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Novice Elementary Teachers' Developing Visions of Effective Science Teaching

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Abstract Theories of how people learn and how science connects to students' lives provide frameworks for exploring the development of teachers' visions of effective science teaching. These frameworks can inform elementary teacher preparation programs about how to communicate theory-based practices of effective science instruction to support pre-service teachers' abilities to identify and enact science instruction that contributes to student learning. Part of a larger study, the present study uses a grounded theory design to examine three teachers' developing visions of effective science teaching through their teacher preparation and into their first year of teaching through a series of interviews. Findings revealed several factors contributing to their visions of science teaching: their memories of their experiences as elementary students, their teacher preparation, and institutional policies related to science instruction. Implications for helping novice teachers connect their visions with enacting practices situated in the realities of classrooms are discussed.

Keywords Visions of effective science teaching · Elementary pre-service teacher preparation · Longitudinal

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The ability of elementary school teachers to recognize, reflect on, and enact effective science teaching practices requires content knowledge, models of effective teaching, experience, and practice. The study presented sought to identify novice teachers' developing visions of effective science teaching focusing on five elements derived from learning theory documents: motivation, eliciting students' prior knowledge, intellectual engagement with relevant phenomena, use of evidence to critique claims, and sense-making. Our understanding about what is effective teaching has been informed in recent decades by cognitive research about learning. Two key documents, *How People Learn: Brain, Mind, Experience, and School* (National Research Council [NRC] 2000) and *How Students Learn; History, Mathematics, and Science in the Classroom* (NRC 2004), have increased our understanding about practices that connect with students' lives and contribute to student learning. These critical advances in our understanding of the learning process provide educators and researchers with important links between teaching and learning. The cognitive learning theory elements identified in these key documents help frame the development of models of effective science teaching (Banilower et al. 2008). These elements are further featured in an assessment called Teachers' Beliefs about Effective Science Teaching (TBEST) (Smith et al. 2014) that was designed to document teachers' beliefs about these elements of science instruction. The TBEST assessment builds on these five elements of learning theory that were used in this study as markers of effective science teaching. We focused on the TBEST subscale that measures learning-theory-aligned science instruction (LTASI) because this subscale indicates teachers' identification of effective science teaching aligned with cognitive learning theory (NRC 2000) that informs our current understandings about critical elements of effective science teaching.

Building off these elements of effective science teaching and using TBEST scores for case selection, the present longitudinal study explored three elementary school teachers' developing visions of effective science teaching beginning while they were enrolled in a STEM-focused teacher preparation program in the USA through their first year of teaching spanning a three-year period. Here we refer to emerging teachers' *visions* as their developing ideas about effective science teaching practices. Understanding beginning teachers' visions of effective teaching can help us design more effective teacher education and inservice professional development. The visions belonging to pre-service teachers (PSTs), while rich with insight and potential to illuminate factors that may influence these visions, are rarely explored. This study aims at uncovering factors that influence PSTs' developing visions of effective science teaching during their teacher education and in their first year of teaching. In operationalizing novice teachers' visions of effective science teaching, we examined their "professional knowledge landscapes" (Clandinin 2015, p. 189) that include their *memories and ideas about science and science teaching, their experiences in teacher preparation including field experiences*, and *their projection of their futures as teachers of science* to answer the following research questions:

1. How did participants' visions of effective science teaching align with the five learning theory elements of effective science teaching?
2. What factors influence participants' developing visions of effective science teaching?

This study is part of a larger study examining the influence of STEM-focused teacher preparation on graduates' science and mathematics knowledge, efficacy, beliefs, and teaching practice. In the sections that follow, we present theoretical concepts that frame our study followed by a description of our research and findings.

