Jaber, L. Z. (accepted). "He got a glimpse of the joys of understanding" – The role of epistemic empathy in teacher learning, *The Journal of the Learning Sciences.*

"He Got a Glimpse of the Joys of Understanding" – The Role of Epistemic Empathy in Teacher Learning

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Abstract

Background. Efforts to promote reform-based instruction have overlooked the import of affect in teacher learning. Drawing on prior work, I argue that teachers' affective experiences in the discipline are integral to their learning how to teach the discipline. Moreover, I suggest that both affective and epistemological aspects of teachers' experiences can serve to cultivate their *epistemic empathy*—the capacity for tuning into and valuing someone's intellectual and emotional experience within an epistemic activity— in ways that support student-centered instruction.

Methods. Using a case study approach, I examine the learning journey of one preservice teacher, Keith, who after having expressed strong skepticism about responsive teaching, came to value and take up responsive teaching in his instruction.

Findings. The analysis identifies epistemological and affective dynamics in Keith's interactions with students and in his relationship with science that fostered his epistemic empathy. By easing his worries about arriving at correct answers, Keith's epistemic empathy shifted his attention toward supporting students' sensemaking and nurturing their relationships with the discipline.

Contributions**.** These findings highlights teachers' affective experiences in the discipline as integral to their learning how to teach; they also call attention to epistemic empathy as an important aspect of and target for teacher learning.

Keywords:

Responsive teaching, epistemic empathy, teacher education, epistemology, affect, science learning, science teaching.

Within science education, there is increasing interest in supporting students to understand science not only as a body of knowledge, but more importantly as a way of thinking, acting, talking, and feeling (Duschl; 2008; Ford, 2008; Hammer, Russ, Mikeska, & Scherr, 2008; Jaber & Hammer, 2016b; National Research Council, 2012; Stroupe; 2015; Windschitl & Calabrese Barton, 2016). This interest has motivated attention to engaging learners in the "doing of science" as an instructional target beyond "academic content" (Hammer, 2016, p. 251). This target, Hammer explains, is about "students learning to have and pursue their own ideas, to recognize and question hidden assumptions, to come up with new possibilities, and to test and revise their ideas" (p. 251).

Achieving this vision of science education requires a re-examination of the role that teachers play in the classroom. It entails centering instruction around learners' questions, curiosities, ideas, and experiences, calling for more responsive and adaptive classrooms (NRC, 2012). This in turn requires teachers to be increasingly attuned to students' varied ways of thinking and feeling in science, and to use those as building blocks for instruction—a pedagogical approach often referred to as *responsive teaching* (Maskiewicz & Winters, 2012; Robertson, Scherr, & Hammer, 2016; Thompson, Hagenah, Kang, Stroupe, Braaten, Colley, & Windschitl, 2016).

Responsive teachers listen closely to the meanings in students' ideas and questions, identify productive disciplinary beginnings therein, and adapt their instructional objectives and activities to build on those beginnings while working toward larger learning goals (Ball, 1993; Ball & Forzani, 2010; Duckworth, 2006; Hammer, 1997; Hammer, Goldberg, & Fargason, 2012; Levin, Grant & Hammer, 2012). Responsive teaching, then, shifts "the emphasis away from

teacher as knowledge provider – and toward students as agents of their own learning and knowledge construction" (Robertson & Richards, 2017, p. 318).

While a number of studies illustrate what responsive teaching looks like and its affordances for student learning and engagement (e.g., Ball, 1993; Bresser & Fargason, 2013; Hammer, 1997; Maskiewicz & Winters, 2012; Michaels, 2005; Radoff, Robertson, Fargason, & Goldberg, 2018; Thompson et al., 2016; Salter & Atkins, 2013), less is known about *how* teachers—especially preservice teachers—come to understand, embrace, and implement responsive teaching (Kang & Anderson, 2015). All the more, there is evidence to suggest that teachers may in fact be skeptical and hesitant to enact responsive teaching, worrying that it may lead away from lesson objectives or generate misunderstandings (Radoff et al., 2018; Robertson & Richards, 2017). Researchers and teacher educators are therefore exploring different ways to support teachers to understand and take up responsive teaching in their instruction.

This study aims to contribute to these efforts by examining the learning journey of one preservice science teacher, Keith, who after having expressed strong skepticism about responsive teaching at the beginning of an early teacher education course, came to value and embrace this instructional approach. By analyzing Keith's journey, I aim to develop empirical and theoretical insights with respect to his learning, insights that could inform teacher education efforts striving to foster teacher responsiveness.

In what follows, I first situate the study in research on teacher learning and reform-based instruction. I then discuss emerging efforts to promote teacher learning for responsive teaching. I argue that by attending primarily to cognitive aspects of teacher learning, current efforts overlook a central element of that learning—*the affective*. Drawing on research on affect in student learning, I propose that if we were to better support teachers' uptake of reform

instruction such as responsive teaching, we must attend to teachers' affect. I then argue that attending to both affective and cognitive aspects of teacher learning can help us appreciate how teachers develop *epistemic empathy* (Jaber, Southerland, & Dake, 2018)—a capacity for tuning into and valuing students' intellectual and emotional experiences within an epistemic activity—in ways that foster teachers' responsiveness. Drawing on Keith's journey, I show how by placing student thinking and emotions at the center, epistemic empathy served to ease Keith's anxieties about responsive teaching, shifting his attention toward students' sensemaking and their personal relationship with the discipline. I end with implications for teacher education to cultivate epistemic empathy as a target for teacher learning.

Background

Teacher Learning and Student-Centered Instruction

Researchers have documented various challenges and complexities pertaining to teachers' uptake of reform-based visions of instruction, such as ambitious and responsive teaching (e.g., Anderson, Smith, & Peasly, 2000; Davis, Petish, & Smithey, 2006; Kang & Windschitl, 2018; Southerland, Sowell, Blanchard, & Granger, 2011; Windschitl & Calabrese Barton 2016). One commonly reported challenge relates to teachers' initial or entering conceptions of teaching and learning. These conceptions are often rooted in teachers' own histories and experiences as learners throughout their childhood and years of schooling, what Lortie (1975) has termed "apprenticeship of observation."

Such conceptions take the form of acquired "cultural scripts" about teaching (Kang & Windschitl, 2018) and shape science teachers' initial orientations to teaching and learning—their epistemological understandings of and practical approaches to the discipline and to what counts as effective teaching and learning within that discipline. For instance, past success experiences in

traditional teacher-centered science classrooms may promote a view of science teaching as being about the delivery of content and of science learning as being about the acquisition of such content (Davis et al., 2006; Kang & Windschitl, 2018).

When preservice teachers begin their programs with a conception of learning as about knowledge acquisition where the teacher is the authority figure in the classroom, such orientations may be in tension with student-centered teaching practices called for in their teacher education programs (Anderson et al, 2000; Danielowitch, 2007; Stroupe, 2016; Opfer & Pedder, 2011; Richardson, 2003). As they get exposed to ideas and experiences that conflict with their own, teachers may experience a sense of dissonance that could prompt them to either resist new ideas or to interrogate their incoming assumptions about teaching, learning, and the subject matter in light of these new ideas (Anderson et al., 2000; Southerland et al., 2011; Opfer & Pedder, 2011). When supported to frame these tensions as opportunities for reflection and learning, teachers may come to expand their repertoires of pedagogical concepts and practices (Anderson et al., 2001; Clarke & Hollingsworth, 2002; Danielowitch, 2007; Kazemi, Ghousseini, Cunard & Turrou, 2016). It is through this process that teachers' incoming orientations to teaching and learning may serve as an impetus for growth and for their uptake of reform-based visions of instruction (Clarke & Hollingsworth, 2002; Kang & Windschitl, 2018; Kazemi et al., 2016).

Efforts to Promote Teacher Learning for Responsive Teaching

The aforementioned body of work underlines the need to attend to teachers' incoming assumptions and orientations in the design of teacher education and professional development programs to optimize teacher learning. Such attention becomes especially important when teachers are presented with visions of instruction that may be new to them, such as responsive

teaching. In science, responsive teaching entails a major shift in terms of what teachers need to do and practice in their classrooms (Radoff et al., 2018; Robertson et al., 2016; Thompson et al., 2016). Therefore, teachers may be anxious about enacting responsive teaching, worrying that it would lead to misunderstandings and steer away from lesson objectives.

Given the sense of ambiguity and uncertainty that student-centered pedagogies such as responsive teaching may evoke, providing teachers the time and space to experience, interrogate, and make sense of such pedagogies in light of their prior experiences in the discipline is essential. As Robertson and Richards (2017) argue, "teachers need opportunities to sense-make about both the [pedagogical] approach itself, and about their relationship to it" (p. 315). This is especially true for teachers who may not have experienced student-centered pedagogies in their own learning (Coffey & Edwards, 2016; Kang & Windschitl, 2018; McNeill, Pimentel, & Strauss, 2013; Southerland et al., 2011). As such, teacher educators continue to examine ways to support teachers to make sense of and develop comfort with responsive teaching.

So far, teacher education efforts have primarily focused on cognitive aspects of teacher learning, either by supporting teachers to develop conceptual knowledge about reform instruction or by offering teachers practical experiences and tools that they can use in their own instruction (Kang & Windschitl, 2018). Conceptual knowledge includes theories of learning, frameworks on student-centered instruction, and knowledge about student-centered curricula that could help teachers conceptualize a vision of teaching that aligns with reform calls (Kennedy, 2006; Thompson, Windschitl, Braaten, & Stroupe, 2013). Practical experiences provide teachers opportunities to engage in practices that embody reform instruction and to experience tools that could support them to teach in more student-centered ways. These tools may include discursive moves to elicit student thinking and orchestrate discussions (e.g., Cartier, Smith, Stein, Ross,

2013; O'Connor & Michaels, 2019), specific strategies to set up classroom norms (e.g., Thompson et al., 2013), and modeling and argumentation routines to position students as sensemakers in the classroom (e.g., Grooms, Enderle, & Sampson, 2015; Kang, Windschitl, Stroupe, & Thompson, 2016).

