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Science Teachers' Negotiation of Professional Vision around Dilemmas of Science Teaching in a Professional Development Context

Jonathan McCausland ^{a*}, Jennifer Jackson^a, Scott McDonald^a, Kathryn Bateman^{b**}, Amy Pallant^c, and Hee-Sun Lee^c

^aCurriculum and Instruction, The Pennsylvania State University, University Park, Pennsylvania, USA; ^bCreate for STEM, Michigan State University, East Lansing, Michigan, USA; ^cThe Concord Consortium, Concord, Massachusetts, USA

ABSTRACT

Learning to teach is a culturally situated activity. As teachers learn, it is important to understand not only what teachers learn, but how they learn. This article describes a qualitative case study of a subset of four teachers' learning during a professional development surrounding a plate tectonics curriculum. Using qualitative methods, this study tells the story of how the four teachers negotiated professional vision for science teaching around dilemmas that emerged throughout the professional development. By taking a sociocultural perspective on professional vision, researchers can gain insight into how and what teachers learn in professional development settings because it renders teacher learning complex and nuanced. Additionally, we argue negotiating professional vision parallels sensemaking. Sensemaking around science teaching includes grappling with epistemic issues of science in addition to pedagogy and curriculum. Implications for science teacher education are discussed. Specifically, we argue learning to teach requires teachers to engage in conversations that create opportunities to "get somewhere" in relation to dilemmas they have about teaching. In this way, professional vision is an ongoing process of learning that has no endpoint or ideal articulation of teaching or science. Therefore, by framing professional vision as a process of learning we are able to push back on simplistic descriptions of teaching and science.

KEYWORDS

Dilemmas; professional development; professional vision; teacher learning

Introduction

This paper describes the learning of a group of teachers in a professional development experience as they negotiate the meaning of curricular materials and pedagogy in order to use it in their particular school contexts and align the materials and pedagogy to their own teaching practice. The goal of the professional development (PD) was to support teachers in integrating a curriculum about plate tectonics grounded in Ambitious Science Teaching (Windschitl et al., 2018) into their teaching practice in contextually specific ways. In what follows, we describe professional vision (Goodwin, 1994), the theory of learning guiding our

CONTACT Jonathan McCausland  jdmccausland@nmhu.edu  Department of Teacher Education, New Mexico Highlands University, STEC Building, Room 106, 1031 11th Street1, Las Vegas, NM 87701

*Current affiliation: Department of Teacher Education, New Mexico Highlands University.

**Current affiliation: Youth Engineering Solutions, The Pennsylvania State University.

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analysis. We will also describe the difficulty teachers can have in taking on new forms of practice, like Ambitious Science Teaching, using Windschitl's (2002) theorization of dilemmas in teaching. Afterward, we will describe the context and how our methods contribute to our understanding of our research question: *How do teachers negotiate professional vision around dilemmas in teaching during a professional development?*

Professional vision

Teaching is culturally situated in activity (Gutiérrez & Rogoff, 2003; Rogoff et al., 2003). Describing how professions are situated socioculturally, Goodwin (1994) theorizes that groups of people develop professional vision or, "socially organized ways of seeing and understanding events that are answerable to the distinctive interests of a particular social group" (p. 606). What defines a profession of people is how they identify and make meaning of specific objects and practices that are salient to the goals of their specific profession. This means teacher learning can be viewed as the way teachers recognize and respond to phenomena playing out in the complex social activity of professional teaching practice.

Goodwin (1994) breaks down the process of professional vision by describing it as a way individuals make sense in and through social activity. Goodwin (1994) defines professional vision in terms of three practices, "highlighting," "coding," and "producing and articulating material representations" (p. 606). Highlighting is how something relevant to a profession is made salient. When highlighting, individuals may literally highlight, using markers or highlighters, parts of documents. They may also use discursive moves like pointing or verbally describing something. By highlighting, professionals, like teachers, can make elements of their profession "visible to others" (p. 610). After highlighting, individuals code. Coding is how something's meaning is negotiated. By highlighting, then coding (i.e. making meaning), teachers organize their perception of people and events in ways that are culturally specific to their community of teachers. This produces a profession's contextualized and dynamic "coding scheme" for the organization of shared cultural practice. Ultimately, some key aspects of cultural practices of highlighting and coding are externally reified as material representations. By material representation, Goodwin (1994) means ways of writing or otherwise creating physical manifestations as a means of embodying practice. For example, the NGSS is a material representation; the NGSS is our collective, negotiated representation of part of our professional vision as science educators and researchers.

Professional vision is the negotiation of the meaning of objects and practices involved in a profession. In this way, professional vision is a cultural process that is constantly playing out dynamically within communities. This does not mean that individuals in communities have to agree. An example of professional vision can be seen in McDonald's (2016) analysis of the variations in professional vision between expert and novice science teachers. By having expert and novice teachers watch the same video and identify examples of "inquiry science teaching" (p. 98), McDonald (2016) found that each group or community understood the video differently. While the differences are not important for our purposes here, it is important to note McDonald (2016) did not enter with an a priori idea about what each community *should* notice. Additionally, the teachers within the study were not framed as being right or wrong, they were just different in their highlighting and coding of the video. Yes, these differences have consequences for the practices of teaching and thus the learning in which students are engaged, but the judgment of the quality of teaching is determined

within the community of teachers. With this said, McDonald (2016) focused on the “what” of professional vision rather than the “how” professional vision gets negotiated (i.e. learned). The “how” is one of the focuses of this study.