Conceptual Frame

Effective Science Teaching

Science instruction is often identified using two labels: *reform* and *traditional*. While science teaching typically is a mix of the two, not falling neatly into the classifications, these characterizations do however inform models of effective science instruction. Reform instruction has been described as student-led inquiry with students working in groups and engaged in hands-on, minds-on activities that include student explanations of phenomena. Traditional science teaching is commonly characterized as teacher-directed lectures and lab activities designed to confirm predetermined outcomes. Clearly, these two models of instruction do not measure student learning, and rigid adherence to either model is not recommended; however, research suggests that students learn best when teachers connect new ideas to students' lives (NRC 2000, 2004). Below we describe the five elements of effective instruction that were identified by Smith et al. (2014) as markers for effective teaching.

Motivation Motivation is a complex psychological construct used to explain behavior and effort applied to activities. Ford (1992) describes motivation as a combination of individual goals, emotions, and personal beliefs. Cognitive and affective influences contribute to a person's decisions about how to behave to achieve expected outcomes (Ajzen and Madden 1986; Bandura 1977). Motivation for learning has its roots in cognitive and behavioral psychology, and students' perceptions of task value and self-efficacy contribute to their motivation for learning (Schunk and Pintrich 2002). Schunk et al. (2012) define motivation in education as "the process whereby goal-directed activities are intimated and sustained" (p. 5). Motivation can come from internal desires or goals that stem from personal interest (intrinsic motivation) or from external factors (extrinsic motivation) such as achieving a grade. Learning what motivates people to engage in certain activities, what keeps them interested and to what degree, can assist in maintaining and/or improving retention in that activity (Fortus and Vedder-Weiss 2014; McInerney et al. 2004). "For all students, motivation and attitudes toward science play an important role in science learning" (Duschl et al. 2007, p. 203), and effective instruction often begins with students' existing notions about the world.

Eliciting Students' Prior Knowledge Students enter school with notions about the world that may support or hinder learning (Duschl et al. 2007). When student ideas do not align with accepted science understandings, teachers need to help students examine their ideas by first identifying students' notions, then providing students with experiences that help refine students' understandings with scientifically accurate knowledge. Yet large-scale observation studies have found that only a small fraction of lessons take into account students' prior knowledge, and teachers seldom press for explanations (Banilower et al. 2006; Roth and Garnier 2006; Weiss et al. 2001). Building on students' existing notions while connecting new science learning to their lives encourages students' intellectual engagement.

Intellectually Engaging Students with Relevant Phenomena To make science instruction intellectually engaging for students, there is a need to move beyond *hands-on* to include *minds-on* approaches to teaching and learning by connecting activities to conceptual understandings. Students who are engaged in science activities need support investigating meaningful questions and considering relationships between new knowledge and prior conceptions. Part of intellectual engagement includes the intellectual risk taking and struggles involved in learning (Beghetto and Baxter 2012). Further, there is a link between students' willingness to share and test tentative ideas, and their development as learners (Beghetto 2009; National Research Council 2004). Testing ideas through observation and manipulation of science notions helps students learn the importance of using evidence to support and make sense of new ideas.

Using Evidence to Critique Claims Many researchers have examined the structure of a scientific argument to support students' explanations that can be defended with evidence (e.g., Iordanou and Constantinou 2015; Osborne et al. 2016; Sandoval and Reiser 2004; Zembal-Saul et al. 2002). Student participation in science requires that they produce and evaluate evidence to support claims in addition to acknowledging that new evidence may require revision of current understandings (Duschl et al. 2007; Michaels et al. 2008). When teachers provide students with complex questions that require student discourse, teachers create opportunities for persuasive argumentation to make and critique claims using evidence (Fishman et al. 2017; Osborne et al. 2016). Further, active engagement with sense-making provides content understandings beyond superficial memorization of facts (Passmore et al. 2014). As identified in the US Next Generation Science Standards (NGSS), providing students with opportunities to build and critique evidence-based claims is critical for helping students make sense of the world (Duschl et al. 2007; NGSS Lead States 2013; NRC 2012).