To equip teachers with the conceptual knowledge and practical tools that can support their implementation of responsive teaching, researchers and teacher educators have examined a variety of approaches. One prominent approach focuses on the use of videos and student artifacts to develop teachers' familiarity with reform instruction and to hone their attention to student thinking (e.g., Barth-Cohen, Little, & Abrahamson, 2018; Santagata & Taylor, 2018; Tekkumru-Kisa, Stein, & Coker, 2018; van Es, Cashen, Barnhart & Auger, 2017). This approach, premised on the notion that teachers need "to see images of possibilities" (Barnhart & van Es 2018, p. 51) of student-centered instruction, has shown some promising results. For instance, van Es and Sherin (2010) found that in-service teachers who participated in "video clubs"—a video-based professional development program centered on examining student thinking in classroom videos—became more attuned to the details in students' ideas, which in turn translated to practices of eliciting student thinking within instruction. Relatedly, in the context of preservice teacher education, Barth-Cohen and colleagues (2018) showed that engaging preservice teachers in targeted analysis of classroom video records broadened their sense of what students are capable of.

Other efforts have worked to develop teachers' facility with responsive teaching by providing them opportunities to experience these instructional practices for themselves as science learners (Atkins & Frank, 2016; Dini, Jaber, & Danahy, 2019; Hammer & van Zee, 2006; Salter & Atkins, 2013; Watkins, Coffey, Maskiewicz, & Hammer, 2017; Watkins, Jaber,

& Dini, 2020). In this line of work, teacher educators and professional development facilitators model responsive teaching by engaging teachers in scientific inquiry and developing instructional activities from the teachers' own ideas and questions. Watkins and colleagues (2017), for instance, discuss a professional development program that engaged teachers in sustained open-ended inquiry over a period of three years to develop teachers' facility with doing science in responsive and unscripted ways. The underlying assumption is that such experiences will support teachers to engage in scientific inquiry as learners themselves and, in turn, more easily recognize and leverage the beginnings of science in their own student inquiry (e.g., Hammer & van Zee, 2006).

Theoretical Framework

Affect as Integral to Teacher Learning

While the aforementioned body of work has contributed important theoretical and empirical knowledge about teacher learning, existing efforts to promote responsive teaching have enjoyed limited success (Banilower, Smith, Weiss, Malzahn, Campbell, & Weis, 2013; Capps, Crawford, & Constas, 2012; Levin, 2008; Robertson & Atkins Elliott, 2020). With their focus on cognitive aspects of teacher learning, I argue that current efforts have overlooked the import of affect within that learning. Meanwhile, studies on student learning have identified affective dynamics such as the excitement for a question, the vexation in the face of intellectual challenges, and the irritation at inconsistencies, as part and parcel of learning science (e.g., Alsop, 2005; Bellocchi & Ritchie, 2015; Fortus, 2014; Gupta, Elby, & Danielak, 2018; Jaber & Hammer, 2016a, 2016b; Radoff, Jaber, & Hammer, 2019). This line of research has moved accounts of learning beyond "cold cognition" (Mason, Gava, & Boldrin, 2008), highlighting affect as central to the design and analysis of learning experiences.

Applied to science teacher learning, these insights call attention to affect not as an add-on but rather as integral to what teachers must experience, grapple with, and refine in learning to teach science. Such insights, however, have not been considered and leveraged in teacher education. As highlighted in the aforementioned literature, most efforts to promote reform instruction have focused on teacher cognition without explicit attention to the role of affect in science teacher learning and sensemaking.

More recently, however, emerging research in teacher education is explicitly attending to affect in science teachers' experiences, growth, and identity development (e.g., Avraamidou, 2020; Bellocchi, Ritchie, Tobin, Sandhu, & Sandhu, 2013; Davidson, Jaber, & Southerland, 2020; Finkelstein, Jaber, & Dini, 2019; Hufnagel, 2015; Gilbert & Byers, 2017; Robertson & Atkins Elliott, 2020; Zembylas, 2003, 2005). While limited, this body of work begins to highlight the importance of affect in teacher learning, such as in its role in teachers' relationship with the discipline, in their navigation of tensions and uncertainties in learning and teaching science, and in how they leverage emotions as sites of self-transformation and growth. In line with these efforts, I argue that in order to understand and support teacher learning around responsive teaching, we must attend to both teachers' affect in tandem with their conceptual and epistemological learning.

Affect, Epistemic Empathy, and Responsive Teaching

As noted earlier, responsive teaching can be challenging to enact for a number of reasons (Levin, 2008; Radoff et al., 2018; Robertson & Atkins Elliott, 2020; Robertson & Richards, 2017). Responsive teachers must navigate the seemingly conflicting goals of building on students' own sensemaking efforts and interests while also moving them toward canonical targets. They also wrestle with how to help students persevere in moments of frustration while resisting the urge to

intervene to ease students' struggle. Most importantly, responsive teachers must learn to *hear* students' ideas (Ball, 1993, 1997) and to recognize and build on the productive beginnings in student thinking, especially when that thinking is idiosyncratic or when it is in tension with the canon or with teachers' ways of thinking.

In other words, navigating the intellectual and emotional terrain of responsive teaching requires that teachers develop comfort with uncertainty and an attunement to students' sensemaking experiences in the classroom. To do so, teachers need to move beyond their familiar ways of thinking to take on the learners' perspectives and see how, *to the learners*, their ideas, feelings, and questions make sense (Sikorski, 2016). As Ball (1993) notes, "making sense of children's ideas is not so easy. Children use their own words and their own frames in ways that do not necessarily map into the teacher's ways of thinking" (p. 18); as a consequence, often times "the unusual and novel may be out of earshot" (p. 18). This discrepancy between a teacher's and a student's frame of reference calls attention to the importance of empathy in making sense of and responding to learners' experiences in the classroom.

Building on prior work (Jaber et al., 2018), I propose that *epistemic empathy*—the capacity for tuning into and appreciation someone's intellectual and emotional experiences within an epistemic activity—is key for attending to, interpreting, and responding to students' work during instruction. While research documents that many teachers consider empathy as central to their identity and role as educators, most accounts portray empathy as occurring outside of, and separately from, students' *epistemic* experiences—experiences centered on the construction, communication, and refinement of knowledge to make sense of phenomena (Jaber et al., 2018). Such portrayals include, for example, teachers' empathy with regards to familial, relational, and personal dynamics that may be affecting students' lives and performance at school

(e.g., Aspy, 1972; Chang, Berger, & Chang, 1981; Dolby, 2012; Feshbach & Feshbach, 2009; Tettegah & Anderson, 2007; Warren, 2018). While certainly important for the work of teaching, these broader conceptualizations of empathy are not necessarily aimed at learners' epistemic work. Epistemic empathy on the other hand entails stepping into students' intellectual and emotional experiences in moments of sensemaking to gain perspective on their own ways of thinking and feeling, a perspective that enables teachers to be more attentive and responsive to students' contributions in their instruction. In these ways, epistemic empathy may have unique affordances for responsive teaching.

Research Question

One purpose of this paper is to argue that teachers' affective experiences in the discipline are integral to their learning how to teach the discipline; the second is to show how affective and epistemological aspects of teachers' experiences can serve to cultivate their epistemic empathy in ways that support their responsiveness to students. In the rest of the manuscript, I draw on the learning journey of one preservice science teacher, Keith, who significantly shifted his views on responsive teaching throughout an early teacher education course. At the beginning of the course, Keith who was majoring in physics saw teaching as about imparting his own science understandings and knowledge to his students; as such, Keith was strongly skeptical of responsive teaching. Throughout the course however, Keith came to perceive teaching as the cultivation of students' own ways of thinking and feeling in science—a vision aligned with the goals of responsive teaching. The question driving my analysis is: *How did Keith develop a vision for responsive teaching and what supported his learning?*

Methods

Context

The context of this study is an undergraduate course for preservice science and mathematics teachers offered early in a teacher education program at a public university in Southeast United States. The class met in person for 15 weeks, with 3 hours of in-person interactions each week supplemented with online interactions on a web-based discussion board. The course was centered on student learning in science and mathematics and on theories that explain how people learn within these disciplines. While the course itself was not about instructional practices such as lesson planning and teaching strategies, promoting preservice teachers' awareness of and experience with responsive teaching was one of my overarching goals as the course instructor.

Informed by research on teacher learning and responsive teaching, I designed instructional activities to foster preservice teachers' attention to student thinking by having them: analyze and discuss videos and transcripts of K–12 student work in science and math; grapple with science and mathematics questions in open-ended ways and reflect on those experiences as learners; read and discuss articles on student thinking and responsive teaching; and tutor middle and high school students on a weekly basis with the goal of eliciting student thinking and reflecting on those interactions in a tutoring journal. These activities happened concurrently and were embedded throughout the course. While certain activities such as readings, discussions, and tutoring, occurred every week, a combination of the other activities took place almost on a biweekly basis.

Epistemic empathy was not explicitly discussed in the course; however all course activities and discussions were intended to promote preservice teachers' attunement to and appreciation of learners' diverse ways of reasoning and feeling in science and mathematics.

Throughout the course, preservice teachers were encouraged and challenged to take learners' perspectives and to make sense of their intellectual and emotional experiences in the discipline, both in the videos we watched and within their tutoring contexts. Preservice teachers were also encouraged to make connections between the course activities and their own experiences as science and mathematics learners, to reflect on their views on teaching and learning in their STEM disciplines, and to reflect on their own learning in this pedagogy course.

Research Design

Given the exploratory nature of this research, a case study approach was well suited as it allowed me to examine in depth the "what", "how", and "why" behind Keith's learning to become responsive (Yin, 2016). As Yin (2016) suggests, a case study provides "the opportunity to shed empirical light on some theoretical concepts or principles" (p.38). I purposively selected Keith as the focal participant for my study with this in mind. More specifically, in line with a revelatory case study approach (Yin, 2017), I selected Keith for three main reasons: First, although all other preservice teachers in the course progressed toward more responsive visions for instruction (see Jaber et al., 2018), Keith was unique in his transformation as he started from a place of strong skepticism about responsive teaching. As compared to others, Keith had shown the most significant shift in his views on teaching, and as I show in a previous analysis, in his expressions of epistemic empathy throughout the course (Jaber et al., 2018). Second, Keith was a particularly good informant (Erlandson, Harris, Skipper, & Allen, 1993; Merriam, 1988) given that he was very articulate in describing and reflecting on his experiences in learning science and in learning about teaching. Additionally, his affective expressions during the course signaled to me as the instructor that Keith was interacting in deep and meaningful ways with the course material. For all these reasons, examining Keith's learning journey provided a unique opportunity to construct

in-depth understandings of his learning, understandings that could generate novel empirical and theoretical insights on teacher learning and responsive teaching (Flyvberg 2006; Yin, 2017).

Given the study's focus on characterizing and understanding Keith's learning, an interpretive inquiry approach that attended closely to participants' viewpoints and realities aligned well with my research goal (Denzin & Lincoln, 2011). Accordingly, as I describe in the data analysis section below, I centered my analysis on the ways Keith himself described shifts in his orientation to teaching as well as on factors that he identified as personally influential for his learning.

