research article, is to examine possible reasons for the disconnect between the faculty PD instructors (part of the PD project

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team) and the teacher participants regarding computer science, modeling, and eventual classroom implementation based on the discourse that was used during the PD. The authors investigated the following research question guiding the PD inquiry:

- How did the "modeling" language used during the professional development impact the teacher participants and faculty (who promoted computer science modeling practices) when they returned to instruction?

As an overview, after applying Burke's (1966) terministic screens, and schema theory (Tracey & Morrow, 2012), and analyzing transcripts from interviews, pre/post surveys, and emails, the authors discovered that the term *modeling* created confusion for the teachers that may have led to difficulties with practice. These discursive issues may have contributed to the differences between the faculty expectations and the participants' actual application in their classrooms, but they also provide some guidance for creating new teacher PD. This article first highlights considerations for successful PDs, and then discusses the context of the PD that was presented with computer science modeling. The findings from the analysis of the surveys, interviews, and follow-up email surveys are then presented, as well as the potential reasons for the disconnect and implications for future PDs.

Literature Review

Traits of Quality Professional Development

The educational research community agrees that more research into effective PD to change teaching practices and student learning is needed (NAEP, 2015; NASEM, 2015; Pellegrino, 2021; Roth et al., 2019). In teacher PD, Garet et al. (2001) argued that there are two main models: a traditional model and a reform model. The traditional model is top-down and aims to improve perceived needs in the skills of a faculty; a reform model focuses on building up the faculty through collaborative and classroom-embedded practices. The traditional model tends to be criticized, and not considered to be overly effective, while the reform model, with active learning, may be more in line with how teachers learn new material (Garet et al., 2001). However, it is not this dichotomy that is important, but the methods used during the PD. Regardless of the approach, some factors for effective PD appear consistent. The PD experience should: be a sufficient duration (more than short term or single day workshops); focus on content and how the participants can learn, design, and deliver in a collaborative format that fosters active creation of knowledge (instead of merely receiving knowledge); include a showcase of effective practice; provide mentoring and support, feedback, and time for reflection; and be conducted throughout the year in ways that embed practice in the participants' classrooms (Bates & Morgan 2018; Darling-Hammond et al., 2017; Desimone et al., 2002; Abrahams et al., 2014; Garet et al., 2001; McGee et al., 2013; Zaccarelli et al., 2018). Scaling PDs is another key consideration (Borko et al., 2014), in addition to effective PDs including "clear communication, hands-on activities, planned time for reflection and discussion, and intentional partnership building" (Burrows, 2015, p. 35). There is also evidence that PDs including analysis-of-practice result in more student learning (Roth et al., 2019; Taylor et al., 2017), and PDs with attention on formative assessment in relation to curricular goals and student understanding result in increased pedagogical content knowledge (Falk, 2011).

Other studies should also be considered, such as one that noted that self-reporting of the participant PD experiences could be positive, but that the positivity did not necessarily translate to improved practices (Abrahams et al., 2014). Another study, similarly, found that even though some of the teachers' practices changed after a year-long PD, teachers' beliefs did not show a correlating change, leading them to wonder if the teachers would revert to their previous methods after the PD (Wilkinson et al., 2017). Additionally, enthusiasm ebbs and flows during a PD, with high engagement at the beginning and end, with a dip in enthusiasm in the middle (Burrows et al., 2016). Warren Little (2012) challenged the educational research community to consider two broad metaphorical starting points with micro-process studies, which include emphasis on situated interaction in PD with the following:

> The first entails a strategy of "zooming in" for a deeper understanding of the practices and perspectives in play in specific moments (events, activities) as teachers and others assign various meanings to data, make inferences from data, create explanations for observed patterns, and imagine useful responses to the patterns they detect. A second starting point takes the form of "zooming out" to locate those specific interactions in the structure and fabric of organizational life—for example, by tracing the emergence of new organizational routines and the ways they juxtapose, modify, transform, or displace established ways of working. (p. 160)

The PD project described in this article "zooms in" on teacher perspectives in relation to models and modeling, and then "zooms out" to find those instances during the PD. This strategy enabled the authors to discover why were the PD modeling results were different than expected in relation to teaching modeling in K-12 settings.

The principles of effective PD, and potential discrepancies between perception and practice factored into this study. This project RAMPED PD was a mix of a traditional and a reform model. The participants traveled to a regional location to study for 2 weeks; and, the learning was collaborative and active with offered support once the teacher participants were back in the classroom. Participants actively engaged in computer science modeling activities throughout the 2-week session, and they were provided with the opportunity to engage with the faculty throughout the year and years to come. As the authors reflected on the PD project, they found that although the participants self-reported enjoyment of their PD experience, most did not seemingly enact significant changes to their classrooms. While this trend is not unique, it did leave the authors questioning whether the modeling language used during the PD created some of the modeling disconnect (and lack of teching modeling in the classroom), since an enormous amount of planning went into creating the active PD spaces to ensure authentic engagement, meaningful learning, and partnership building (Burrows, 2015; Burrows et al., 2016; Darling-Hammond et al., 2017 Loukes-Horsley et al., 2010; Shernoff et al., 2017; Srikoom et al., 2018).