Engaging Students in Sense-making Effective science lessons should include opportunities for students to make sense of their ideas and explorations (National Research Council 2004), and young students in particular need support with making sense of these experiences. Such teacher support includes rich questioning, facilitating class or partner discussions, and connecting to students' prior knowledge. Sense-making discussions should be more about science as a process and building knowledge rather than superficially memorizing facts (Banilower et al., 2010; Passmore et al. 2014). "Learning is an active process. We need to acknowledge students' attempts to make sense of their experiences and help them confront inconsistencies in their sense-making" (NRC 2004, p. 476). As students use evidence to make sense of findings and claims, they may gain a deeper understanding of science content and practices. These five intertwined elements have been identified as contributing to science learning and we use them as a way to build our descriptions of our novice teachers' visions of effective science teaching.

Teachers' Visions of Effective Science Teaching

In this study, we present research on novice teachers' visions about teaching and learning to examine how these visions might ultimately influence teachers' decisions about instruction. We position our examination of novice teachers' visions of effective science teaching in the context of their developing roles as science teachers. Next, we present research on teacher beliefs, along with literature on teachers' visions of high-quality instruction (e.g., Hammerness 2001, 2003, 2008; Kennedy 2006; Munter 2009, 2014) that informed our study.

Beliefs

The interrelationships between beliefs, knowledge, and behaviors should be a key focus for teacher educators (Tosun 2000). Teacher beliefs are a construct widely discussed in education, and Pajares (1992) described ongoing debates among educational researchers about the relationships between teacher knowledge and beliefs. Beliefs cannot be directly observed or measured but rather must be inferred from what people say, intend, or do, thus challenging education researchers to connect teacher beliefs with teacher knowledge and behaviors (Luft and Roehrig 2007). Bybee, who has written extensively about the 5E model of science instruction (Bybee et al. 2002), connects this model with cognitive research in *How People Learn* (NRC 2000). Bybee (1993) identified classroom teachers as "the decisive component in reforming science education" (p. 144), thus guiding teacher educators and professional developers to attend to teacher beliefs as teachers' beliefs position their larger visions of instruction.

Visions

Teachers' visions build on their beliefs about effective instruction and are dynamic in nature (Kennedy 2006; Munter 2014). Kennedy uses the term visions to describe teachers' plans; in other words, their purpose and actions that foster student learning. Hammerness (2001) defined teachers' visions as "a set of images of ideal classroom practice for which teachers strive" (p. 143). She suggests that identifying teachers' personal visions can help researchers move from seeing teachers as obstacles to reform efforts to deeply exploring teachers' responses to reforms. In a longitudinal study that looked closely at teachers' career paths, Hammerness outlined that teachers sometimes leave teaching because their visions of effective instruction do not match the reality of teaching at their particular school. It is possible, however, that while the visions of effective instruction were dynamic for these teachers, the visions of their capability to make those instructional visions a reality were stifled by the institution in which they were teaching. Hammerness (2001) makes the distinction between personal and institutional visions, with the latter requiring teachers to align more closely with institutional goals rather than developing and aligning with their own vision of ideal classroom practice. Institutional visions can support teachers' goals but have the potential to disconnect from authentic practice when, for example, school visions are developed without input from teachers (Fullan 1993; Senge 1990). Munter (2009) identified the importance for teachers and district/administrative instructional leaders to share visions of high-quality instruction, thus presenting a united vision for student learning.

The alignment of teacher and administrator visions was a key factor identified by Kennedy (2006) as she elaborated on the complexity associated with the maintenance of teachers' visions. She explained how at any given time teachers simultaneously attempt to balance six components that make up their vision for effective instruction. The components of these visions are the following: the need to cover all of the required content, whether or not students are learning and how to help those who are struggling, getting students to participate in class, maintaining the momentum of a lesson, and establishing a community of practice in the classroom, all while accommodating for the cognitive and emotional needs of each student (Kennedy 2006). Kennedy explained that when teachers implement a lesson plan, they typically focus on one or two of these components of their instructional vision, giving little attention to the others. If teachers strive for but are unable to achieve the *ideal* they may lose confidence as effective teachers.