Data Sources

Throughout the course, myriad data were collected including video records of all classroom discussions from the course, preservice teachers' tutoring journals, pre- and post- responses to questions about their science or mathematics teaching and learning experiences, written reflections on videos of student inquiry, online discussion posts, and weekly reflective slips at the end of class. A research assistant videotaped all class sessions and kept detailed content logs and analytical memos throughout the course, highlighting topics that were discussed as well as interesting contributions from students in the form of questions they raised or reactions to what was going on in class. In addition to these field notes, after the course ended, I watched the video recordings of classroom discussions and produced a content log specific to Keith's contributions, noting the timestamps when he participated in the discussion and describing the context and substance of his contributions. I drew on this entire dataset to explore Keith's journey toward responsive teaching.

Data Analysis

I collaborated with another researcher unaffiliated with the course to analyze the data after the course ended. During the first rounds of the analysis, we met on a regular basis to discuss our interpretations of the data, subjecting the data to multiple viewing and analysis in order to (1) depict the change in Keith's orientation to science teaching including his goals, roles, and priorities as a science teacher, and (2) identify factors that might explain this change. The analysis involved various cycles of reading, organizing, discussing, and coding the data.

We began by familiarizing ourselves with the entire dataset, a process that involved reading and re-reading all of Keith's written assignments, as well as reviewing all the identified video clips where Keith participated in classroom discussions. Next, using a constructivist grounded approach (Charmaz, 2006), each researcher examined the data independently for evidence of Keith's orientation to science teaching and how it shifted over time. This included, for example, instances where Keith described his ideal science teacher, where he talked about his responsibilities as a teacher, or when he wrestled to make sense of what it means to teach responsively in light of his assumptions about "good" science teaching. Drawing primarily on keywords that Keith used repeatedly, we each annotated and categorized the identified data excerpts using descriptive coding (Saldaña, 2015) to depict patterns and shifts in the language that Keith used to describe teaching. Additionally, we attended to instances that involved the use of temporal language where Keith spoke of something in transition or as changing or shifting (examples include: "When I started the course, I had the general idea that […] Now, having not only learned some of the theory in class but having genuine experience as well, [...]; "I see now is not nearly as important as I may have asserted at the beginning of the semester"; "prior to the course").

Through these analyses, we identified two dynamics that were salient in Keith's learning experiences as a science learner and as a novice science teacher: *affective dynamics*, related to his feelings and emotions; and *epistemological dynamics*, related to his ideas about knowing and learning in science. For example, we tracked affect-laden language by highlighting words that carry an emotional tone such as *enjoyed, satisfaction, uncomfortable, light up, joys*, *rewarding, addicting, confident, eagerness,* and *spectacular*. We did the same for epistemological dynamics, tagging words such as *memorization, intuition, procedural understanding, sensemaking, real-world reasoning, scientific terminology, pattern recognition,* and *conceptual learning*.

As an analysis team, the combination of an insider perspective (mine as the course instructor) and an outsider perspective (the analyst unaffiliated with the course) allowed us to broaden our interpretations, to hold each other accountable to the available evidence, and to interrogate and revise our assumptions. We searched for distinct differences and overlaps across our analyses, and in cases of tensions, we subjected our alternative interpretations to critical interrogation in light of the data. Our ongoing negotiations and discussions raised new questions and challenged us to refine our interpretations and ultimately develop a comprehensive and multi-layered understanding of Keith's experiences. In these ways, our collaboration was central for accounting for validity threats and ensuring trustworthiness of our findings.

The last round of analysis centered on generating working themes (Braun & Clarke, 2006) with respect to Keith's learning. First, in light of the insights generated from the various rounds of collaborative analysis, I categorized Keith's views on teaching along a continuum: teacher-centered views, reflective of Keith's incoming orientations, and student-centered responsive views that aligned with Keith's teaching orientations at end of the semester. Second, I characterized affective and epistemological aspects of Keith's relationship with science and in

his interactions with K-12 student inquiry that I argue served to cultivate his epistemic empathy. Keith's epistemic empathy, I show, supported him to be more attentive and responsive to students' intellectual and emotional experiences in science, shifting his concern away from students' arriving at correct answers to nurturing their personal relationships with the discipline.

Findings

The findings are organized in two sections, each with two sub-sections: The first section, *Developing a Vision for Responsive Teaching,* describes (a) Keith's initial views on teaching and in particular his opposition to student-centered responsive instruction, and (b) shifts in those views toward a vision for responsive teaching. The second section, *The Role of Epistemic Empathy in Keith's Learning,* identifies how epistemic empathy supported the shift in Keith's views on teaching by highlighting (a) how Keith channeled his expanding relationship with science to connect with students' cognitive and emotional experiences in the classroom, and (b) how interacting with K-12 students helped Keith recognize and appreciate the science in their inquiry, further supporting the shift in his views.

Developing a Vision for Responsive Teaching

(a) Initial opposition to responsive teaching

Describing his vision of an "ideal" science teacher at the beginning of the course, Keith wrote:

> A deep knowledge of the subject area—far beyond the level being taught—is, to me, the most important feature of a science educator. Teachers need a vast well of knowledge from which to draw (Pre-questionnaire, 1/12).

Keith's attention to teachers' "well of knowledge" "far beyond" the content being taught was in line with his assumption that a science teacher's prime responsibility is to "help the students get to the correct interpretation" (Video reflection, 1/15), a perspective prevalent in his early posts. It

is therefore not surprising that when watching videos of student inquiry from responsive classrooms at the beginning of the course, Keith expressed concerns about "leav[ing] students with the wrong ideas." Referring to two video clips from a fifth grade classroom[1], he noted:

> In neither video did it seem like the teacher was about to guide the conversation towards the proper solution […] If I were in this teacher's position I would eventually help the students get to the correct interpretation of the problem. After all, even a thorough, engaging discussion can be detrimental if they all leave with the wrong ideas. (Video reflection, 1/15).

Keith described this perspective in another post, commenting on the same video:

> I think it would have been even more helpful to have time during class to discuss the correct answer [...] That way the students leave with the correct answer, but still be able to ponder it and throw out their own ideas (Reading reflection, 2/1).

These excerpts highlight Keith's attention to providing students the established scientific answers to questions. Concerned that student thinking may lead in non-canonical directions, Keith viewed responsive teaching as potentially "detrimental" to student learning.

Few weeks later, in reacting to another video from a mathematics classroom[2] where a third grader Sean was arguing that number 6 is both even and odd given that it can be grouped into three groups of 2s (an odd number of groups), and two groups of 3s (an even number of groups) (Ball, 1993), Keith noted that part of his responsibility as a teacher would be to "resolve" student confusion (Video reflection, 2/20). Keith expressed a similar sentiment in a class discussion on cognitive dissonance: "Don't you wanna minimize disequilibrium as much as you

[1] The videos are from the Responsive Teaching in Science project (Co-PIs: Drs. David Hammer and Fred Goldberg); http://ase.tufts.edu/education/responsiveteachinginscience/

[2] The video is from the project Mathematics Teaching and Learning to Teach, University of Michigan. (2010); SeanNumbers-ofala, available at http://hdl.handle.net/2027.42/65013.

can though? You wanna minimize that period of time when there is that discomfort about learning something" (Classroom discussion, 2/2). These concerns drove Keith to initially resist the notion of letting students grapple with phenomena, insisting instead that "you need to show them the patterns" (Classroom discussion, 2/2), an idea aligned with a "delivery pedagogy" (Stroupe, 2016). In another classroom discussion, he noted:

> Usually like if you show somebody why this is, or that you can link this to this [gesturing from one hand to the other], then they're like "oh!" and then they can see the pattern and sort of like internalize what they saw (Classroom discussion, 2/23).

When challenged by his classmate who questioned whether one can indeed learn by being shown something or from someone else's mistake, Keith asserted in a spirited manner:

> If the person in front of me on a sidewalk falls into a hole, then I'll walk around the hole! [gesturing vividly] Or if somebody runs up and says "I fell into a hole around the corner", I'll likely know to go around it! [laughter in the classroom] (Classroom discussion, 2/23).

He continued animatedly:

> Using a math example, if you're teaching somebody: "okay … you think you wanna use this technique, but you really don't want to, because it's horrible and it doesn't lead to the right answer and here is why." If you actually go through it and show them why it's a terrible mistake, so they don't do it themselves and set their thinking straight (Classroom discussion, 2/23).

Troubled by the notion of letting students wrestle with ideas and make mistakes, Keith was vexed by responsive teaching. In his initial posts, he frequently used emphatic negative language such as "detrimental", "horrible", "terrible mistakes", portraying his trepidation with respect to responsive teaching.

(b) Progress toward responsive teaching

Midway through the course, as he continued to learn about responsive teaching and to see rich examples of its enactment in classroom videos, Keith started to question some of his incoming assumptions. He started to recognize the importance of students' active involvement and agency in shaping a lesson, noting that it would be important to integrate "a certain amount of flexibility" in lesson plans to "adjust to" and "take advantage of" students' sensemaking:

> Something I have taken from the readings, as well as the entire course so far, is the notion of paying attention to what students already know, their "common sense" as Hammer and van Zee (2006) put it... This suggests to me that lesson plans, which I have always assumed to be rigid things, must have in them a certain amount of flexibility, such that educators are able to adjust to what their students are thinking and take advantage of their inherent sensemaking (Reading reflection, 3/9).

As he began to entertain the possibility of being more responsive, Keith acknowledged that implementing this vision will be challenging: "I am very instructionally-minded, and so it will take something of an extra effort for me to pay more attention to the student and not my own bank of knowledge" (Exit slip, 2/16). Part of the challenge, he noted in another post, is learning to "be much more aware of my current students' situations" (Exit slip, 2/23).

Despite acknowledging the difficulty of teaching responsively, Keith started to express a sense of excitement for responsive teaching and its value for disciplinary learning: "I will be curious to see what ideas my students can come up with for reasoning about physical phenomena, and then trying to use their ideas for their advantage to shape how I respond" (Exit slip, 3/1).