Computational Modeling

Darling-Hammond et al. (2017) explain that PD utilizing models of effective practice supports teacher learning and student achievement. However, their "use of models and modeling" does not fit the definition of 'model' in this article's PD study. For this [project] PD, the term *model* immediately set the various faculty involved on separate paths: computer science data models (the intended use as used by Hodosh et al., 2013), teacher modeling practice ('I do -we do -you do' as used by Deagon, 2021), teaching and framework models (learning, process, concept, logic, change as used by Priemer et al., 2020), harnessing role models (representation from individuals as used by Bell et al., 2010; Faulkner & Latham, 2016; Hutton, 2019; Windschitl, 2004), and creating various project, curricular, and other models (exemplars as used by Darling-Hammond et al., 2017). See Figure 1 for an overview of these five concepts of modeling. Computer science modeling (what the project PD focused on) is a concept that can involve computational thinking and often promotes transformation and visualization of data (Borowczak & Burrows, 2019; Burkins & Yaris, 2019; Hodosh et al., 2013, Lovett & Forbus, 2017; Psycharis, 2018). To that end, computer science is a combination of problem-solving and optimization for domain specific applications, while balancing the societal and ethical implications of implementing algorithms as software often executed on real-world hardware platforms (Borowczak & Burrows, 2019; Lovett & Forbus, 2017; Psycharis, 2018). Additionally, computational thinking is specifically targeted reasoning through complex problems (Borowczak & Burrows, 2019; Grover & Pea, 2018; NRC, 2010; Wing, 2008). Several authors argue that computer science and computational thinking are separate disciplines (Barr & Stephenson, 2011; Kotsopoulos et al., 2017). As the STEM integration experts, the PD team promoted computational thinking as a component of computer science modeling, which includes the skill set of creating a representation of an algorithm (making a model). The representation of the algorithm manifesting in the model can be either theoretical (e.g., climate change models) or practical (e.g., new building construction). Wing (2008) explained computational thinking as that it is an "approach to solving problems, designing systems and understanding human behavior that draws on concepts fundamental to computing" (p. 3717).

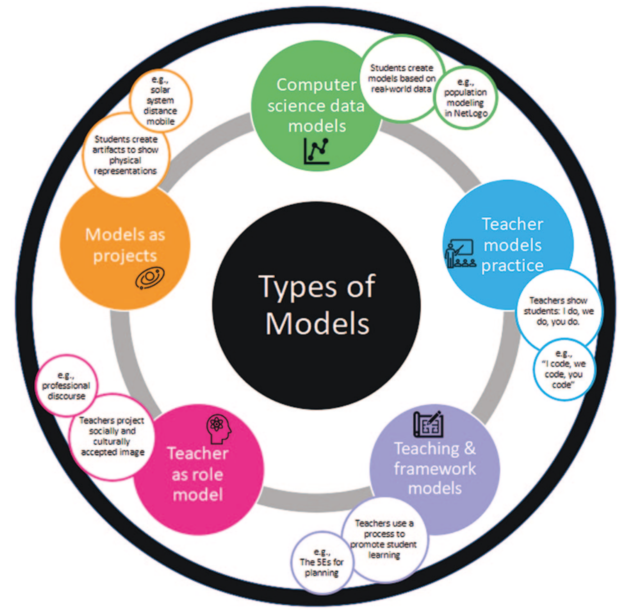

Figure 1. Educator identification, definitions, and examples of various model interpretations.

The concept of computational thinking is complex as it draws several connected ideas into direct and supportive contact with the other. It has been described it as "the application of high level of abstraction and an algorithmic approach to solve any kind of problem" (Weintrop et al., 2016, p. vi). For classroom purposes, it can be described as "a definition of computational thinking for mathematics and science in the form of a taxonomy consisting of four main categories: data practices, modeling and simulation practices, computational problem solving practices, and systems thinking practices" (Weintrop et al., 2016, p. 127). Computer science modeling is an important concept in STEM as it showcases the ability to display evidence, but computer science and computational thinking have been largely absent in the K-12 as well as higher education sectors (Sentence et al., 2018). With all the quickly changing pieces of a larger computer science puzzle, these types of STEM topics and their STEM discipline integration is on the horizon (Johnson et al., 2020).

Others discuss embodied modeling, which "introduces the students to the relevant computational rules represented by the agent-based programming commands, [and] helps them debug their programs and deepens their understanding of the graphs in the simulation" (Sengupta et al., 2018, p. 17). In other words, embodied modeling engages the student through the active learning of working with the problems, experiencing the programming rules that would help them understand the problems, and producing solutions to their problems. They found that students "were able to develop progressively more complex forms of mechanistic explanations of emergence" (Sengupta et al., 2018, p. 19) as they worked through the embodied modeling in the classroom. They believed that the emergence of computational modeling, and embodied modeling, in the classroom could help students grasp deeper STEM concepts, and it was their articulation that spurred the authors to create this article.

Teacher Modeling

Separate from computational modeling, the first author envisioned modeling as entirely different when it was mentioned in the PD conversation. One example of his modeling concept is explicated in Bandura's Social Learning theory (Tracey & Morrow, 2012). In Bandura's four phases of observational learning, the students see and watch the model, think about and process what took place, attempt the activity that was modeled, and then receive feedback based on their attempts (Tracey & Morrow, 2012). Coming from a literacy education perspective, the first author envisioned modeling where the teacher *models* the strategy or technique that a teacher wants a student to use (Deagon, 2021; Duke et al., 2011). The authors refer to this as teacher modeling practice in Figure 1. This is when teachers make their invisible thinking about a text visible to the student by doing a think aloud or walking them through a step in a comprehension or composition process (Beers, 2003; Deagon, 2021). Further, Burkins and Yaris (2019) clearly explained modeling as:

> The teacher presents students with a new skill or strategy. At the beginning of the lesson, the teacher provides students a model for what new learning looks like by thinking aloud or otherwise demonstrating the skill or strategy in action. Students watch carefully as the teacher demonstrates. (p. 1).