Dilemmas in teaching

Learning new ways of teaching can be difficult for teachers. When learning new practices, teachers may be put in the position of (re)negotiating their professional vision because the new pedagogy may extend or contradict their current practice. Windschitl (2002) refers to the tensions teachers can experience when learning new practices as dilemmas. According to Windschitl (2002), teachers face conceptual, pedagogical, cultural, and political dilemmas when learning new curriculum or ways of teaching.

Conceptual dilemmas capture teachers’ understandings of learning. Conceptual dilemmas are about the theory of learning guiding a teachers’ practice. For example, a science teacher might engage students in modeling because the NGSS asks for students to learn science by participating in authentic science and engineering practices (NGSS Lead States, 2013). Another teacher, not adhering to the NGSS, may only teach students the steps of the scientific method. Recognizing the integrated nature of learning and knowledge, Braaten and Sheth (2017) expand upon Windschitl’s (2002) original definition by including epistemic understandings of science within conceptual dilemmas. This means that conceptual dilemmas concern both how teachers understand learning and what they consider science to be as an epistemic practice.

Pedagogical dilemmas surround how teachers understand instructional practice. This dilemma is about the mechanical implementation of pedagogy, not the underlying theory of learning guiding the actions taken by teachers. According to Windschitl (2002), a teacher’s practice must evolve to include thinking about student ideas, facilitating student discussion to engage in problem solving, and assessment that is about process rather than products. What is important to note here is how other factors may contribute to this dilemma. For example, a teacher who lacks content knowledge may struggle to design a learning experience for students whose ideas do not align with canonical science. To be clear, the pedagogical dilemma focuses primarily on disciplinary aspects of teaching content and practices.

The final two dilemmas that Windschitl (2002) outlines are cultural and political dilemmas. Cultural dilemmas focus on how teachers negotiate integrating students’ cultural practices and norms into the classroom. For example, balancing the desire to be culturally responsive and navigating opposing expectations from society, school, and other actors is a cultural dilemma (Braaten & Sheth, 2017). Political dilemmas encompass all other facets of being a teacher that require negotiating within a complex system. An example of this could be the limited power a teacher has in their school context to make changes to their curriculum due to policy constraints. Both dilemmas matter in PD contexts because cultural dilemmas can and should alter how science is taught where political dilemmas demand teacher educators find creative ways to support teachers in reform efforts when they encounter institutional constraints.

Ambitious science teaching

Ambitious science teaching (AST) is the way we conceptualize science teaching. AST represents a way of teaching science and is grounded in four distinct sets of teaching practices

(Windschitl et al., 2018, 2012). Each of the four core sets of practices are intended to have students participate in learning as described by the NGSS. Even though AST practices are defined, they not intended to be prescriptive and used the same way in every context (Hammerness et al., 2020). Instead, AST should be taken up in ways that are purposeful, recognize the relational nature of teaching, and how, “teachers and students continually and jointly re-negotiate power and possibility in every interaction (Philip, 2019, p. 5).

Materials and methods

This case study (Dyson & Genishi, 2005) is about how a group of teachers negotiated professional vision during a four-day PD that occurred as part of a technology-enhanced earth science curriculum project funded by the National Science Foundation. Windschitl’s (2002) dilemmas were used to characterize what teachers’ negotiated while Goodwin’s (1994) theorization of professional vision helped us describe the process of how teachers’ negotiated specific dilemmas that emerged. Within this section, we will provide contextual information about the PD, describe the data collection methods, and give a descriptive account of the analysis that was performed.

Professional development context

During the summer of 2018, a group of teachers gathered for a four-day PD focused on learning about a plate tectonics curriculum and Ambitious Science Teaching (Windschitl et al., 2018). The professional development included 17 middle and high school Earth science teachers from across the country, representing urban, suburban, and rural school districts. The demographic make-up of the teacher participants included nine women and seven men. Racially, one teacher self-identified as Indian while the remaining 16 self-identified as White. The facilitation team included a White woman, Katie, and a White man, Scott, who are the fourth and third authors of this paper.

Prior to the start of the PD, Jonathan, Scott, and Katie created conjecture maps to plan for how learning would occur (Sandoval, 2014). The plan included teachers being provided opportunities to interact with the online plate tectonics curriculum and participate in curricular co-design (Penuel et al., 2009; Severance et al., 2016) by having teachers help test, adapt, and revise the designed curriculum. The PD was structured for teachers to negotiate professional vision around dilemmas salient to them that emerged within the learning context being designed. While there was no way to anticipate exactly what dilemmas would be salient, we anticipated the teachers would raise pedagogical and political dilemmas around how to use Ambitious Science Teaching in their personal classrooms. The reason for designing the professional development to focus on negotiating professional vision was to support teachers in melding, reconfiguring, and transforming idealized notions of teaching with realistic and contextually appropriate notions of teaching that would meet the needs of each teacher and their specific context.