Through the rest of the course, Keith became increasingly aware of the need to provide students opportunities to formulate and refine their own ideas about phenomena. In his final post, Keith discussed a marked shift in his understanding of his role as a teacher, from one who acts as a "transmitter of information" "play[ing] the role of a textbook" to one who serves as a "mediator" to facilitate student sensemaking (Final paper - 4/18). He depicted the possibilities and affordances he came to see in responsive teaching both for students' learning as well as his own, describing it as "a very exciting position to be in":

> [H]aving not only learned some of the theory in class but having genuine experience as well... I see that regardless of one's own knowledge level, the key part is being present, by which I mean being willing to genuinely attend to a student, listen to his or her ideas, draw out their thinking, and help them develop their thoughts using what they already have, rather than going off of your own thinking… It is actually a very exciting position to be in, and it has allowed me to develop mentally and become a more flexible thinker as a result… and view a topic in a variety of different ways. It is something I have developed just over the past few months, but it is something I find that I enjoy and even look forward to whenever I begin to work with someone else (Tutoring log, 4/12).

These reflections show a clear shift in how Keith came to view his goals and priorities as a teacher as about "being present," "willing to genuinely attend to a student," "help[ing] them develop their thoughts using what they already have." Keith's new appreciation for and excitement about responsive teaching are strikingly different from his incoming stance where he was concerned that such instruction may lead away from the "correct answer" and be "detrimental" to student learning. While a shift in his views was evident by the end of the semester, the change was neither incremental nor linear. As we saw in the findings, week-to-

week in light of various activities and videos, Keith fluctuated between being excited about and resistant to responsive teaching, slowly easing his concerns to eventually embrace this instructional approach. In the next section, I examine the role of epistemic empathy in facilitating the shift in Keith's views on teaching and his uptake of responsive instruction.

The Role of Epistemic Empathy in Keith's Learning

(a) Connecting his own experiences with science to his goals for student learning

Throughout the course, Keith had varied opportunities to reflect on his experiences as a science learner and his motivation to pursue physics. Through this process, Keith came to interrogate and expand aspects of his relationship with science (Sawtelle & Turpen, 2016), including his *epistemology*—his views on and approaches to doing science—and his *affect*—the feelings and emotions he experiences in science.

In a paper submitted at the end of the semester where he was invited to reflect on his learning in the course, Keith explained how his own education has informed his initial views on learning and teaching science:

> Coming into this course, I had my own views on teaching science and mathematics. I held the belief that the most important factor in a student's education was how effectively the educator conveyed information: how well the instructor knew the material and could present it. This was all based off of my own personal experiences through school and college, which revolved around the notion of listening to the teacher, taking what they give you, and turning it into knowledge. To me, the learning process was a transfer of information from the teacher to the student, and this is what my education has been based on for years (Final paper, 4/18).

Describing his AP physics class, he noted:

> A vast majority of the class was spent on AP-exam material; all of our homeworks were practice questions, our tests old AP exams, and we even had weekly equation quizzes in the second semester meant to help us memorize as many equations as we could (Reading reflection, 1/25).

It is evident from these excepts that his early experiences learning science in high school have colored the ways in which Keith initially viewed his roles, goals, and priorities as a science teacher, where his focus was on effectively conveying information and facts to students.

As Keith reflected on his science experiences in the course, he started to compare his high school science to his advanced physics college courses, noting a disconnect between those experiences: "What I found was that when I got to college, and began taking genuine physics classes, much of what I learned in high school did not translate well" (Reading reflection, 1/25). He added: "I don't recall ever really learning anything spectacular, or making any big revelations like I have in college" (Reading reflection, 1/25). Keith contrasted his high school physics experiences, which were far from "anything spectacular," to his college experiences, noting that much of the focus in high school was "collecting of facts and memorization, so that we could pass whatever exam was coming up next. 'Understanding' and intuition were merely implicit goals, second to achieving good grades" (Interview, 4/24).

Through these reflections, Keith started to problematize aspects of his K-12 instruction that deprived him—and perhaps other students as well—from experiencing science in meaningful ways. Keith started to pay attention to the difference between learning as acquiring information "to pass an exam" and learning as the refinement of intuition and understandings. This distinction became particularly salient for Keith after engaging in class in an investigation on division (Philipp, 2000). Keith and his peers were alarmed when they realized they had never

understood the reason behind nor questioned the process of "inverting and multiplying" when dividing by fractions, which prompted a generative discussion on procedural versus conceptual learning. Right after class, Keith wrote:

> Something I personally have picked up is the notion that conceptual understanding is absolutely, fundamentally crucial to learning…I think as a physicist this is extremely relevant, since we are infamous for our many equations and formulas that seem to have nothing in common with one another, when in fact, every equation in classical mechanics (what a majority of students learn) can be derived or connected to a small handful that I could probably count on one hand. As the field which boasts a "theory of everything," our classes seem shattered or disjoint (Reading reflection, 2/25)

In this post, there is evidence of Keith's expanding epistemology regarding what counts as knowledge and learning in physics. Connecting his learning in the course to his broader experiences in physics, Keith pointed out the problematic emphasis on memorizing equations and the fragmented nature of physics curricula. In another post, he wrote:

> In many physics classes, there is a severe disconnect when the focus of the course switches from mechanics to electrostatics, and it is often conceived that the two have nothing to do with one another. However, there are connections that could be made even on an introductory level, such as the fact that the normal force which counteracts gravity and allows you to sit in your chair without falling through it in fact arises from the electric repulsions between the atoms in your body and those of the chair; hence, when you are sitting in your chair (a "mechanical" situation), you are in fact levitating due to the electric force (an "electrostatic" situation), only on an atomic scale (Reading reflection, 2/13).

Keith realized that drawing such disciplinary connections and developing a "deep understanding" of physics starting from "intuition" are "intensely rewarding" experiences, driving his excitement about physics as he described few weeks later:

> When I was in high school, and the first couple of years of undergrad, my primary motivators (or reinforcements) were my grades… what I put the most effort into was the satisfaction of doing well on an external level, reflected in my report card... It wasn't until recently—not quite a year ago, in fact—when in the midst of my now deep, upper-division studies in physics that I began to develop this "intuition" common across all fields and those who truly dedicate themselves to them. While it is even now still in its infantile phase, the intuition I am beginning to develop in my field is of an intensely rewarding nature (addicting, some might say), and has completely overshadowed the more external rewards I once prized in high school. Now, to me, grades come secondary to a genuine and deep understanding of my studies, which is something I hope every student can experience at some point (Reading reflection, 3/26).

Keith started to draw on his own disciplinary experiences as a physics learner, including his frustrations and joys, to connect to and empathize with K-12 students' intellectual and emotional experiences in the science classroom. Leveraging his personal experiences in the discipline, and in particular the feelings he derived from "genuine and deep understanding," Keith came to see the importance of providing "every student" opportunities to have similarly rewarding and meaningful science experiences. In a subsequent post, he wrote:

> I know from my own experiences that at the heart of it all lies a fundamental reasoning and sense that "clicks" on an immensely satisfying level. There is so much "sense" in physics that so many people tend to miss, and that is perhaps something that I through my

> efforts can bring out for more students and lead them down the path that I've come to love so dearly (Reading reflection, 4/2).

In a deeply affective tenor ("immensely satisfying"; "love so dearly"), Keith described how achieving coherent understandings in physics—a "sense" that your reasoning "clicks"—can provoke intense emotions. Such satisfying emotions, he noted, are rarely experienced in science classrooms, motivating him to provide his students opportunities to experience them in his role as a teacher. It is through the "joys of understanding," Keith noted, that people come "to do wonderful things; they write books, develop theories, perform experiments, compose masterpieces, all without a single thought to what is 'required' for a grade" (Reading reflection, 3/26). Drawing on his recent realizations of what it *feels* to deeply understand and figure something out, Keith became more intentional about making instructional choices that support K-12 students to experience the "joys of understanding."

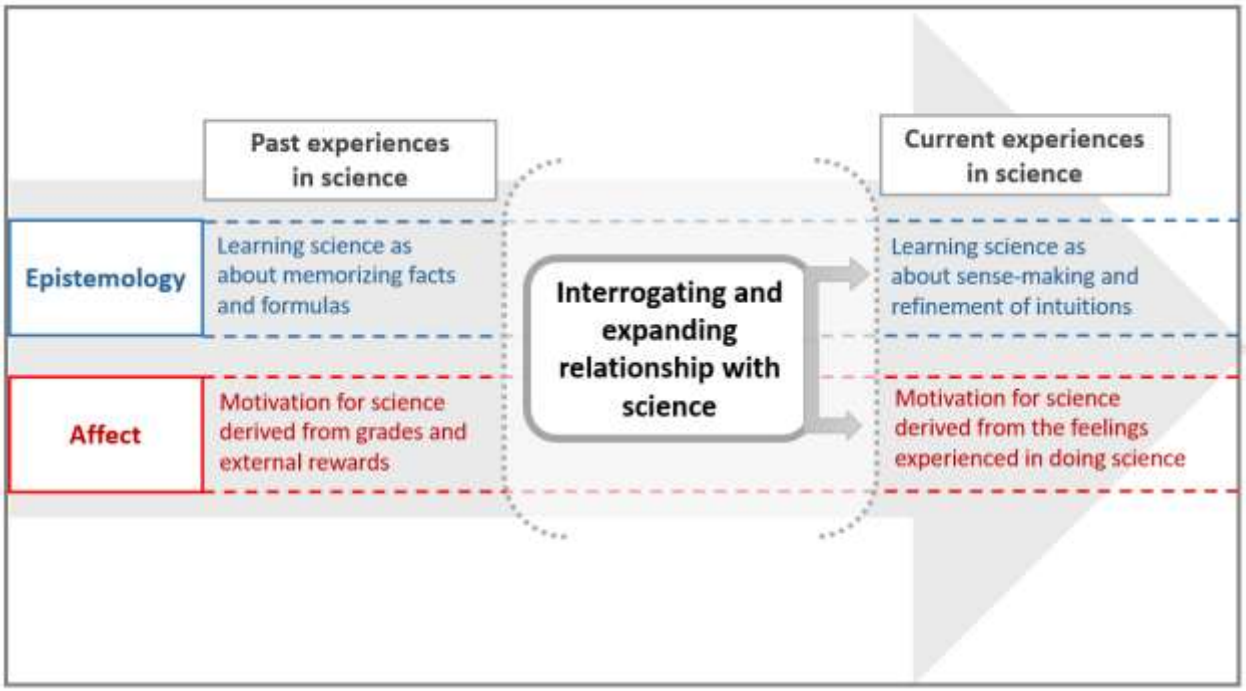

Figure 1. Epistemological and affective dynamics in Keith's relationship with science.