In other words, showing students teacher thinking, as they demonstrate for the students what it is that teachers do, as they read texts so the students can understand that it is a process that takes place, and not simply something that happens.

Theoretical Frameworks

Two specific theoretical frameworks informed this examination of the potential PD modeling disconnect between the faculty and the participants and are explained in more detail in the next sections: terministic screens and schema theory. Each framework added a level of understanding as to why the participants might have interacted with the discourse differently than the faculty intended.

Terministic Screens

Burke (1966) utilized terministic screens to explain how different people understand the same word. A terministic screen is "any nomenclature [that] necessarily directs the attention into some channels rather than others" (p. 45). In other words, the way speakers use words leads listeners to a certain termination, a certain end, which then crucially impacts how that word is perceived after it is used and could potentially produce differences that make understanding more difficult. As Burke noted, "Much that we take as observations about 'reality' may be but the spinning out of possibilities in our particular choice of terms" (p. 46). In a PD, the terms that the faculty used functioned as certain terministic screens that were relevant to what was happening. The participants, on the other hand, may have had a different concept of that terministic screen, which could have sent them down a path that was different than originally intended. One term, such as *modeling*, could have a positive or negative impact depending on the screens through which those terms were understood. What may be a carefully chosen word by the faculty could be viewed through an entirely different terministic screen by the participants, leading to a miscommunication, or worse, and could seriously impact the overall quality of the PD session simply because the terministic screens functioned distinctly for the faculty and participants.

Schema Theory

While terministic screens function in both the faculty and participants, schema theory explains how the participants take what is being taught and create their own knowledge and learning. Schema theory suggests that learners attach information to previously generated, though mutable, schema in their own understandings (Tracey & Morrow, 2012). From this perspective, a learner, when confronted with new information, attempts to find connections to preexisting schema in order to make sense of it. When the new information can connect to previous schema, the learner has an easier time learning and understanding the new information. However, if there are no connections, or misleading connections, the learner may have a more difficult time with the new information. Granted, schema can change, and be altered, and information that does not connect to current schema can shift schema for the learner (Tracey & Morrow, 2012), but that initial moment of learning can be either positively or negatively impacted by the connections to the schema of the learner. As an example, Quinlan (2019) utilized schema theory as a framework to explain what happened as preservice teachers engaged in digitally examining an authentic crime scene. She argued that "schema development would be akin to talent development that is sustained and becomes a working schema that students could retrieve and apply to other situations" (Quinlan, 2019, p. 417). In the case of this research study, the modeling question was not just about application of working schema, but about how that working schema of the participants might be different than that of the faculty.

Terministic screens and schema theory functioned together throughout this study. As Gee (2021) noted, meaning is a constant negotiation between the speaker and the listener: "meanings are not definitions; rather, meanings are conventional ways of using words in talk and in writing across multiple contexts" (p. 115). As an example, the authors of this research did not begin with the same concept of model. The second author was enthusiastic about teaching and implementing 'modeling' in the PD and spoke enthusiastically about the potential for integrations across K-12 classrooms, supports that it could offer students, and the potential

Table 1. Overall participant demographics in RAMPED.

	40 total participants	
Baseline participant characteristic	n	%
Gender		
*Female	27	67.5%
*Male	13	32.5%
Grades Taught		
*Elementary (E)	13	32.5%
*Middle School (MS)	9	22.5%
*High School (HS)	11	27.5%
*Combination (E, MS, HS)	7	17.5%
Subjects Taught		
*Science	9	22.5%
*Technology/Library	4	10%
Engineering	2	5%
*Mathematics	2	5%
*STEM combination	5	12.5%
*Computer Science/Computers	3	7.5%
*Industrial Arts/Welding	3	7.5%
*All subjects (elementary)	7	17.5%
*Other disciplines	5	12.5%

Note. Some group participants marked with an * were interviewed during the two-week session

benefits for teaching integrated STEM content. Yet, the terministic screen for *modeling* was a stumbling block. The second author referred to computer science modeling of scenarios (Sengupta et al., 2018); the first author referred to the teacher practice of I do-we do-you do (Burkins & Yaris, 2019). From there the schema of the first author struggled both to understand the second author and other faculty, and to more fully understand how modeling was going to be used in the classroom. The terministic screen caused the initial confusion, but the first author also had no schema to attach to computer science modeling. This initial miscommunication, based on terministic screens and schema, foreshadowed the difficulties of the participants in the RAMPED PD sessions.

These two theoretical perspectives shaped the analysis and assisted us in understanding why certain aspects of the PD did not match the project RAMPED team's expectations. Through these theories, the team began to understand where terministic screens led to the discrepancy between the language that the faculty used from their schema and the language that the participants heard and applied to their schema.