The PD created opportunities for teachers to participate in collaborative discussions while learning about a plate tectonics curriculum on an online learning platform. The plate tectonics curriculum module was composed of five activities allowing users to learn about plate tectonics through engaging with Seismic Explorer (a manipulable USGS-based data visualization of earthquakes and volcanoes on the world map) and Tectonic Explorer (see Figure 1; a computational model-based simulation of tectonic plate movements on

a three-dimensional Earth-like planet). The curriculum also includes other data sets and visualizations for students to reason with. For example, students are provided GPS data from around the Earth showing how land masses are moving and paleomaps, or maps that depict what the Earth looked like over geologic history according to the latest scientific data and thinking (see [Figure 2](#)).

Teachers were also introduced to summary tables during the professional development (Windschitl et al., 2018). Summary tables are a way to make student thinking visible and support students in making conceptual connections as they complete a unit (Windschitl & Thompson, 2013; Windschitl et al., 2018; Wray et al., [in press](#)). During the plate tectonics curriculum, the summary table provides a way for students to record observations, participate in sensemaking, and construct claims with evidence and reasoning that will eventually support their understanding of the overarching driving question of the curriculum: “What will Earth look like in 500 million years?” This driving question directly aligns with each of the activities within the curriculum. By having the teachers participate in the process of generating a shared summary table for use in a teacher’s edition of the curriculum, we were able to investigate how teachers made sense of the curriculum, especially Tectonic Explorer, a central feature of the curriculum.

Data collection

We collected 18 hours of video and audio recordings. We only recorded the PD when teachers were talking about teaching and the curriculum. We did not record when scientists lectured about content or teachers were learning about procedural and technical aspects of using the curriculum (e.g., setting up a profile on the website). The video captured whole group interactions as well as audio of facilitator interactions, and individual audio recorders gathered what occurred during small group interactions among teachers at different table sets. These data sets were used to characterize dilemmas and capture key moments of talk that occurred amongst the teachers. Furthermore, by placing audio recorders at tables of teachers, we were able to document teacher talk during large group conversations, small group interactions, and one-on-one discussions. Lastly, we collected field notes (Emerson et al., 1995) which were used to characterize the data and provide entry-points during analysis. The field notes helped us identify particularly compelling moments during the PD.

Data analysis

Our analysis was a three-pronged approach using V-Note (see, <https://v-note.org/>), a video analysis software, to find patterns in the data. This process was led by Jonathan and Jennifer, the first and second authors of the paper. We met throughout the analytic process, where we shared our perceptions to reach consensus. Through our iterative process of analyzing and discussing, we were able to generate a singular-salient narrative that represents our major findings and describes the salient events and patterns that occurred during the PD. The narrative we produced is not meant to be objective or unbiased, but is intended to demonstrate our understandings of how teachers negotiate professional vision around dilemmas in teaching and enrich the field’s theoretical understanding of teacher learning. We openly admit that the final narrative shows some details and hides others, however this is no different than any other method (Lensmire, 2019; Wright, 2019).

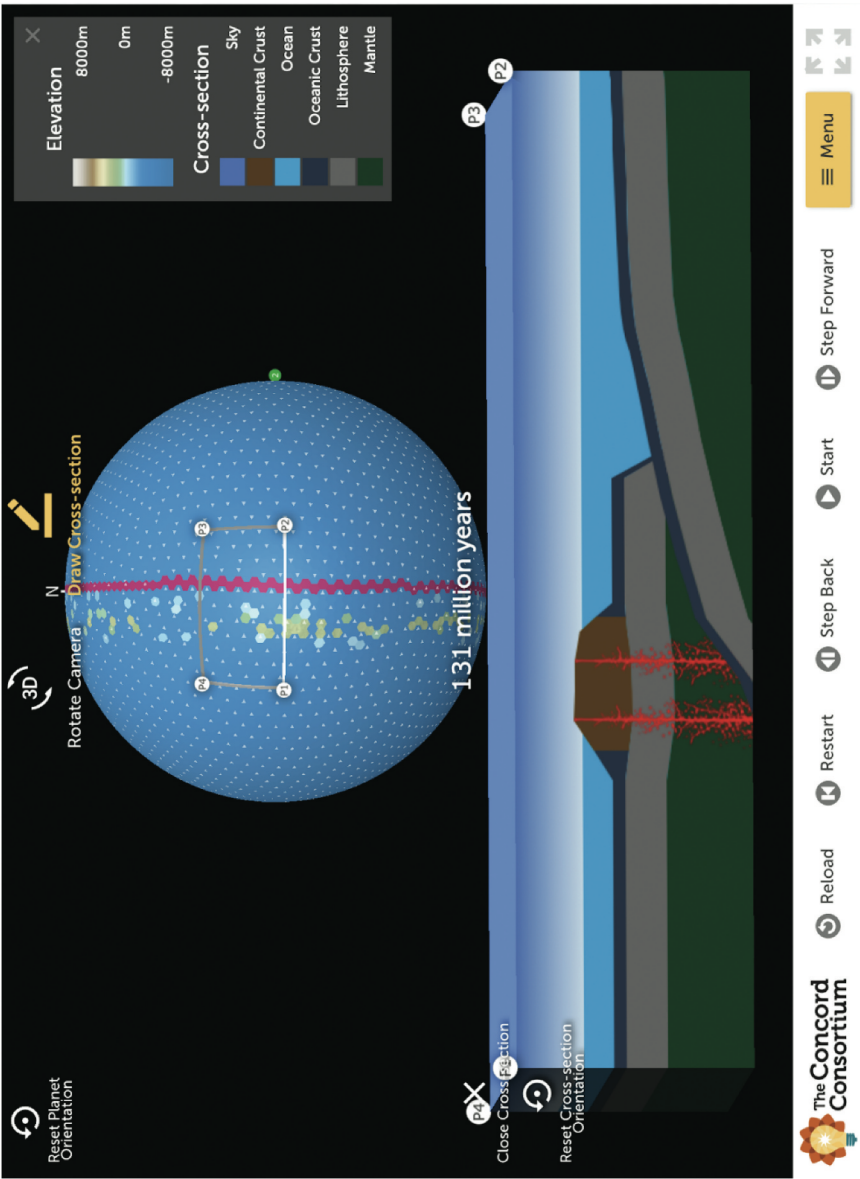
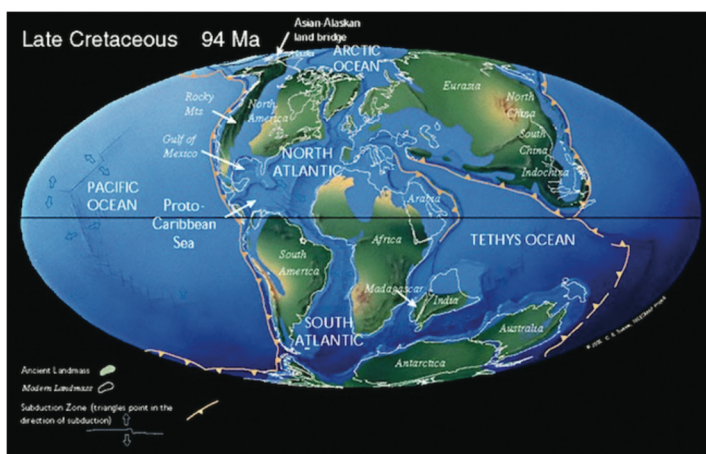