In order to align our study with teacher visions of effective science teaching, we selected participants using a series of PSTs' TBEST scores (specifically the LTASI subscale) in a process described below. Since we know of no assessment of novice teachers' *visions* per se, we used the TBEST scores to capture participants' views on teaching and learning related to elements of effective teaching.

TBEST

The TBEST instrument was originally developed to investigate the impact of professional development and as a means to predict classroom practice and student learning (Smith et al. 2014). As an instrument that identifies teachers' beliefs about effective science teaching, it provides researchers with a window into pre-service and novice teachers' developing visions of effective science teaching. TBEST has three subscales, one that identifies *learning-theory-aligned science instruction* (LTASI) and two that describe practices that do not align with effective science instruction: *hands-on above all else*, which indicates students are involved in activities but without attention to including sense-making, and *confirmation practices* where student activities occur following instruction to confirm direct instruction rather than students building conceptual understandings on their initial engagement in the phenomena of study.

Teachers are asked to respond to descriptions of instruction in each of the three categories. Teachers who agree with LTASI statements are able to identify effective instruction supported by cognitive and developmental sciences about how students learn as synthesized in *How People Learn* (NRC 2000). The fundamental learning principles associated with LTASI are the following: (1) students come to the classroom with preconceptions about how the world works, (2) factual knowledge and conceptual knowledge contribute to understanding, and (3) students must control their learning through metacognitive practices. Teachers who select *hands-on above all else* and *confirmation practices* identify practices that do not align with learning theory supported science instruction.

Methods

Study Context

This study is part of a larger research project that involved 245 participants across four cohorts of graduates of a STEM-focused teacher preparation program in the USA. Two of the researchers taught the science method courses in the STEM-focused teacher preparation program, the first during PSTs' junior year focused on K-2 (classrooms for students aged 5–7 years old) science education and the second in the PSTs' senior year focused on grade 3–5 (classrooms for students aged 7–10 years old) science education.

In the present longitudinal study, one cohort of participants ($n = 55$) was recruited for an in-depth case study component at the start of their junior year. Sixteen of the 36 who volunteered were selected to participate based on stratified sampling (with three strata) using GPA as the variable. TBEST was administered to pre-service teachers throughout their teacher preparation and into their first year of teaching to document their developing beliefs about effective science teaching. TBEST scores were used for case selection as described below, and interviews provide in-depth data documenting teachers' developing visions of effective science instruction.

We documented TBEST (Smith et al. 2014) scores from four time points across the study period and used the path of scores to examine the trajectory of participants' beliefs of effective science teaching. Complete TBEST scores from each of the four time points were available for 12 of the 16 case study PSTs. These 12 PSTs became the sample for the present study. We focused on the TBEST subscale that measures LTASI because this subscale indicates teachers' identification of effective science teaching aligned with learning theory (NRC 2000) that informs our current understandings about critical elements of effective science teaching. Teachers who select responses in this subscale indicate their strong visions of effective science teaching. Trajectory organization and selection processes are described below.

Case Selection

In order to compare each case study's TBEST scores to that of the overall group of participants for case selection ($n = 245$ from the larger study), we converted their TBEST scores to z-scores using the overall participant group's mean. We then graphed the z-scores of the 12 case studies at all four time points and grouped them into tertiles (see Fig. 1). These tertiles helped to identify those participants with LTASI score trajectories from the beginning of their teacher preparation to their first year of teaching that were *high*, *stable*, and *low*. The high tertile included participants whose LTASI overall trajectory over the four time points had ending scores that increased more than half a standard deviation from the group mean. The stable tertile group included participants whose LTASI scores neither increased nor decreased half a standard deviation from the group mean across the time points. The low-tertile group included participants' scores that decreased over half a standard deviation over the group mean from the beginning of the study to the end. We purposefully selected (Patton 2002) one case study from each tertile to participate in this study because their trajectories best represented the patterns of others in their tertile.