Methods

As a project overview, during the summer of 2018, 40 teachers from across the west came to a university campus to participate in a 2-week PD centered around computer science and its integration into the classroom called project RAMPED. Participants attended four sessions throughout the 2 weeks to experience how to integrate computer science into the classrooms and help students identify common computer science themes (e.g., patterns and problem-solving). This PD came at a time when the state placed an increased focus on computer science, mandating that every district teach computer science within the next few years. Specifically, RAMPED focused on using meaningful examples that teachers could use "as is" or transform to integrate computer science and computational thinking into their classrooms. The examples provided K-12 teachers and their students real-world instances and hands-on experiences. Importantly for the PD team, the project did not provide a packet of ready-to-use' lessons to take immediately into teaching nine weeks or a semester. Instead the PD focused on already created lessons freely available and helping participants investigate the underlying computer science concepts and their ability to integrate into other subjects, so they could apply computer science in their own classrooms. The participants were encouraged to transform the examples. The faculty leaders were reflective as well as reflexive during the PD.

Participants

In this qualitative research study, 40 teachers from 19 school districts across the region attended, ranging from elementary teachers to high school teachers (full K-12 range participation). Most participants taught math or science, but there were also teachers of English, choir, and other disciplines, representing the integration that was one of the focal points of the PD (see Table 1 and Table 2). Participants attended four sessions including machine learning, anomaly detection, large astronomical distances, and virtual reality, which all related to computer science and its integrative potential. Data was collected via surveys, interviews, and a follow-up email.

Data-Collection

The authors collected survey, interview, and email responses as data sources. At the beginning of each session, every participant completed a survey on a number of topics relevant to computer science in the classroom. For this study, two questions were uniquely important for data analysis. First was, "When you think about modeling in the classroom, what do you envision? What comes to your mind? What do you see?" Second was, "Write about a way that you have used modeling in your classroom or have seen (or heard about) another teacher use modeling in the classroom." Participants were given no context for these questions, other than that they were for helping the team to situate the week's events. At the end of the session, participants completed a survey with the same two questions. Again, they were given no instructions, but this occurred after they completed sessions centered around computer science and modeling. It is important to note that computer science in this project included some coding, but it was made explicit that computer science was not coding, and coding was a tool that computer scientists utilized. Additionally, during the sessions over the 2 weeks, 14 participants were pulled aside and interviewed (see Table 1).

Table 2. Breakdown of participant demographics in RAMPED.

	Interviewed By Gender			Participants by Gender		
Subjects & Level Taught	Female	Male	Total Interviewed	Female	Male	Total Participants
Elementary School	4		4	10	3	13
1st Grade – all subjects	1		1	2		2
2nd Grade – all subjects				1		1
3rd Grade – all subjects				1		1
4th Grade – all subjects				1		1
Computer Lab				1		1
Computer Science	1		1	1		1
Kindergarten – all subjects					1	1
Math				1		1
Multiple Grades - all subjects	1		1	1		1
Physical Education					1	1
STEM Classes					1	1
Technology/Library	1		1	1		1
Elementary, Middle School		1	1	1	1	2
Science		1	1		1	1
STEM Classes				1		1
High School	2	1	3	7	4	11
Computer					1	1
English	1		1	1		1
Science	1		1	4	2	6
Social Studies				1		1
Special Education				1		1
Welding		1	1		1	1
K-12				2		2
Library				2		2
Middle School	3	1	4	6	3	9
Engineering				2		2
Industrial Arts					1	1
Math	1		1	1		1
Math/Science	1		1	1	1	2
Pre-service – Science	1		1	1		1
Science		1	1		1	1
Technology/Library				1		1
Middle School, High School	1	1	2	1	1	2
Choir		1	1		1	1
Math/Science	1		1	1		1
Trade school AAS. Business					1	1
Welding					1	1
Grand Total	10	4	14	27	13	40

Participants were asked to come outside during the day's activities for the interview as to make the interviews the least disruptive to the participant's time. They were offered different days and times to interview and could change if their selected day and time was inconvenient when it arrived. The interviewer went to the participants, and most interviews were individual; however, two sets of participants interviewed together due to time and scheduling constraints. The questions asked revolved around computer science and coding (both familiarity with and use in the classroom), STEM integration, and modeling. Interviews were recorded and lasted between 10 and 20 minutes. Finally, during the following academic year (2018–2019), participants were encouraged to apply what they learned, and at the end of the year, they responded to a final email survey which asked them what they incorporated into their classrooms, how often they incorporated new ideas from the PD, and what the outcome was after their yearlong experience.

Researcher Involvement

To further understand this study, the reader can benefit from learning about the authors. The three authors participated in various aspects of the yearlong project that started with two weeks in the summer. Author 1 and Author 2 initially discussed the PD sessions and the focus, which included modeling. Author 1, an English teacher educator, helped create survey questions for modeling, and then interviewed participants during the PD. As a literacy researcher, Author 1's background was not in computational modeling, or any of the content of the PD. Author 2, on the other hand, is a science teacher educator, and the lead designer of the PD. She focused on the integrated STEM component and bringing critical PD concepts into the daily activities of the project. Author 2 along with Author 3 created the focus on computer science and computational modeling and helped recruit both faculty and participants for the PD sessions. Author 2 was the educational lead while Author 3 was the content expert lead for the project, and every participant activity was crafted to stretch participant thinking, give time for practice and reflection, focus on content, offer collaborative disciplinary spaces, provide feedback, and promote engagement for over a year of time (starting that summer for two full weeks of 80+ hours). During the entire PD, the faculty leaders were reflecting on what happened but also reflexive in self-assessing and reacting to the PD events and participant feedback.