In sum, as illustrated in Figure 1, Keith's expanding relationship with science involved both epistemological and affective dynamics that helped him reframe his roles and priorities as a science teacher. As he reflected on his own journey as a science learner, Keith realized that most of his early experiences in science were shaped by a view of learning as about acquisition of content. This view implied that motivation to learn science derived from being successful in school as reflected by grades and other extrinsic measures. However, in his advanced physics courses in college, Keith experienced science in drastically different ways. Juxtaposing his most recent experiences with his earlier ones, Keith problematized aspects of his science learning and his initial assumptions about K-12 student inquiry. Keith realized that, like him, students must be allowed to experience the feelings inherent in science, such as frustration at inconsistencies, vexation in moments of uncertainty, and satisfaction in figuring things out, to forge their own relationships with the discipline.

Next, I examine how seeing rich examples of student inquiry strengthened Keith's interest in and empathy for students' learning experiences, further stabilizing the shift in his orientation to teaching.

(b) Interacting with students and seeing the science in their inquiry

As Keith started to channel his own experiences in science to connect with learners in science classrooms, he was concurrently interacting with K-12 students both in video-records of student inquiry and during tutoring. While at the beginning of the semester Keith expressed a number of worries and anxieties regarding student inquiry and student-led discussions, through his interactions with students throughout the course he started to shift his views on student inquiry. In part, Keith was surprised by K-12 students' creative ways of making sense of phenomena and became intrigued by their ideas, questions, and keenness to understand. Keith was also amazed

by the emotions that students experienced in moments of sensemaking and came to see those emotions as productive for their learning. Watching a video of third grader Isaac explaining to his peers how wheels roll to make a toy car move[3] (Hammer & Radoff, 2014), Keith noted:

> I was impressed by the other students' eagerness to question Isaac; for instance, "how does the scratching make it stop?" "Does it go forever?" And so on. [...] many of the students seemed willing to probe him and his ideas in order to more clearly understand him (Video reflection, 3/17).

Keith also commented on Isaac's patience in responding to his peers and his creativity in coming up with new ways to convey his thinking:

> In response, Isaac maintains his patience (which, again, I was impressed with), and continuously finds new ways to explain what he is thinking. For instance, when his bicycle analogy didn't seem to be working, he drew on remote control cars instead, as well as the physical model. This ability to think about and present his idea in a multitude of ways is a very critical skill in science, since it is often required of scientists to demonstrate their research to a variety of audiences with potentially different backgrounds (Video reflection, 3/17).

As he continued to interact with student thinking, Keith became increasingly attentive to and appreciative of students' intellectual and emotional work in science. Watching high school students make sense of a video of an imploding railroad tanker[4] (Windschitl & Thompson, 2013), Keith excitedly noted students' eagerness to explain what was going on:

[3] The video is publically available at http://studentsdoingscience.tufts.edu/case-studies/isaacs-wheels/more/
[4] The video is publically available at https://ambitiousscienceteaching.org/high-school-%E2%80%A2-gas-laws-%E2%80%A2-legacy-series/#1479471624903-b0aecf97-376a

> [T]hey started naming off ideas on why it may have done so right away, without any prompting from the teacher. This kind of eagerness to dive into a scientific concept, particularly one that seems counterintuitive, is really neat to see (Video reflection, 2/25).

Similar episodes of student thinking continued to intrigue Keith and helped him trust that children are resourceful and can engage productively in reasoning about phenomena if given the opportunity. Reflecting on these episodes, Keith wrote: "you can almost 'see' the science in them in those moments" (Exit slip, 4/5). "Seeing the science" (Hammer & van Zee, 2006) in student inquiry compelled Keith to orient to student thinking with a fascination akin to that with which he viewed scientific phenomena, appreciating the beauty and coherence in their reasoning:

> how fascinating some students' ideas can be when left to their own reasoning. This has certainly shaped my view of "instruction", since I will be curious to see what ideas my students can come up with for reasoning about physical phenomena, and then trying to use their ideas for their advantage to shape how I respond (Exit slip, 3/1).

His fascination with student thinking inspired Keith to rethink how he could make room for students' ideas and productively leverage them in his instruction. Relatedly, seeing nascent forms of disciplinary feelings in student inquiry such as eagerness, enthusiasm, and tenacity to make sense of phenomena motivated Keith to cultivate similar feelings in his students. For example, after watching a video of sixth grader Sandra excitedly exploring magnets and recounting her experience a few years later (Jaber & Hammer, 2016a), Keith wrote:

> The Sandra video really stood out to me... I hope that I can, in essence, recapture some of the fascination for science that Sandra seemed to have (Exit slip, 2/16).

Referring to the same video few weeks later, Keith remarked:

> The fact that Sandra (from several weeks ago) discovered that intense internal reward system at such a young age is proof that, no matter the circumstances, genuine understanding is available to any who seek it, and to bring students to this realization will undoubtedly be the part of my career I enjoy the most (Reading reflection, 3/26).

These insights were reinforced by Keith's weekly tutoring experiences during which he worked with middle and high school students on science and mathematics questions. Commenting on these experience, he noted:

> I know through my experiences that every single student I've worked with has some kind of productive beginnings in some way, these beginnings being as unique as they are, and I genuinely hope that I have helped to bring that out in them (Tutoring log, 3/26).

Keith continued:

> There are many times when, in the process of working with a student, a concept "clicks" for them, such that they can figure out many of the problems on their own by drawing from a deeper understanding. This happened two weeks or so ago, I believe, when I was working with a student... he would grin and say "I got it!" [...] and for a brief moment the student got a glimpse of some of the joys of the intuition and understanding that education brings, [...] a glimpse of the kinds of joys I myself experience in my own studies" (Tutoring log, 3/26)

In this excerpt, Keith explicitly related his own motivations and drives as a physics learner—and in particular the joy of figuring things out—to his tutee's experiences. As he continued to interact with students, Keith learned to tap into his own experiences in science in ways that helped him empathize with K-12 students' experiences in the classroom. As summarized in Figure 2, while initially worried about student inquiry, Keith came to trust that grappling with uncertainty and

experiencing the feelings inherent in science are a central part of learning science for *all* learners, including himself and his future students.

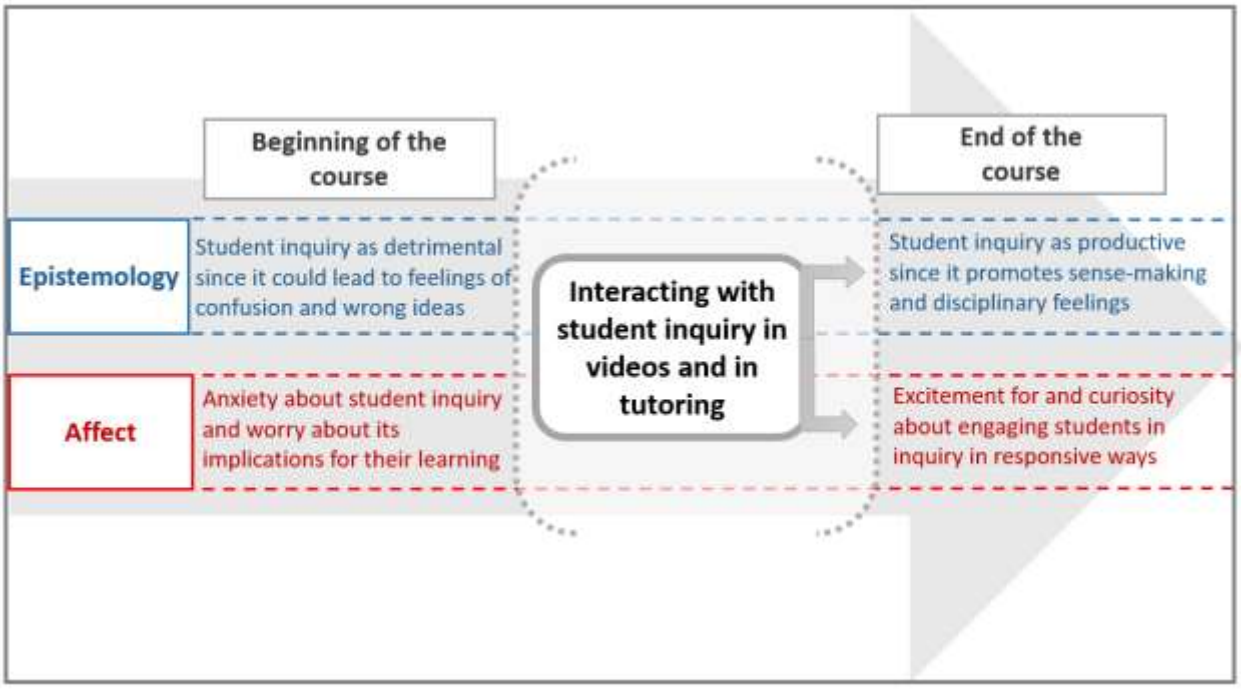

Figure 2. Epistemological and affective dynamics in Keith's interactions with student inquiry.

In light of these realizations, Keith started to re-envision his role as a teacher, from one who "transfer[s] information to the student" to one who "bring[s] out" students' thinking and emotions (Tutoring log, 2/26) and cultivates their personal connections with the discipline. Keith nicely articulated this perspective in his final paper where he wrote:

> Professional science is not a series of lectures, receiving loads of information from a single source without any personal input. Rather, science requires personal involvement, innovation, and confidence, things which simply are not taught in modern-day classrooms. Part of the challenge may be because they cannot precisely be "taught;" they must rather be cultivated in each individual student in a way unique to them... Perhaps, then, this requires a redefinition of our notion of "teaching", and that is one of the major

things – perhaps the most significant – that I have learned through this course (Final paper, 4/18).

Discussion

Contributions to Research on Teacher Education

The goal of this study was to understand how Keith wrestled with, made sense of, and ultimately embraced responsive teaching. In line with existing research on reform instruction, the findings highlight the complex and multilayered nature of teacher learning and enactment of reformed visions of teaching (Anderson et al., 2000; Davis et al., 2006; Kang & Windschitl, 2018; Robertson & Atkins Elliott, 2020). The literature is replete with studies that document such complexity, particularly with respect to novice teachers' learning. Anderson and colleagues (2000), for instance, discuss how preservice teachers' incoming assumptions and goals for student learning interact with and shift in response to the pulls and pushes that they experience in their education programs and field placements. Like the preservice teachers in Anderson et al.'s (2000) study, Keith's story highlights the importance of attending closely to teachers' incoming experiences, visions, and goals to better understand and optimize their engagement and learning within teacher education programs.