Figure 1. Tectonic explorer (Concord Consortium, 2019).



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Backward in time

Forward in time

All images from Paleogeographic Maps by C.R. Scotese, © 2013, PALEOMAP Project, (www.scotese.com).

Figure 2. Example paleomap from plate tectonics module (Concord Consortium, 2019; Scotese, 2001).

To begin our analysis, we organized the video and audio into an event map (Kelly & Chen, 1999) to identify moments where participants negotiated a dilemma. We did not identify the specific dilemma teachers were negotiating, we only looked for moments where teachers were engaging with a question or tension. The purpose of the event map was to locate moments where teachers participated in conversations about dilemmas they have in teaching and to characterize the entire corpus of data to further our analysis.

Second, we characterized the dilemmas teachers grappled with throughout the PD. Using Windschitl's (2002) framework, dilemmas were described as conceptual, pedagogical, cultural, or political. By describing the dilemmas teachers engaged with, we were able to identify patterns and trends in the dilemmas teachers negotiated. We were also able to identify moments central to the negotiation and development of professional vision during the PD.

We completed our analysis by describing the interactions between community members (teachers and facilitators) using professional vision (Goodwin, 1994). We used the practices of professional vision (highlighting, coding, and creating material representations), to get a sense of *how* the teachers negotiated professional vision around the dilemmas. To be clear, we were interested in the process of the negotiation of professional vision, and while we could provide counts of dilemmas or key practices of professional vision, they are not pertinent to this paper. Table 1 represents our general characterization and description of conceptual and pedagogical dilemmas. We only included these dilemmas because they were most salient to the PD given that teachers rarely raised cultural or political dilemmas.

Findings

While seventeen teachers participated in the professional development, our findings will focus on a subset of teachers because their interactions were central to the entire PD. These four focal teachers (see Table 2 below) are all secondary science teachers, leaders in their school districts, and have participated regularly in ongoing professional development during their careers. For clarity, we all have different relationships with the focal participants in the PD. Scott and Katie knew Severus, Keith, and Bruce before the PD, Amy and Hee-Sun knew Melanie, and Jonathan and Jennifer did not have relationships with anyone who participated in the PD.

The interactions described below surround conceptual and pedagogical dilemmas initially raised by one teacher, Severus. We chose to use the dilemmas raised by Severus because his initial dilemmas were taken up by the entire community including teachers, facilitators, and curriculum designers at multiple points during PD. Although we will not present every negotiation of Severus' dilemmas in this paper, what we do present will allow us to demonstrate how dilemmas are negotiated by teachers and ultimately result in the changing of the curriculum to represent the community's professional vision. To be transparent, Severus was uniquely outspoken, and further analysis could be done on gender dynamics that arose within the PD, but this is beyond the scope of this paper. Nevertheless, Severus' dilemmas were a central aspect of the entire PD and not mentioning them would mischaracterize how the community, but specifically, the subset of teachers in this study negotiated professional vision.

The dilemmas raised by Severus encapsulate the major dilemmas that emerged during the professional development. However, the segments of dialogue presented here do not

Table 1. Dilemmas in teaching (Windschitl, 2002).