As noted above, the initial confusion between Authors 1 and 2 created the impetus for this study to examine participant perceptions of '*model*.' Noting author positions is important (Creswell & Poth, 2018), because positioning does help explain why the authors viewed this confusion as important. As a science educator, Author 2 was incredibly excited about the potential of models in the classroom, but Author 1, from a literacy and English background, believed Author 2 was talking about a different kind of modeling. When the authors discussed these issues, the team wondered, if the participants had the same thoughts and confusions. Thus, the problem investigated was, "Why were the PD modeling results different than expected in relation to teaching modeling in K-12 settings?"

Analysis

The authors coded the data points by groupings themes in the data (Saldaña, 2013). Because modeling was one focus of the project PD, as well as one of the initial confusions between the authors, the data was themed by looking for instances when the participants defined or described modeling. At those points, the data were coded as "modeling is x." For example, one participant said, "I envision modeling as me modeling what they need to do, and so the students watch me do it, and then they do it." This was coded as, "modeling is I do-we do-you do." In response to the same question another participant said, "I think about programmatic representations of any interesting system or process. I mainly use agent-based modeling with students because they enjoy it." This was coded as "modeling is a computer model." All interviews, pre- and post-surveys, and emails were coded in a similar fashion. On the first coding, eight themes were developed throughout the data, and then applied to each. For the second coding, those eight initial themes were combined into three meta-themes, and all data were coded again with these meta themes to ensure that all categories were used for each piece of data. Once coding was complete, specific examples of each code were then analyzed to look for common trends or ideas throughout the data. Triangulation of the data was considered during analysis, and the authors addressed the phenomenon of stakeholder modeling perceptions by using multiple data sources to focus on consistency (Denzin, 1978), as well as multiple types of analyses to promote study rigor (Leech & Onwuegbuzie, 2007).

Findings

Overall, there was confusion about the term modeling with not only the faculty team leaders, but also with the teacher participants. One participant clearly articulated what the authors found in the data: "I'm taking this computer class, and he keeps using this word "modeling" in a different term. . . so I don't think he's thinking the same modeling. I think we're not on the same page." For this participant, the different terministic screens around the term *modeling* created initial confusions, but the participant was able to identify this issue. This type of discrepancy continued to appear; even though some participants embraced the faculty's use of modeling, the majority did not.

Surveys

In the pre surveys, participants responses to the modeling question were grouped into eight initial themes around the terministic screen for modeling: 1) modeling is computer/conceptual modeling; 2) modeling is I do-we do-you do; and 3) modeling is projects. There were 5 instances of participants writing that modeling is computer/conceptual modeling, 29 instances for I do-we do-you do, and 6 instances for modeling as projects (see Figure 1). The authors found a difference between total participants and total coded instances because some participants described modeling as more than one meta theme. Given the lack of context before participants responded to this survey, their responses were not surprising, but it did show that there were differences in the terministic screen *modeling* that could lead to differences in schema access and understanding. Because of the numbers of coded instances, the first two meta-themes will be further analyzed.

Those who wrote of computer/computational modeling tended to write something like this participant: "When I think of modeling, I think of systems and physical or mathematical representations of real-world phenomena. I see student/student and student/teacher collaboration to define system boundaries and determine appropriated scaling, variables, and constraints." There was a clear focus on using the model to represent a system of processes so that students could see or understand how something might function. For example, another participant wrote, "The kids were studying wildlife issues in [state] and they created models in NetLogo to show how some of the pressures [that] wildlife face change their breeding, eating, etc. . . patterns." This response closely aligned to the perspective of the faculty of the PD.

However, those who thought of modeling as I do-we do-you do represented the majority of the participants. One participant was very succinct: "When I think of modeling in the classroom, I think of the classic approach of I do, we do, you do. This approach can be used in any situation with teaching be it modeling behavior, reading strategies, math games, basic robotics kits like WEDO2.0, and art projects." In this case, modeling was not limited to computer science, which was one facet of the project; in fact, the participant noted that it could be used an any situation. Another participant linked the concept to computer science but kept the concept of the model the same: "I think of the I do-we do- you do approach. I'm not in a regular classroom. I'm strictly in the computer lab! When it comes to programs, Lego robotics or daily lessons, it's always best to show and gather understanding together through hands on approach before turning [the students] loose." Modeling was teaching the students how to do the procedure, demonstrating for them, and then working with them as they moved into the process themselves. Again, the concept of modeling dealt with helping students perform a task and not what the faculty envisioned with the concept of modeling. It appeared that many participants had a specific terministic screen regarding modeling; the attached schema surrounding that terministic screen led to some discrepancies between faculty and participant concepts of modeling before the PD began. During the PD, the team did not realize the confusion quickly enough to adjust teaching and activities to accommodate the different terministic screens.

The participants completed the post in a classroom on the last day of the PD. After 2 weeks of intensive classes on computer science modeling, impact of the PD on the participants was not as large as expected. On the survey, there were 24 instances of defining modeling as I do-we do-you do (down from 29 pre-survey responses), compared to 11 instances of modeling as computer/conceptual modeling (up from five pre-survey responses). There were also four instances of modeling as projects (down from five pre-survey responses). Even though the final survey was completed during the last session, four participants did not complete the survey.