Keith's story also extends prior work by urging us to attend to the role of affect in teacher learning and their uptake of student-centered instruction. More specifically, the findings, summarized in Figure 3, highlight key affective and epistemological dynamics in Keith's learning trajectory that were central to cultivating his epistemic empathy, and in turn, his responsiveness to students' experiences. Keith initially advocated for a teacher-centered vision for instruction. Underlying this vision was a tacit conception of science learning as about acquiring the established body of knowledge about the world. This conception is premised on an

understanding of knowledge as a "thing" to be transferred, which "calls to mind teaching as *providing* and learning as *acquiring* (Hammer, Elby, Scherr, & Redish, 2005, p. 116, emphasis in original). In a sense, Keith felt responsible to impart scientific knowledge to students and mitigate their confusion and misunderstandings. The shift in Keith's views on teaching was informed by a corresponding shift in how he oriented to science learning throughout the course—from privileging knowledge acquisition to foregrounding sensemaking and the development of personal connections with the discipline.

This shift, however, was not merely epistemological; rather, it comprised affective dynamics that were central to Keith's experiences in science. It entailed Keith's developing awareness of his own disciplinary feelings together with his growing fascination with and curiosity about K-12 students' ideas and feelings in science. Reflecting on his own experiences in physics, Keith became cognizant of his approach to learning science, including his motivation to make sense of phenomena and the joy he derives from figuring things out. He came to understand science learning as a personal endeavor involving intuitions, emotions, and drives. Recognizing the deeply satisfying feelings that arise within sensemaking, and seeing similar epistemic and affective beginnings in student inquiry, Keith realized that, just like him, students have the right to experience and nurture their personal relationships with the discipline. This motivated him to provide students opportunities to find their own "fascination for science" (Exit slip, 2/16). Over time, Keith's excitement for students' ways of thinking and feeling in science not only compelled him to teach in more responsive ways but also helped him see responsive teaching as a "very exciting position to be in" (Tutoring log, 4/12).

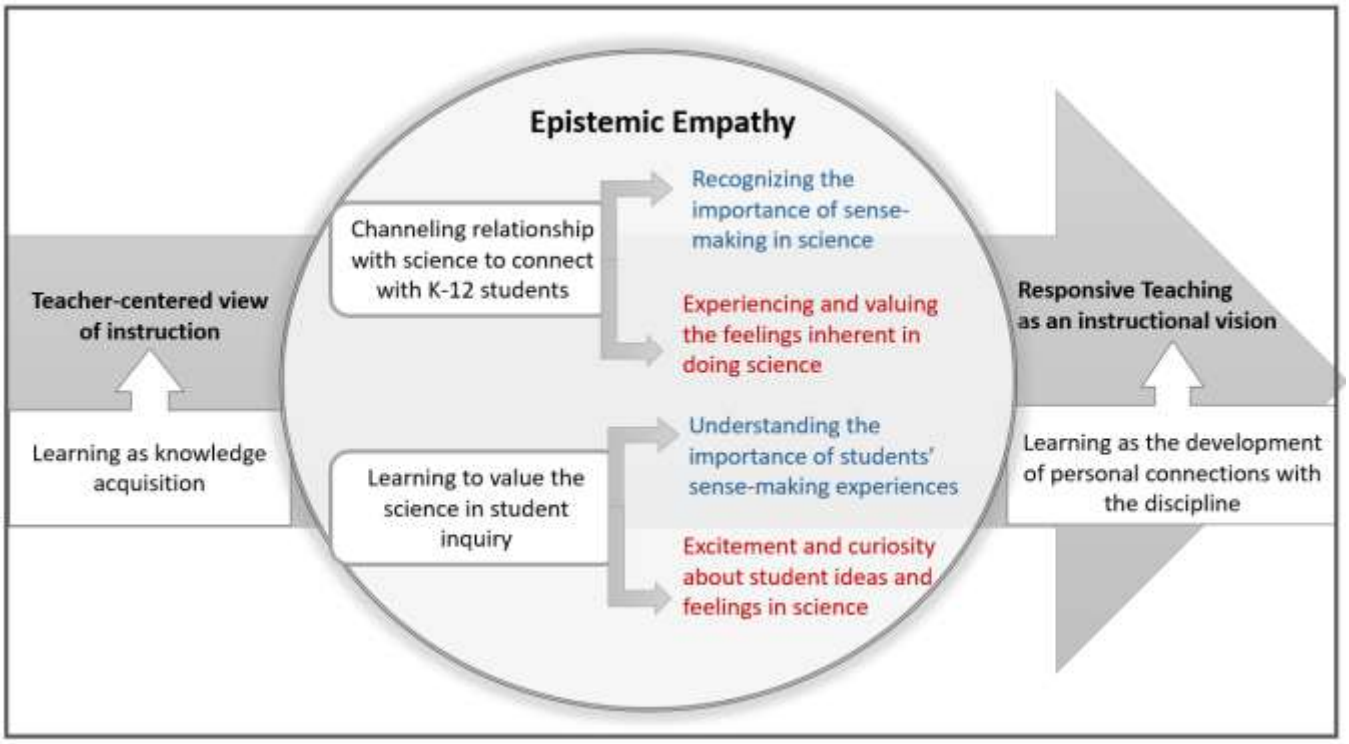

Figure 3. The role of epistemic empathy in developing Keith's vision for responsive teaching.

(Blue text refers to epistemological dynamics and red text refers to affective dynamics in Keith's learning)

The insights garnered from this study point to elements of teacher learning that warrant further examination in future research. First, Keith's journey sheds light on an undertheorized aspect of teacher learning, that is the importance of affect in teachers' experiences of science for their learning how to teach science. More specifically, the findings show that Keith's evolving ideas of what it means to teach science were closely entangled with the feelings and emotions he experienced in learning physics. Recognizing his own feelings as a burgeoning physicist helped Keith appreciate and become more responsive to K-12 students' disciplinary feelings. In these ways, the study illustrates how attending to teachers' affect in the discipline can afford new understandings of teacher learning around responsive teaching, adding to the emerging body of research on affect in teacher education (e.g., Alsop, 2005; Bellocchi & Ritchie, 2015;

Finkelstein, Jaber, & Dini, 2019; Fortus, 2014; Gilbert & Byers, 2017; Hufnagel, 2015; Jaber, Hufnagel, & Radoff, 2019; Zembylas, 2005).

Relatedly, while prior studies suggest that teachers' views of and experiences in the discipline influence their teaching (e.g., Johnson, 2009; Jones & Carter, 2007; Kang & Windschitl, 2018; Lortie, 1975; McNeill et al., 2013; Southerland et al., 2011), Keith's story provides a novel way to understand how such views and experiences may exert their influence and propel teacher learning. As we saw in this study, tapping into and interrogating his own experiences in science supported Keith to become more attuned to the science in student inquiry and to empathize with their epistemic experiences. It is through such empathy that Keith came to reframe his goals for student learning and his priorities as a science teacher. As such, the study motivates attention to epistemic empathy as an aspect of teacher learning that warrants further consideration both in research and in the design of teacher education.

Limitations and Future Research Directions

While this work offers compelling evidence on the role of epistemic empathy in Keith's learning, there are several limitations to the study. First, the available dataset is limited to the course activities. This in turn constrains our understanding of Keith's learning and enactment of responsive teaching to the context of the course. Follow-up data from classroom observations would certainly enrich the findings of the study and possibly generate important insights on both the nature and stability of Keith's uptake of responsive teaching, and the role of epistemic empathy therein. An examination of longer-term impacts of epistemic empathy is particularly important in light of literature that documents changes in teachers' ideas and practices as they get into their own classroom and face various contextual tensions and institutional demands (e.g.,

Anderson et al., 2000; Brickhouse & Bodner, 1992; Ensor, 2001; Grossman & McDonald, 2008; Kennedy, 1999; Levin 2008; Thompson et al., 2013).

Second, while the findings of this work focus on experiences and reflections within one teacher education course, it is likely that other experiences and events in Keith's life were influential on his understandings of science but were not captured in this study. Future work could examine additional facets of Keith and other preservice teachers' stories in science, such as their upbringing and family backgrounds, prior research experiences, and out-of-school encounters with science that may shape their orientation to science and to teaching.

Third, this study focused solely on one teacher learning to embrace responsive teaching. While some of Keith's experiences may resonate with other preservice teachers, each novice teacher's story is unique in some aspects. Given the conceivably wide range of preservice teachers' backgrounds and encounters with science, it is expected that they may have varied understandings of science as a discipline, and therefore varied orientations to and goals for teaching science. Accordingly, the course activities that were consequential for Keith's sensemaking and learning about responsive teaching may be experienced differently by others. Examining the learning trajectories of other preservice teachers in light of their relationship with science and their interactions with K-12 student inquiry would afford opportunities to interrogate and refine this work's findings regarding the relationship between epistemic empathy, teacher learning, and responsive teaching.

Implications for Teacher Education

The study draws attention to the importance of designing and implementing educative experiences within teacher education that target epistemic empathy as an aspect for teacher learning. The findings suggest different ways in which epistemic empathy can be cultivated,

including through interactions with student inquiry and through critical reflections on and reframing of one's relationship with the discipline.

For Keith, and more broadly across our dataset, we found that analyzing episodes of student inquiry and interacting with students during tutoring afforded preservice teachers opportunities to expand their repertoire and appreciation of students' resources and capabilities, and subsequently their openness to responsive teaching (Jaber et al., 2018). As we saw in the findings, examining rich instances of K-12 student thinking helped Keith recognize the productive work that students engage in as they make sense of phenomena and fostered his empathy for students' epistemic experiences in the science classroom. This finding aligns with and contributes to extant research on the use of artifacts of practice, such as videos, transcripts, and student work, to provide teachers with "images of possibilities" (Barnhart & van Es, 2018, p. 51) of learners' disciplinary engagement (e.g., Barth-Cohen et al., 2018; Levin & Richards, 2011; Tekkumru-Kisa et al., 2018; Santagata & Taylor, 2018; van Es & Sherin; 2010) and in turn foster teachers' epistemic empathy for students.

Keith's case also extends this line of work by showing the importance of juxtaposing such artifacts of practice with opportunities for teachers to voice their anxieties and concerns about pedagogies that are new to them. As shown in the findings, having ample opportunities to wrestle with and question responsive teaching was central to Keith's learning to make sense of and ultimately develop a vision for responsive teaching. In a recent study, Robertson and Richards (2017) similarly showed that learning assistants (LAs) who "grappled with questions about whether or not being responsive to students' ideas was okay (and/or fit with their existing ideas about good teaching)" (p. 337) were able to develop a more robust understanding of responsive teaching and its affordances for student learning. Such "sustained, deep sense-

making" opportunities "[t]hrough assignments, class discussions, and course projects that regularly asked LAs to articulate their own position with respect to responsiveness" (p. 338), the authors show, were productive for the LAs' identification with and enactment of responsive teaching.