Dilemma	Definition based on Windschitl (2002)	Examples: highlighting/coding
Conceptual	Dilemma that deals with underpinnings associated with how people learn and/or epistemology of science	<i>Highlighting:</i> "I'm just curious what evidence we have stated there [gestures to the summary table] that plates move slowly over time?" <i>Coding:</i> "It [Tectonic Explorer] is made from data. It's even more beyond even what we said with the paleomaps, how they're a model and not evidence. This is like beyond that."
Pedagogical	Dilemma that involves the mechanics of teaching and/or how to enact particular pedagogical practices	<i>Highlighting:</i> "... I think there is a natural break at the exit questions" <i>Coding:</i> "You're starting to give them evidence before they've actually seen or thought about what they're expected to do."

Table 2. Focal teachers.

Teacher	Background
Severus	He is a White man who teaches middle school science in the mid-Atlantic who had used AST for eight years prior to the GEODE PD. Severus teaches in the same school as Keith and has participated in ongoing professional development with Scott for twelve years.
Keith	He is a White man who teaches middle school science in mid-Atlantic who had used AST for eight years prior to the GEODE PD. Keith teaches in the same school as Severus and has participated in ongoing professional development with Scott for eight years.
Melanie	She is a White woman who teaches high school science and has been recognized as a teacher leader within her state located in the mid-west.
Bruce	He is a White man who teaches high school science in the mid-Atlantic and has participated in ongoing professional development with Scott for five years.

include every individual who participated in the negotiation of the dilemmas, let alone every other dilemma that emerged. The narrative below is intended to demonstrate how the dilemmas raised by Severus were negotiated and resolved by presenting the pertinent moments of the negotiation (Maclure, 2013). We present them in a narrative format in order to render visible “the messy and wonderfully productive complexity” (Truvey, 2012, p. 57) of the focal teachers’ negotiation of professional vision around dilemmas. In other words, we present our findings in narrative format to show the process of negotiation during the PD.

Dilemmas emerge: lack of alignment between curriculum and practice

On the first day of the PD, the teachers were tasked with discussing, in small groups, places in the first activity of the module to stop and have discussions with students (i.e. a pedagogical dilemma). To start the conversation, Melanie, says,

... if I see students are struggling on these first two questions and I am getting responses that don’t make sense then we can go back and talk about those questions to see why. But if they aren’t struggling, then we can move on and I think there is a natural break at the exit questions.

In her comment, Melanie highlighted both the first two questions and exit questions in the curriculum. She codes them as places to stop for discussion. We know she is highlighting because she focused the group’s attention on material representations within the curriculum.

Almost immediately after Melanie’s statement, Severus highlights something else. He says,

I am inclined towards not showing them the paleomaps. Like I want the intervention to occur before anything. I want to give students a map of the Earth and the question of ‘What will this look like in 500 million years?’ Like that is to me, before any of this, that plain question, without giving them any of this.

In his comment, Severus is highlighting the entire first activity, but more specifically, the paleomaps, which are illustrations of scientists’ characterization of the patterns of continents on early Earth. Severus then codes the first activity in the curriculum as not being aligned to his teaching practice by indicating what he would do *before* providing students the first activity of the curriculum. As Severus spoke, Keith muttered “yea” over and over, indicating agreement. After a short back and forth in which Keith states why he agrees with Severus by highlighting the first module and coding it the same as Severus, Keith stated, “That was my thought. You’re starting to give them evidence before they’ve actually seen or thought about what they’re expected to do.” The group of teachers agreed that they “liked” Severus’ and Keith’s proposal of adding a discussion *before* having students engage with the online module.

This section of dialogue sets the stage for what is to come later in the PD. Severus and other teachers often highlight parts of the curriculum as not aligning to their practice. Severus and other community members, often teachers, negotiate professional vision through focusing the community’s attention on particular material representations, like the paleomaps, and coding the material representation in relation to a dilemma. The community then solves the dilemmas by coming to a consensus after a back-and-forth

discussion. These solutions often resulted in changes to a material representation. For example, in the case above, the plate tectonics curriculum was adapted by the teachers to include a discussion at the beginning of the first module.

Negotiating Dilemmas: Are models evidence or not?

Early on the second day, teachers were tasked with creating an exemplary summary table for the curriculum. During the co-construction of a summary table, Severus stated,

I'm just curious what evidence we have stated there [gestures to the summary table] that plates move slowly over time? Like what, as a student looking at the evidence we have described, what evidence would they need or had to have seen?

Severus' question revolved around a conceptual dilemma, or a question about the epistemology of science because Severus was asking the teachers if they had evidence to make a claim about tectonic plates moving over time. By asking his question as he pointed toward the summary table (highlighting) and coding the claims as not grounded in evidence, Severus created an opportunity for the community to negotiate what they considered to be evidence.

In response to Severus, Scott (one of the facilitators) said, "The closest thing that didn't come from this case, that we have to that evidence, comes from the paleomaps, but we don't have any direct evidence, I don't think, but I'm happy to be contradicted." At this point, Bruce got involved and the following dialogue ensued:

Bruce: Yeah, the ages in the models would be information, and it would come up in discussion as to why you aren't seeing earthquakes mapped on those models. So, we have had that . . .

Severus: So, the tectonic model? [voices of other teachers agreeing] Cause the tectonic model I keep going back to, that's a claim that's not evidence.

Bruce: It's more than that I would think if you're basing this model, and this is where the whole concept of computer programming comes in, it's based on laws that you put into that model.