As a PD success, the 11 participant responses showing instances of modeling as computer/conceptual modeling was an increased compared to the pre survey, and those who viewed modeling as computer/conceptual modeling showed that they matched the faculty team members' concepts. One participant further articulated "Modeling is a representation of evidence, or novel approaches to visualized problem/solutions/inquiry." Another wrote that modeling was "creating situations – physically or on a computer – that allows students to conceptualize big pictures into meaningful pieces." One participant wrote that modeling was "building a system to perform a task" and "anomaly detection." These definitions were part of the 2-week session.

Nonetheless, the dominant concept of modeling was still I do-we do-you do. Participants tended to phrase it exactly like that, as this participant did: "I do, we do, you do. I like to give a ton of examples to make sure everyone can be independent with their learning." And another one: "I do, you do, we do. Students learning by observing instructor and peers and then being able to apply and retry." Some thought that modeling was just demonstration, the I do part of the modeling: "I envision demonstration. I demonstrate proper tone production, etc., all the time." Another participant wrote, "Teacher (usually) demonstrating a skill, procedure, or finished project." This concept of modeling fit with the I do-we do-you do structure; they only wrote about the first part without referencing the second and third parts. Again, like at the beginning of the PD, many participants had a set terministic screen and attached schema for modeling, and when asked about modeling in the post interviews, continued to operate with that concept.

Interviews

The participant interviews, which were conducted during the course of the 2-week sessions, yielded similar results, with one exception. No one interviewed spoke about modeling as projects. However, there were 21 coded instances of modeling as I do-we do-you do, and 11 coded instances of modeling as computer/computational modeling. Even during the PD as they stepped out of activities focused on computer science modeling, participants kept their terministic screen about what modeling was and tried to fit the project pieces into that mindset.

Participants who spoke of computational/computer modeling said similar things. One said, "You're talking about vast systems of looking at large amounts of data and running it through processes and getting trends out of it." Another participant was more specific:

> Let's say you're doing like the Ideal Gas Law. So, you can start to manipulate these variables in a simulation, and so as you manipulate these variables you can start to develop an understanding of the patterns and trends and when this goes up, this goes down. When this – so I see it as a way to help students make connections with more complex ideas.

In these cases, the participants aligned their terministic screen with the focus of the PD, and began either to modify their concepts of modeling, or to confirm that they were on the right track.

Yet, many participants still operated under the concept of modeling as I do-we do-you do. "So, modeling for me is when it's I do, we do, you do. So, the instructor or the teacher demonstrates the expectation. Then we all go through the expectation together. And then the [students] are left to do it on their own." Another participant said, "There's modeling where I go up and show them how something is actually done and then I expect them to come back and do it in that fashion or do something similar and take it a step further."

Even when they spoke of computer science ideas, some still referred back to the same concept:

> I like to take the [students] maybe step-by-step the first time, teach them the basic concept, basic programming, basic drag-and-drop and then kind of let them explore a little bit and make combinations for themselves and let me – let them show me what they have learned or what they've done. And then I'll come back and teach another piece. . .

The initial terministic screen of modeling, which was present before the session began, continued to be a dominant concept even during and after the 2-week PD.

Email Question Reflections

Overall, 25 participants (25/40, 62.5%) responded to the email questions sent out at the end of the yearlong PD and follow-up, and the large majority reported trying something new. Twenty-three of the 25 respondents reported using a new idea from the summer PD (23/25, 92%). Even if all 40 participants had responded, and keeping only the positive results from the 25 respondents, a majority of participants would still self-report that classroom changes, because of the PD, were implemented (23/40, 57.5%). The classroom changes and additions ranged from a single 15-minute lesson to a weekly 1-hour activity time. The average amount of new lessons for the group was approximately five lessons or class periods for the year. Of the 25 respondents, two participants reported that they did not implement anything new in their classrooms.

With 23 or 25 respondents reporting a change, the participants reported a range of PD impact on their professional practices from transformation to unengaged. For example, one participant wrote:

> . . .computer science is about problem solving and critical thinking and it enhances what we are already doing in schools. It took me all of RAMPED to understand this concept. . . .we have evolved from finding the "right answer" to creating solutions.

Another wrote, "I purposely inject content from RAMPED into class discussions such as data collection, anomaly detection, algorithms, and spatial analysis." These are representative of the participants who had positive interactions with the content. Those who had less engaged reactions wrote of the inability to add PD content because of time, budget, or supply constraints. A few, though, wrote about the inherent language problems that created a disconnect between the faculty and the participants. One participant wrote:

> Even though all the [faculty] presented their topics very well and demonstrated great knowledge and willingness to enlighten us, they were operating at a level of comprehension several leagues above your average public-school teacher. I was often lost on much of the math and programming language. Sort of like listening to the air traffic control talking to aircraft coming into a large airport.

In relation to this frustration, the participant was complimentary and positive about the event and attempted to implement some of the lessons. Another participant wrote, ". . . everything we did in the summer class was at too high of a level from me to understand, let alone teach to 3rd graders." In both of these cases, the language used, and the level of math discussed for some of the participants, created problems for other participants that made it difficult to bring the concepts to their classroom. They expressed a desire to bring the concepts into their classrooms, and even with the efforts of [project] faculty to bring concepts such as patterns and problem-solving into every session, there were areas of mismatched expectations and language confusion.

Time to create lessons and ability to use those lessons as part of a district curriculum also posed problems for some participants. Although PD time and resources were used to provide support for teachers creating their own materials, one participant wrote:

> I think it would be beneficial to create lessons that tie into our curriculum; being able to adjust some of the language of the lessons we are required to teach, to integrate computer science ideas would be much more helpful than lessons I have to find time to teach separately, make meaningful, and connect to something. . . .