The three case study participants' interviews across three years provided details about their visions of effective science teaching during their teacher preparation and into their first-year teaching (see Fig. 2). The interviews examined factors such as participants' experiences with/in teacher preparation, field experiences, the role of mentors, and school settings in both their field placements and as beginning teachers as we examined the development of their visions over time.

Again, the elements of effective science teaching from the TBEST, motivating learners, surfacing learners' prior knowledge, using evidence to make claims, intellectually engaging learners with phenomena, and making sense of an idea (Smith et al. 2014), guided the study.

Analytical Procedures

In order to establish reliability for coding interviews, the coders first coded individually and then met and discussed the a priori codes. These a priori codes (Miles and Huberman 1984) addressed research question 1 and corresponded to the five elements of effective teaching: motivation, eliciting students' prior knowledge, intellectual engagement with relevant

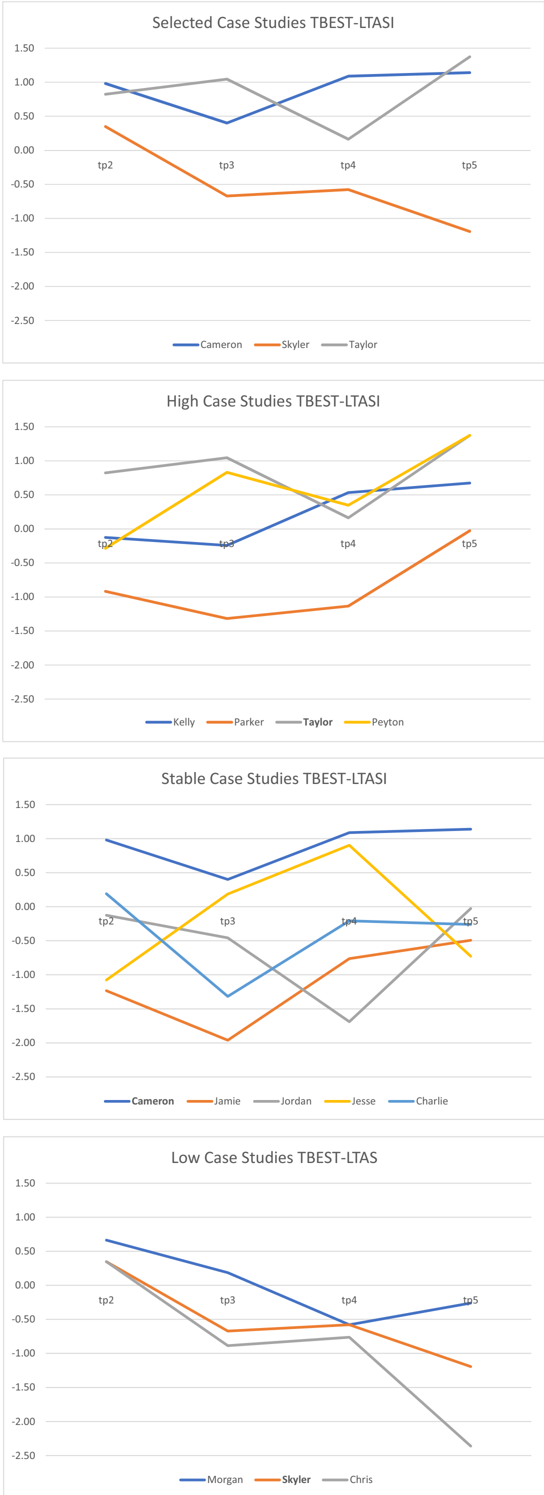

Fig. 1 Case study TBEST *z*-score trajectories and tertiles

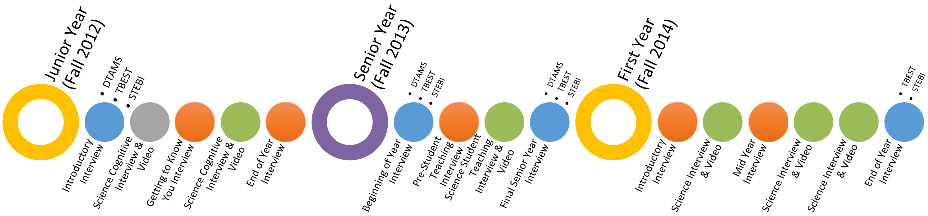

Fig. 2 Timeline of data for case study participants

phenomena, use of evidence to critique claims, and sense-making (Banilower et al. 2008). Using grounded theory practices, the coders' further discussions provided consensus on selective coding themes for factors that influence participants' visions of effective science teaching that came from careful reading of the interviews that addressed research question 2: memories, attitudes about science, field experiences, method courses, and institutional influences (Glasser and Strauss 1967; Strauss and Corbin 1994). These themes supplemented the a priori codes used originally (see Table 1).

The first author initially coded all of the interviews for two of the case studies, while the second author coded all of the interviews for the third case study. Ongoing conversations allowed the researchers to maintain consistency with common interpretations of codes and alignment with theoretical constructs. After final coding, the authors met again to discuss and resolve any discrepancies that arose while coding (Campbell et al. 2013). Researchers also prepared memos that described the teachers' attitudes and behaviors about science and science teaching communicated through interviews during teacher preparation and into their first year of teaching. In the following section, we present the teachers' stories beginning with an overview of their visions of science and science teaching. We focus on visions of effective science instruction, organized using learning theory-aligned themes: motivating students, prior knowledge, using evidence, intellectually engaging students with relevant phenomena, and sense-making.