Scott: It's based on data. Well, there are laws in there, and I mean this goes all the way back to this issue of uncertainty. So, the model is, as it sounds from the name, a model. It is not a real thing.

After some more back and forth, the conversation was ended by Scott by saying the teachers needed to be more specific in the observations they were using to make particular claims. Rather than let the community resolve the dilemma, Scott made a choice to move on and keep the dilemma unresolved.

In this dialogue, the community began to negotiate the conceptual dilemma of whether Tectonic Explorer (TE) was evidence or not. Severus coded the claims being made as inappropriate because TE was not evidence to him. Alternatively, Bruce did not code the claims as inappropriate because he believed TE was evidence. While neither person convinced the other, or the rest of the community, two different perspectives on TE were available to be taken up, TE as evidence and TE as explanation.

When the facilitators engaged the community in completing the summary table again, Severus once again raised the conceptual dilemma by highlighting the summary table and coding the evidence being mentioned by other teachers, drawn from TE, as “not evidence” by stating,

The tectonic model is entirely a model; there's no actual fact there. It is made from data. It's even more beyond even what we said with the paleomaps, how they're a model and not evidence. This is beyond that.

After a brief response from Katie (one of the facilitators), another teacher asked how to logistically use the summary table, but Severus continued. Severus highlighted the summary table and TE and coded the information gleaned from TE as “not evidence.” He instead characterizes TE as “hypothesis testing.” However, Severus began to connect his understanding of the epistemology of science to how he thinks science should be learned and taught. This is indicated when Severus said, “In my mind, I keep returning to that as hypothesis testing. You've got to develop a model and then you can return there and test with that. It's not evidence itself, but it's hypothesis testing later on.” At this point, the conceptual dilemma introduced by Severus became more complicated because the community needed to negotiate what they considered to be evidence and how that mattered for student learning. Severus also alluded to the fact that he was dealing with a pedagogical dilemma about how to teach about plate tectonics without using TE as evidence.

Resolving dilemmas: pedagogical solutions to conceptual dilemmas

Soon after Severus expressed his concerns for the second time, Keith attempted to articulate the multiple dilemmas at play and provide a solution by saying the following:

I guess what I am struggling with, and I think all of us are struggling with is . . . one of key things for me to understand is the thinning of the Earth's crust. If we don't use that model, there is no other way for the kids, there's no other data point to get that information. So, as adults, who understand this at a high level, we can operate under the assumption that the model is not actual data, but it's a necessary tool to help get kids through it unless we are going to derive a whole lot of things that went into building that model. I think that's where we just need to make a judgment call, like, we are just going to use it for data or not. Because if not we are just going to try and pigeon hole it.

In Keith's statement, he highlighted his goals for the curriculum and TE. Keith coded TE as being necessary to helping kids understand plate tectonics. For Keith, there was a disconnect between the use of TE and his personal understanding of how knowledge is created in science, but there was not a disconnect between how the curriculum and his own practice would have the students use TE to learn plate tectonics. Keith separated his personal understanding of science from how he thought science should be learned and taught. Rather than adopt Severus' perspective that learning science should mirror a rigid epistemology of science that considers some objects evidence and some not, Keith suggested using TE as evidence because the practices around using evidence were more important than the concerns around modeling for him.

Eventually, after Katie and Keith agreed that regardless of the route they took pedagogically, the conceptual dilemma will not be perfectly resolved, Severus, still unconvinced, said,

My problem is that if you set up the model based on your model; your model is going to show what you programmed the model to show. So, what's the difference between telling them it's moving apart and just showing them. Like to me, there is no difference between just showing them the tectonic model and just telling them. We might as well just tell them because they aren't developing the model at all if we are just showing them these things. There's no distinction except that there is a better drawing than what you would do on your overhead.

Again, Severus struggled with aligning the ways the curriculum and the community treated science epistemically and how that aligned with his belief on how students should learn science. This dilemma is now merged with a pedagogical dilemma. It is merged because teachers were negotiating what counts as science and how to help students learn science pedagogically. For example, Severus coded Keith's solution to the pedagogical dilemma as akin to lecturing, something that did not align with how Severus (or Keith) thought students learn science.

As soon as Severus finished speaking, Bruce again coded the curriculum's use of TE as aligning with their conceptual understanding of science by saying:

Yeah, I disagree, and this is also a little plug for computer programming and mathematics being that important because they are different in my opinion based on the laws that are generated within that computer program. So, however they create this model, it's a test of a hypothesis, not a test of the theory, which is why we are still in that middle column saying, we can, based on this computer programming, we can see what happens, based on the laws of physics, how well that computer program is made. Whatever. The point is that it's beyond us simply making a drawing because you can then create even more questions, more additional possible "theories," more testing, based on that first column, which is your original observations of data in the first place. So, it is . . .

At this moment, Bruce again highlighted TE, but coded it as a hypothesis test, not a test of the theory of plate tectonics. For Bruce, TE incorporated laws of physics, which can be empirically proven, therefore, students are able to participate in authentic practices of science like asking questions and engaging in more "testing" which generates data to make claims with. What Bruce is arguing is not dissimilar from what Morrison (2015) argues, in that simulations are potentially closer to experiments because they can give us new information about the natural world. This is also how Bruce dealt with TE pedagogically. Therefore, it can be assumed that Bruce believed that TE was aligned to their conceptual understanding of science, how students should learn science, and their own practice.