As stated above, the goal of project RAMPED was not to provide a strictly followed set of lessons, but to create a deeper understanding for computer science application that would enable the participants to modify and create their own resources for the classroom. For this participant, however, the lessons learned from the PD felt more like extracurricular subjects in a school curriculum that was already defined, instead of computer science modeling integration into any discipline. This example, which was echoed by some other participants, demonstrates some of the differences in transferable lessons between the faculty instructors and teacher participants. The faculty wanted to change a mind set about computer science and modeling in the classroom; some participants wanted immediate lessons to instantly enact in the classroom.

Surprisingly to the authors, no participants mentioned modeling specifically in their emailed answers, either the computational modeling that was the focus of the project PD, or the I do-we do-you do modeling that was prominent in the participants' conceptual understanding of the term. This could be due to the lack of a specific modeling question on the email survey, or in the implicit nature of the modeling definition during the session, but it could also be because the participants had returned to their home schools, and their personal terministic screens and schema, and did not see a need to explain it further. Either way, the absence of modeling from the email responses was curious could be an important omission and telling for the authors of the study.

Discussion

Educational researchers agree that quality teacher PDs are both needed and require attention to multiple components (see critical pieces of PD from the literature review such as Darling-Hammond, 2017), and that changing mindsets is difficult (see terministric screens and schema theory in theoretical frameworks); however, even though those two pieces were tackled during the PD project creation, there were persistent disconnects. For example, the [RAMPED] PD was: 1) set at a sufficient duration (yearlong); 2) focused on content (STEM modeling); 3) anchored on how the participants learned, designed, and delivered content (work sessions to create lessons with support); 4) set in a collaborative and active format that fostered active creation of knowledge (problem solving labs with self-selected level and pacing); 5) showcased effective practice (successful lessons showcased and practiced); 6) provided a space for mentoring and support (yearlong follow-up sessions and offers of co-leading lessons); and 7) provided a space for offering feedback, providing time for reflection, in ways that embed practice in the participants' classrooms (feedback provided on summer lessons and just-in-time feedback on videos) (e.g., Bates & Morgan 2018; Darling-Hammond et al., 2017; Desimone et al., 2002; Garet et al., 2001; Abrahams et al., 2014; McGee et al., 2013; Zaccarelli et al., 2018).

With all of this attention to PD creation, upon reflection, the authors identified that there was not enough attention on terministic screens and schema theory in setting up the PD computer science modeling activities. Although the PD did result in a majority of teachers (57.5%) reporting that classroom changes were implemented, the PD could have delivered a more substantial impact. The classroom implementations likely did not include the attention to computer science modeling that the PD creators intended, and the student work that was provided by the teachers was not analyzed for this study.

There is great positive potential for computer science modeling in the K-12 classroom, but based on this study, that must be fostered on a larger scale than initial PD construction. Sengupta et al. (2018) argued that "by engaging in iterative cycles of building, sharing, refining, and verifying computational models, students refine their understanding of what actions and interactions of agents represent an 'event,' which are then displayed on graphs" (p. 17). This statement is what drove the heart of the RAMPED. By assisting participants to visualize and understand this modeling potential for their students, the faculty were inspired to support participants to take PD 'model' learning back to K-12 classrooms to engage students in new levels of computer science thinking. It was during the PD sessions, and in subsequent check-ins with the participants after the initial two weeks, that the project team found a participant language divide that was keeping the positive messages about the computer science modeling practices from being fully realized. As a result, and after this study, the team realized that modeling language used by the instructors, and the interpretations of that language by the participants, created confusion for all parties invovled.

The authors found that the term *model* was especially problematic. The majority of the participants came to the PD with a terministic screen of *model* firmly in place. When participants heard *model*, many immediately thought of the I do-we do-you do concept, as evidenced by their responses in the interviews and surveys. The results of this study show that the PD instruction on modeling throughout the sessions did not move participants past their original terministic screen of modeling. Consequently, the computer science modeling that the faculty were teaching had no schema to attach to in the participants' views, which led to the disconnect. When the participants heard *model* and attached that to their schema of *model*, their attention was necessarily directed toward certain things (how the teacher models, what the model is, how the students learn from the model) and not toward what the representation of the computer science model taught by the instructors. Even though it is just one word, the participants' terministic screen for *model* and attached schema were powerful enough to overcome even direct faculty instruction on modeling throughout the two summer weeks and in the follow-up sessions held throughout the year.

Gee (2021) echoed this concept: "People in a given social group, by repeated practice, come to agree (consciously or unconsciously) how to use a word in a range of contexts. When problems arise, they negotiate the matter" (p. 113). In this PD, because the differences in terministic screens around the word modeling were not initially recognized, the full negotiation between faculty and participants could not take place, and without that negotiation, both groups were left with their own meanings. As participants went back to their districts, then, negotiation could no longer occur not only because of proximity and distance, but also because a lack of understanding by both parties that further negotiation was necessary.

Since terministic screens determine the meanings people focus on and the schema they can attach to (Burke, 1966), the necessity of negotiation is not a minor issue. As Gee (2021) pointed out, meanings must be constantly evaluated and modified; "because words are conventions about how to say things in different contexts, they are, like all conventions, prone to become out of date, no longer useful" (p. 114). In this case, the different terministic screens operating in the PD caused the term *modeling* to lose its usefulness. Without the important negotiation of those screens between faculty and participants, the focus of the PD, which was the faculty's terministic screen with modeling, mostly became lost, leading to more disconnect between all involved.