In line with research on the role of reflection in teacher learning (e.g., Clarke & Hollingsworth, 2002; Danielowitch, 2007; Kazemi et al., 2016), this study also draws attention to the importance of providing teachers opportunities to critically reflect on their own approaches to and emotional experiences in science. For Keith, thinking deeply about and interrogating his own science learning experiences prompted him to problematize some of his incoming assumptions about teaching. These reflections also allowed him to tap into the joys he experienced in sensemaking, joys he found "intensely rewarding," even "addicting" (Reading reflection, 3/26). However, not all preservice teachers may have necessarily had similarly meaningful encounters with the discipline. As such, Keith's case study also highlights the importance of creating opportunities within teacher education where teachers can experience science as an exciting and joyful pursuit of sensemaking and forge personally meaningful relationships with the discipline. Such opportunities may allow teachers to recognize their own joys, vexations, and drives in science, and in turn be more open and responsive to their students' excitements, questions, and puzzlements.

Finally, this study invites us as teacher educators to also be more open and responsive to our preservice teachers' excitements, questions, and puzzlements about instructional visions and practices that may be new to them, such as responsive teaching. To do so entails being patient and understanding when teachers express resistance to ideas presented to them, and empathizing with their experience of uncertainty and doubt as they wrestle with and interrogate their own

ideas, goals, and assumptions. This work necessitates on the part of teacher educators a stance of empathy and openness to learning *with* the teachers both within teacher education courses and in the complex realities of classroom environments that are in and of themselves infused with uncertainty.

Acknowledgements. I am incredibly grateful for Leema Berland, Rosemary Russ, and the anonymous reviewers for their constructive and generous feedback throughout the review process. Special thanks as well to Sherry Southerland, Shannon Davidson, and Jennifer Radoff for their helpful comments on previous versions of this manuscript. Additionally, I am thankful for Mustafa Fakhri for his support in the data analysis part of the work. I am grateful as well for Tiffany-Rose Sikorski, David Hammer, Vesal Dini, and Rabih Chehayeb for rich discussions on epistemic empathy that helped crystallize this work. Last but not least, I would like to thank Keith for his generous sharing of his experiences and his investment in learning.

Funding. This work was supported in part by the National Science Foundation under Grant No. DRL 1844453, "CAREER: Cultivating Teachers' Epistemic Empathy to Promote Responsive Teaching." The views expressed here are those of the author and are not necessarily endorsed by the foundation.

References

Alsop, S. (2005) Beyond Cartesian dualism. Encountering affect in the teaching and learning of science. Dordrecht: Springer, Science and Technology Education Library.

Anderson, L. M., Smith, D. C., & Peasley, K. (2000). Integrating learner and learning concerns: Prospective elementary science teachers' paths and progress. Teaching and Teacher Education, 16(5-6), 547-574.

Atkins, L., & Frank, B. (2016). Examining the products of responsive inquiry. In A.D. Robertson, R.E. Scherr, & D. Hammer (Eds.), Responsive teaching in science and mathematics (pp. 56-84). New York, NY: Routledge.

Avraamidou, L. (2019). Science identity as a landscape of becoming: Rethinking recognition and emotions through an intersectionality lens. Cultural Studies of Science Education, 1-23.

Ball, D. L. (1993). With an eye on the mathematical horizon: Dilemmas of teaching elementary school mathematics. The Elementary School Journal, 93(4), 373-397.

Ball, D. L. (1997). What do students know? Facing challenges of distance, context, and desire in trying to hear children. In International handbook of teachers and teaching (pp. 769-818). Springer, Dordrecht.

Ball, D. L., & Forzani, F. M. (2010). Teaching skillful teaching. Educational Leadership, 68(4), 40-45.

Banilower, E. R., Smith, P. S., Weiss, I. R., Malzahn, K. A., Campbell, K. M., & Weis, A. M. (2013). Report of the 2012 National Survey of Science and Mathematics Education. Horizon Research, Inc.

Barnhart, T., & van Es, E. (2018). Leveraging analysis of students' disciplinary thinking in a video club to promote student-centered science instruction. Contemporary Issues in Technology and Teacher Education, 18(1), 50-80.

Barth-Cohen, L. A., Little, A. J., & Abrahamson, D. (2018). Building reflective practices in a pre-service math and science teacher education course that focuses on qualitative video analysis. Journal of Science Teacher Education, 29(2), 83-101.

Bellocchi, A., & Ritchie, S. M. (2015). "I was proud of myself that I didn't give up and I did it": Experiences of pride and triumph in learning science. Science Education, 99(4), 638-668.

Bellocchi, A., Ritchie, S. M., Tobin, K., Sandhu, M., & Sandhu, S. (2013). Exploring emotional climate in preservice science teacher education. Cultural Studies of Science Education, 8(3), 529-552.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. Qualitative Research in Psychology, 3(2), 77-101.

Bresser, R., & Fargason, S. (2013). Becoming scientists: Inquiry-based teaching in diverse classrooms, Grades 3-5. Stenhouse Publishers.

Brickhouse, N. W., & Bodner, G. M. (1992). The beginning science teacher: Narratives of convictions and constraints. Journal of Research in Science Teaching, 29, 471–488.

Capps, D. K., Crawford, B. A., & Constas, M. A. (2012). A review of empirical literature on inquiry professional development: Alignment with best practices and a critique of the findings. Journal of Science Teacher Education, 23(3), 291-318.

Carpenter, T. P., Fennema, E., Franke, M. L., Levi, L., & Empson, S. B. (2000). Cognitively Guided Instruction: A research-based teacher professional development program for elementary school mathematics. Madison, WI: NCISLA, Wisconsin Center for Education Research, University of Wisconsin.

Cartier, J. L., Smith, M. S., Stein, M. K., & Ross, D. K. (2013). 5 practices for orchestrating productive task-based discussions in science. National Council of Teachers of Mathematics.

Charmaz, K. (2006). Constructing grounded theory: A practical guide through qualitative analysis. Thousand Oaks, CA: Sage publications.

Clarke, D., & Hollingsworth, H. (2002). Elaborating a model of teacher professional growth. Teaching and Teacher Education, 18(8), 947-967.

Coffey, J., & Edwards, A. R. (2016). Examining the products of responsive inquiry. In A.D. Robertson, R.E. Scherr, & D. Hammer (Eds.), Responsive teaching in science and mathematics (pp. 145-162). New York, NY: Routledge.

Council of Chief State School Officers (CCSSO). (2010). Common core state standards for mathematics. Retrieved from http://www.corestandards.org/assets/CCSSI_Math Standards.pdf

Danielowich, R. (2007). Negotiating the conflicts: Reexamining the structure and function of reflection in science teacher learning. Science Education, 91(4), 629-663.

Davidson, S., Jaber, L. Z., & Southerland, S. (2020). Emotions in the doing of science: Exploring epistemic affect in elementary teachers' science research experiences. Science Education, 104(6), 1008-1040.

Davis, E. A., Petish, D., & Smithey, J. (2006). Challenges new science teachers face. Review of Educational Research, 76(4), 607-651.

Denzin, N. K., & Lincoln, Y. S. (Eds.). (2011). The Sage handbook of qualitative research. Sage.

Dini, V., Jaber, L. Z., & Danahy, E. (2019). Dynamics of scientific engagement in a blended online learning environment. Research in Science Education, Online first.

Duckworth, E. (2006). The having of wonderful ideas and other essays on teaching and learning (3rd Edition). New York, NY: Teachers College Press.

Duschl, R. (2008). Science education in three-part harmony: Balancing conceptual, epistemic, and social learning goals. Review of Research in Education, 32(1), 268-291.

Ensor, P. (2001). From pre-service mathematics teacher education to beginning teaching: A study in recontextualizing. Journal for Research in Mathematics Education, 32, 296–320.

Erlandson, D. A., Harris, E. L., Skipper, B. L., & Allen, S. D. (1993). Doing naturalistic inquiry: A guide to methods. Sage.

Finkelstein, C., Jaber, L. Z., & Dini, V. (2019). "Do I feel threatened? No… I'm learning!"-Affective and relational dynamics in science PD. Science Education, 103(2), 338-361.

Flyvberg, B. (2006). Five misunderstandings about case research. Qualitative Inquiry. http://qix.sagepub.com.

Ford, M. J. (2008). "Grasp of practice" as a reasoning resource for inquiry and nature of science understanding. Science & Education, 17(2&3), 147-177.

Fortus, D. (2014). Attending to affect. Journal of Research in Science Teaching, 51(7), 821-835.

Gilbert, A., & Byers, C. C. (2017). Wonder as a tool to engage preservice elementary teachers in science learning and teaching. Science Education, 101(6), 907-928.

Grooms, J., Enderle, P., & Sampson, V. (2015). Coordinating scientific argumentation and the Next Generation Science Standards through argument driven inquiry. Science Educator, 24(1), 45-50.

Grossman, P., & McDonald, M. (2008). Back to the future: Directions for research in teaching and teacher education. American Educational Research Journal, 45(1), 184–205

Gupta, A., Elby, A., & Danielak, B. A. (2018). Exploring the entanglement of personal epistemologies and emotions in students' thinking. Physical Review Physics Education Research, 14(1), 010129.

Hammer, D. (1997). Discovery learning and discovery teaching. Cognition and Instruction, 15(4), 485-529.

Hammer, D. (2016). Epilogue. In A.D. Robertson, R.E. Scherr, & D. Hammer (Eds.), Responsive teaching in science and mathematics (pp. 249-253). New York, NY: Routledge.

Hammer, D., & Radoff, J. (2014). Children doing science: Essential idiosyncrasy and the challenges of assessment. Commissioned paper for Successful Out-of-School STEM Learning: A Consensus Study.

Hammer, D., & van Zee, E. H. (2006). Seeing the science in children's thinking: Case studies of student inquiry in physical science. (Book and DVD) Portsmouth, NH: Heinemann.

Hammer, D., Elby, A., Scherr, R. E., & Redish, E. F. (2005). Resources, framing, and transfer. In J. P. Mestre (Ed), Transfer of learning from a modern multidisciplinary perspective. Greenwich, CT: IAP. (pp. 89-119).