At this point, it became clear that the community would not reach consensus on the conceptual dilemma of whether TE was evidence. Making a final effort to convince everyone of their perspective, Severus tried to argue that TE was no different from telling students what to draw. Severus made it clear that TE was excellent for testing a model, but giving students TE was, "not really giving them [students] the chance to debate and come up with the model [of plate tectonics]." Eventually, Scott reentered the conversation, outlined the dilemmas once again, and suggested that a way to solve the dilemmas would be to provide GPS data that showed that the continents are moving. Severus then continued the conversation:

I'm not saying go back to first principles because then we are getting down to, ok you now have to derive all the physics, you've got to derive every single thing. I'm definitely not saying that, but we have all the observational data necessary and it is built into this. We are just putting the model before data or putting the model before they have the chance to come up with the model.

As the conversation concluded, it was clear that members in the community still disagreed on how to handle TE. Still, the teachers did agree there were two options, treat TE as evidence or not. For each teacher, regardless of their perspective on how TE fits epistemically into science, they resolved the conceptual dilemma facing them by agreeing to put GPS data into the curriculum. By doing this, teachers who aligned with Severus did not need TE to be treated as evidence, but teachers who believed it to be evidence could use it as such. Both perspectives co-existed and allowed each teacher to align their conceptual commitments with their pedagogical practice.

Discussion

It was the negotiation of professional vision that drove the learning of teachers throughout the PD. This is visible in how teachers negotiated professional vision when Severus argued an activity should be placed *before* the actual start of the curriculum. After discussing the dilemma and agreeing on a solution, the dilemma was resolved. By agreeing, as a community, to the change in the material representation, teachers had their learnings represented in how the entire community structured the curriculum.

Interrelatedness of dilemmas

Windschitl (2002) is clear that learning to teach in new ways involves dilemmas and there is interplay between multiple dilemmas in teaching. In fact, dilemmas cannot be separated from one another. For example, Windschitl (2002) articulates how a teachers' practice is contingent on how they understand learning. Braaten and Sheth (2017) demonstrate the intersections of dilemmas by showing how tensions in one teacher's pedagogy are connected to multiple dilemmas. Our findings further support Windschitl's (2002) articulation that dilemmas emerge when teachers are learning to teach in new ways and that dilemmas are interrelated because the focal teachers negotiated conceptual and pedagogical dilemmas simultaneously throughout the PD.

Our findings show that some teachers within the PD integrated their teaching practice (pedagogical dilemmas) with their epistemological perspective on what counts as evidence in science (conceptual dilemmas). Particularly, the teachers in the narrative were concerned with what and how students were learning. The focal teachers understood, implicitly, that science must be learned by engaging students in science practices. This is clear in the arguments the teachers made in their discussions about TE. For example, Bruce argued students could ask more questions and see more patterns using TE, Severus believed TE is only for testing explanations, and Keith stated TE should be used as evidence for the plate tectonics unit. Regardless of their perspective on TE, each teacher advocated for science teaching that engages students in practices advocated for in the NGSS. Our findings show these teachers can and do think about teaching in ways that integrate disciplinary core ideas and science and engineering practices (NGSS Lead States, 2013). That is to say, we show empirical evidence that conceptual and pedagogical dilemmas are integral to these science teachers' pedagogies as Windschitl (2002) argues, theoretically.

Negotiating professional vision as sensemaking

Goodwin (1994) claims communities are constantly negotiating professional vision. Professional vision is a sociocultural process. This means professional vision, like other sociocultural perspectives on learning, is a situated process rather than a static, ideal body of knowledge (Danish & Gresalfi, 2018; Gray et al., 2022). There is not an ideal professional vision because it is constantly negotiated. In this way, a community's professional vision, and by extension, individuals' professional vision, is constantly changing as contexts shift.

By taking a sociocultural perspective on professional vision, we deviate from other scholars who use professional vision to describe teacher learning. For example, using the term "noticing" in place of professional vision, Stürmer et al. (2014), state that, "Noticing involves identifying classroom situations and events that, from a professional perspective, are decisive for effective instructional practice" (p. 37). For these authors and more (e.g., Seidel et al., 2011; Sherin & van Es, 2009), professional vision is about knowledge that allows teachers to notice and interpret features in a classroom. While we agree professional vision involves noticing and interpreting phenomena in classrooms, we argue professional vision is a situated social process and is negotiated based on "what works" for the community, rather than an ideal and, in our opinion, context-independent body of knowledge.

Based on our findings, using professional vision from a sociocultural perspective analytically has the advantage of being able to attend to *how* teachers are learning and *what* they are learning. We are able to show the complexities and nuances in how a case of teachers articulate their teaching practice. Actual talk is rarely straightforward and structured in a way that renders ideas and philosophical arguments explicit (Kelly et al., 1998). This means when a priori measures are used analytically, context and utterances that could be important may be left out of analyses of teachers' learning. By paying attention to how teachers negotiate professional vision, not just the end state of the negotiation or only what a teacher "notices," we can make more nuanced claims about the learning that takes place. In this study's case, pedagogical and conceptual dilemmas were negotiated in tandem. By treating professional vision as a process, we conveyed how complex and nuanced the dilemmas being negotiated by the case of teachers were.