The project team does recognize several limitations in this study. One limitation is attempting to reach a large audience (40 teachers) of all subjects and grade levels (teachers of students aged five to 18). This was an intentional choice by the project team (which included state leaders and community members) as a proof of concept. The team realized that this is not the ideal method to hone PD messages and experiences, and this study reinforces that idea (e.g., elementary teachers experience different needs than secondary teachers). Another limitation was the distance between participants and faculty. While the participants and faculty were mostly from one state and all together over the summer, the geographical distances between the individuals ranged between a few miles to hundreds of miles during the academic year follow-up sessions. Although email and other virtual meeting mechanisms were in place during the academic year, this distance proved troublesome to some participants that wanted more one-on-one instruction. The third large limitation was the self-selection of the teachers to participate in the PD. There was a statewide call for participation, and thus this was not a random sample of participants. Lastly, with only 40 participants this study can serve as a guide for others to consider but cannot be generalizable to the larger population of teacher PD participants.

Implications

As the team planned and enacted the next PD after [RAMPED], there were two major implications that were utilized and recommended for computer science modeling. First, the team did not take terms for granted, nor did they assume that because the content had been announced and because the term was a vital part of that content, that participants would necessarily gain this knowledge without explicit definitions of the terms and a focus on schema building. The team should have noticed this earlier in the PD creation, as the authors spent a few weeks each thinking about modeling (but doing so in completely different ways). By the time the authors came to this understanding almost at the end of the summer sessions, it was too late for replanning the PD sessions, and the authors, from different disciplines, thought it might only be a miscommunication. The authors, after the PD and after analyzing the data from this study, found mismatched mindsets for modeling, integrated STEM, and even for simple messages that were made explicit like problem-solving, critical thinking, and patterns. This work focused on models.

The project team encourages being explicit about the definitions and concepts being used, not just in how they are used, but also in how participants demonstrate and apply them (by one definition of modeling used by Darling-Hammond, 2017). This may sound simplistic in educational settings. However, content areas and cultural interactions are different enough that the same terms are used in multiple content areas, but with different meanings. For example, in the Common Core State Standards (CCSS) for mathematics, computational modeling is present, and aligns with what the faculty believed about modeling. However, in writing instruction, modeling refers to both the teacher writing along with the students and presenting the model, and with teachers using examples, or models, from the texts that students are reading to help them explore new writing techniques. Elementary teachers, like the ones who attended the PD, can be exposed to one or both of these definitions.

Second, the project team strongly encourages open negotiation of the terms being used in the PD. If PD providers do not clearly and consistently explain and define the disciplinary terms used, and also give participants the opportunity to negotiate their understandings with what is presented, then PDs run the risk of opposing participants' terministic screens, and either lack of schema or misplaced schema. Again, this negotiation is not a minor issue since the terms used determine the perspective and values of the person using them (Gee, 2021). When terministic screens and meaning do not match, and when there is no space for negotiation, the potential for discrepancy grows, as does the potential that the participants' experiences will not match the faculty's PD intent.

These may appear to be inconsequential steps, too small to be worthwhile and too obvious to be mentioned. However, the absence of clear meanings and two-way negotiation of those meanings can lead to either a derailing of the PD, or at least a feeling of failure by those who planned the event. In this case, the team's expectation of teachers producing sustained computer science modeling in their classrooms was only partially met. During the two weeks, everyone was engaged, integrated STEM activities were explored, and participants showcased their work. The interviews were full of positivity and enthusiasm about the PD experience. Even the post surveys and email responses had positive things to say about the experience. However, even though the instructors offered to work with the teachers (in-person or virtually) on their schedules and enact any part of the program they desired, the transfer to practice was not as impactful as originally desired. A change in explicitly defining the terms, and embracing the competing motivations, though, may have had an impact. Lastly, the authors, wanting to explore the successes as well as the K-12 teacher challenges, write this article to open discussion around computer science education and modeling, and encourage others to continued research studies on language use and STEM integration.

Future Directions

Bourdieu's Theory of Capital (1986) could provide a future direction for this type of work. The concepts of capital help to explore the motivations behind those presenting the PD (e.g., faculty) and those attending the PD (e.g., participants), specifically embodied cultural capital and economic capital. Further, Howard (2011), made the connection between Bourdieu's theory and the classroom. In her examination, writing instructors viewed the classes and assignments as a way for the students to build embodied cultural capital as they gained the skills necessary for writing in the academy and beyond for economic capital. For the students, efficiency is important, because the goal is conversion to economic capital; for the instructors, learning is important, since it will enhance the individual's embodied cultural capital. These concepts of capital could be translated to a PD study. Is motivation for being in a PD what was assumed (e.g., teaching, learning, embodied cultural capital) or is it the economic advantage (e.g., stipend, economic capital), or could it be a blend of both and what could shape this perception?

While the differences in desired capital could be an important avenue for future study, the necessary discursive negation between schema and terministic screens should take place. Adding a space for that negotiation to this PD may have positively impacted the results. Ensuring that space for terministic and schema negotiation is present will be an important implication for our future PD work.

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Ethical Approval

This STEM PD study was approved by the Institutional Review Board of the University of Wyoming (protocol #20150921AB00901, 21 September 2015).

Informed Consent

Written consent was obtained from the participants.

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