Hammer, D., Goldberg, F., & Fargason, S. (2012). Responsive teaching and the beginnings of energy in a third grade classroom. Review of Science, Mathematics and ICT Education, 6(1), 51-72.

Hammer, D., Russ, R., Mikeska, J., & Scherr, R. (2008). Identifying inquiry and conceptualizing students' abilities. In R. Duschl & R. Grandy (Eds). Establishing a consensus agenda for K-12 science inquiry (pp. 138-156). Rotterdam, NL: Sense Publishers.

Hufnagel, E. (2015). Preservice elementary teachers' emotional connections and disconnections to climate change in a science course. Journal of Research in Science Teaching, 52(9), 1296-1324.

Jaber, L. Z., & Hammer, D. (2016). Learning to feel like a scientist. Science Education, 100(2), 189-220.

Jaber, L. Z., Hufnagel, E., & Radoff, J. (2019). "This is really frying my brain!": How affect supports inquiry in an online learning environment. Research in Science Education, Online first.

Jaber, L. Z., Southerland, S., & Dake, F. (2018). Cultivating epistemic empathy in preservice teacher education. Teaching and Teacher Education, 72, 13-23.

Johnson, C. C. (2009). An examination of effective practices: Moving toward elimination of achievement gaps in science. Journal of Science Teacher Education, 20, 287-306.

Jones, M. G., & Carter, G. (2007). Science teacher attitudes and beliefs. In S. Abell & N. Lederman (Eds.), Handbook of research on science education (pp. 1067-1104). Mahwah, NJ: Lawrence Erlbaum Associates.

Kang, H., & Anderson, C. W. (2015). Supporting preservice science teachers' ability to attend and respond to student thinking by design. Science Education, 99(5), 863-895.

Kang, H., & Windschitl, M. (2018). How Does Practice-Based Teacher Preparation Influence Novices' First-Year Instruction? Teachers College Record, 120(8), 1-44.

Kang, H., Windschitl, M., Stroupe, D., & Thompson, J. (2016). Designing, launching, and implementing high quality learning opportunities for students that advance scientific thinking. Journal of Research in Science Teaching, 53(9), 1316-1340.

Kazemi, E., & Wæge, K. (2015). Learning to teach within practice-based methods courses. Mathematics Teacher Education and Development, 17(2), 125-145.

Kazemi, E., Ghousseini, H., Cunard, A., & Turrou, A. C. (2016). Getting inside rehearsals: Insights from teacher educators to support work on complex practice. Journal of Teacher Education, 67(1), 18-31.

Kennedy, M. M. (1999). The role of pre-service teacher education. In L. Darling Hammond & G. Sykes (Eds.), Teaching as the learning profession: Handbook of policy and practice (pp. 54–86). San Francisco, CA: Jossey-Bass.

Kennedy, M. M. (2006). Knowledge and vision in teaching. Journal of Teacher Education, 57(3), 205–211.

Levin, D. M. (2008). What secondary science teachers pay attention to in the classroom: Situating teaching in institutional and social systems (Doctoral dissertation).University of Maryland at College Park, College Park, MD.

Levin, D. M., & Richards, J. (2011). Learning to attend to the substance of students' thinking in science. Science Educator, 20(2), 1-11.

Levin, D. M., Grant, T., & Hammer, D. (2012). Attending and responding to student thinking in science. The American Biology Teacher, 74(3), 158-162.

Lortie, D. C. (1975). Schoolteachers: A sociological study. Chicago, IL: University of Chicago Press.

Maskiewicz, A. (2016). Navigating the challenges of teaching responsively: an insider's perspective. In A. Robertson, R. Scherr & D. Hammer (Eds.), Responsive teaching in science and mathematics (pp.105-125). New York: Routledge.

Maskiewicz, A., & Winters, V. (2012). Understanding the co-construction of inquiry practices: a case study of a responsive teaching environment. Journal of Research in Science Teaching, 49(4), 429-464.

Mason, L., Gava, M., & Boldrin, A. (2008). On warm conceptual change: The interplay of text, epistemological beliefs, and topic interest. Journal of Educational Psychology, 100(2), 291-309.

McNeill, K. L., Pimentel, D. S., & Strauss, E. G. (2013). The impact of high school science teachers' beliefs, curricular enactments and experience on student learning during an inquiry-based urban ecology curriculum. International Journal of Science Education, 35(15), 2608-2644.

Merriam, S. B. (1988). Case study research in education: A qualitative approach. Jossey-Bass.

Michaels, S. (2005). Can the intellectual affordances of working-class storytelling be leveraged in school? Human Development, 48, 136-145.

Miller, E., Manz, E., Russ, R., Stroupe, D., & Berland, L. (2018). Addressing the epistemic elephant in the room: Epistemic agency and the next generation science standards. Journal of Research in Science Teaching, 55(7), 1053-1075.

National Research Council (NRC). (2012). A framework for K-12 science education: Practices, crosscutting concepts, and core Ideas. Washington, DC: National Academies Press.

NGSS Lead States. (2013). Next Generation Science standards: For states, by states. Washington, DC: The National Academies Press.

O'Connor, C., & Michaels, S. (2019). Supporting teachers in taking up productive talk moves: The long road to professional learning at scale. International Journal of Educational Research, 97, 166-175.

Opfer, V. D., & Pedder, D. (2011). Conceptualizing teacher professional learning. Review of Educational Research, 81(3), 376-407.

Radoff, J., Jaber, L. Z., & Hammer, D. (2019). "It's scary but it's also exciting": Evidence of meta-affective learning in science. Cognition and Instruction, 37(1), 73-92.

Radoff, J., Robertson, A. D., Fargason, S., & Goldberg, F. (2018). Responsive teaching and high-stakes testing. Science and Children, 55(9), 88-91.

Richards, J., & Robertson, A. D. (2016). A review of the research on responsive teaching in science and mathematics. In A.D. Robertson, R.E. Scherr, & D. Hammer (Eds.), Responsive teaching in science and mathematics (pp. 36-55). New York, NY: Routledge.

Richardson, V. (2003). Preservice teachers' beliefs. In J. Raths, & A. C. McAninch (Eds.), Teacher beliefs and classroom performance: The impact of teacher education, volume 6: Advances in teacher education (pp. 1–22). Greenwich, CT: Information Age.

Robertson, A. D., & Atkins Elliott, L. J. (2020). Truth, success, and faith: Novice teachers' perceptions of what's at risk in responsive teaching in science. Science Education, 104(4), 736-761.

Robertson, A. D., & Richards, J. (2017). Teacher sense-making about being responsive to students' science ideas: A case study. European Journal of Science and Mathematics Education, 5(4), 314-342.

Robertson, A. D., Scherr, R. E., & Hammer, D. (2016). Responsive teaching in science and mathematics. New York, NY: Routledge.

Saldaña, J. (2015). The coding manual for qualitative researchers. Sage.

Salter, I., & Atkins, L. (2013). Student-generated scientific inquiry for elementary education undergraduates: Course development, outcomes and implications. Journal of Science Teacher Education, 24(1), 157-177.

Santagata, R., & Taylor, K. (2018). Novice teachers' use of student thinking and learning as evidence of teaching effectiveness: A longitudinal study of video-enhanced teacher preparation. Contemporary Issues in Technology and Teacher Education, 18(1), 11-28.

Sikorski, T. R. (2016). Understanding responsive teaching and curriculum from the students' perspective. In A.D. Robertson, R.E. Scherr, & D. Hammer (Eds.), Responsive teaching in science and mathematics (pp. 103-122). New York, NY: Routledge.

Southerland, S. A., Sowell, S., Blanchard, M., & Granger, E. M. (2011). Exploring the construct of pedagogical discontentment: A tool to understand science teachers' openness to reform. Research in Science Education, 41(3), 299-317.

Stroupe, D. (2014). Examining classroom science practice communities: How teachers and students negotiate epistemic agency and learn science-as-practice. Science Education, 98(3), 487-516.

Stroupe, D. (2015). Describing "science practice" in learning settings. Science Education, 99(6), 1033-1040.

Stroupe, D. (2016). Beginning teachers' use of resources to enact and learn from ambitious instruction. Cognition and Instruction, 34(1), 51-77.

Tekkumru-Kisa, M., Stein, M. K., & Coker, R. (2018). Teachers' learning to facilitate high-level student thinking: Impact of a video-based professional development. Journal of Research in Science Teaching, 55(4), 479-502.

Thompson, J., Hagenah, S., Kang, H., Stroupe, D., Braaten, M., Colley, C., & Windschitl, M. (2016). Rigor and responsiveness in classroom activity. Teachers College Record, 118(7).

Thompson, J., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. American Educational Research Journal, 50(3), 574-615.

van Es, E. A., & Sherin, M. G. (2008). Mathematics teachers' "learning to notice" in the context of a video club. Teaching and Teacher Education, 24(2), 244-276.

van Es, E. A., Cashen, M., Barnhart, T., & Auger, A. (2017). Learning to notice mathematics instruction: Using video to develop preservice teachers' vision of ambitious pedagogy. Cognition and Instruction, 35(3), 165-187.

Watkins, J., Coffey, J. E., Maskiewicz, A. C., & Hammer, D. (2017). An account of teachers' epistemological progress in science. In G. Schraw, J. Lunn Brownlee, L. Olafson & M. VanderVeldt Brye (Eds.), Teachers' personal epistemologies: evolving models for informing practice (pp. 89-113). Charlotte, NC: Information Age Press.

Watkins, J., Jaber, L. Z., & Dini, V. (2020). Facilitating scientific engagement online: Responsive teaching in a science professional development program. Journal of Science Teacher Education, 31(5), 515-536.

Weller, D., & Finkelstein, C. (2011). From "adding inquiry" to "doing science." Science and Children, 48(7), 49–53.

Windschitl, M., & Calabrese Barton, A. (2016). Rigor and equity by design: Locating a set of core teaching practices for the science education community. In C. Bell, & D. Gitomer. (Eds.). *American Education Research Association's Handbook of Research on Teaching. 5th Edition* (pp. 1099-1158).

Windschitl, M., & Thompson, J. (2013). The modeling toolkit: Making student thinking visible with public representations. The Science Teacher, 80(6), 63-69.

Yin, R. K. (2017). Case study research and applications: Design and methods. Thousand Oaks, CA: Sage publications.

Zembylas, M. (2003). Emotions and teacher identity: A poststructural perspective. Teachers and Teaching, 9(3), 213-238.

Zembylas, M. (2005). Beyond teacher cognition and teacher beliefs: The value of the ethnography of emotions in teaching. International Journal of Qualitative Studies in Education, 18(4), 465-487.