We argue professional vision is a way to characterize teacher sensemaking. By sensemaking we mean a, "process of interpreting others' accounts and negotiating shared understanding" (Sandberg & Tsoukas, 2020, p. 2). Negotiating professional vision and sensemaking are both processes by which communities come to understand phenomena. This is a process that unfolded in small groups and in front of the larger community throughout our data as the teachers in the narrative shared their perspectives about dilemmas, worked to understand each other's perspectives, and ultimately worked together to reach agreement on a dilemma. By viewing professional vision as a form of sensemaking, we noticed how the teachers in the narrative made sense of both teaching and science simultaneously because professional vision is a framework that enables us, as researchers, to capture the different utterances and purposes behind the teachers' talk. In essence, professional vision allows us to understand talk at multiple grain sizes simultaneously. For example, our data shows what and how sensemaking occurred by being able to articulate the dilemmas some teachers negotiated while we rendered the purposes of the teachers' utterances visible as talk moved from small groups, to the whole community, and ultimately, how those utterances got reified in curriculum.

Sensemaking to “get somewhere” with dilemmas

The focal teachers often negotiated an agreed upon professional vision in our study, but we also centered an example of a negotiation that did not end in consensus. This is important because teachers have agency and belong to many communities (Bateman, 2019). Therefore, we believe the goal of negotiating professional vision (i.e. sensemaking) is not to get a correct answer or agree upon a “best practice.” It is about “getting somewhere” (Grimes et al., 2019). We use the term “getting somewhere” to describe a process by which teachers attempt to resolve dilemmas in teaching, and while they may articulate a professional vision, those articulations are constantly in flux rather than static. We also use this phrase to describe how there is no endpoint in negotiating professional vision. This can be seen by Keith when he decided to ignore his own conceptual beliefs about science. Keith was not suggesting his solution was “ideal,” just that it would “work.” By agreeing to include the GPS data in the curriculum, each teacher could make their own decision on how to use TE. In this way, the focal teachers “got somewhere,” but did not agree on a solution.

By framing teacher learning as “getting somewhere,” we can create more opportunities for teachers to use more expansive forms of agency and leverage their professional experience to articulate a practice that aligns with idealized versions of practice in ways that are contextually specific. For example, the focal teachers engaged in sensemaking around incoherence between curriculum and their current practice were more likely to alter their practice (Allen & Penuel, 2015). Additionally, increased teacher agency during co-design has shown to lead to, “significant and lasting changes to curricular materials” (Severance et al., 2016, p. 544). Our study aligns with these findings. However, our findings go further in that they suggest the case of teachers did not have an idealized version of practice for all classrooms, but instead had an idealized version of practice for their specific communities. Sensemaking was the teachers’ way to “get somewhere” in regards to aligning the curriculum, their pedagogy, and conceptual understanding of learning and science.

The fact that teachers’ make sense of science and pedagogy to “get somewhere” rather than come to a “correct” or “idealized” form of science and teaching practice has important implications for teacher education. For example, core practices like Ambitious Science Teaching (Windschitl et al., 2018), the underlying pedagogical model of the Plate Tectonics module, are critiqued for decentering equity because the practices can be used as rote, standardized practices (Daniels & Varghese, 2020; Philip, 2019; Philip et al., 2019). By framing learning to teach as a negotiation of professional vision, teachers can critique and adapt core practices to meet students’ needs and wants. Our study suggests that, like students, teachers also make sense of science. Therefore, given that teachers’ science backgrounds shape how they design science classrooms (Windschitl & Stroupe, 2017), it is important for teacher educators to consider how a teacher’s conceptual understanding of science informs their pedagogy.

Teaching and science are easily but inaccurately framed as having right and wrong answers. Literature around teacher and science learning can assume there is a right way to teach or do science. For example, a literature review of asset and deficit perspectives of preservice science teachers’ learning argued that data collection and analysis focused on predetermined outcomes ignores the complexity of preservice teachers’ enactment of practice (Gray et al., 2022). The predetermined nature of the outcomes argues there is one “right” way to teach that is independent from the contextual factors involved in

science teaching. For science, scientific language denoting academic rigor (Brown, 2019), arbitrary non-science related requirements in science classrooms/spaces (McCausland, 2022), and a culture of power in science education (Calabrese-Barton & Yang, 2000), including but not exclusive to, science as white property (Mensah & Jackson, 2018), can portray “right” and “wrong” ways of doing and being in science. Instead, both teaching and science are complex forms of activity that do and have shifted throughout history. Our study suggests, as evidenced by the heterogeneous and multifaceted ways the case of teachers made sense of TE, the curriculum, and their own teaching practice, that learning to teach science consists of making sense of both science and pedagogy simultaneously in ways that are dependent on one’s teaching context.

Teachers “figure out” their teaching practice when they are provided experiences that require them to negotiate where they stand relative to other teachers. This does not mean teachers will always agree because there is not a “one size fits all” professional vision. Instead, dissension should be embraced because it allows teachers to keep learning. As a result, this constant negotiation will only improve our collective understanding of teaching and teaching practice as we work toward providing all students with robust, relevant, responsive, and rigorous science learning experiences they deserve.

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ORCID

Jonathan McCausland  <http://orcid.org/0000-0002-0382-7391>

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