Findings

The three teachers' stories of their developing visions of science teaching follow. Each teacher was selected as a representative from each tertile of case study teachers based on the trajectory of TBEST scores administered during teacher preparation and into their first year of teaching. Here we use gender-neutral pseudonyms from the larger study to protect the identity of the participants, but for the purposes of this paper, we will use female pronouns for consistency. Taylor, the *science enthusiast*, Cameron, the

Table 1 Coding themes

A priori themes	Subcodes
Motivating learners	Memories
Prior knowledge	Attitudes about science
Engaging learners	Methods courses
Evidence	Field experiences
Sense-making	Institutional influences

developing science teacher, and Skyler, the *emerging science teacher*, describe their beliefs about science and science teaching, their visions of instruction, and their instructional practices. Next, we describe their beliefs about science and science teaching, their visions of instruction, and their instructional practices.

Taylor—the Science Enthusiast

Taylor wanted to be a teacher from a young age, and as a student, she enjoyed math and science more than reading and writing. She described her memories of science as positive because of her many memories of teachers providing experiments. Resulting from these positive memories, and as evidenced by these memories of science activities, Taylor emphasized her comfort with science focusing on hands-on activities. Taylor entered the teacher preparation program describing the importance of science in elementary school as "providing students with knowledge about their world" and felt that effective instruction should incorporate "active learning," yet without including goals for connecting activities with students' sense-making.

During junior-, senior-, and first-year teaching interviews, Taylor was asked to map her confidence trajectory levels about her science teaching on a timeline at each stage. The trajectory from her junior semester illustrated that Taylor's initial confidence level was high, only to drop as she began to learn about the complexity of teaching. Once in student teaching and later as a beginning teacher with her own classroom, she recognized the marginalization of science in elementary schools and the obstacles she faced as a science teacher. Mirroring the confidence trajectory during her junior semester, Taylor's trajectory in her first year of teaching again started high and decreased. She felt hindered by the limited schedule for teaching science and the lack of support for science instruction, and while she maintained that she loved science, she was frustrated by the *institutional policy* challenges she faced while striving to achieve her vision of effective science teaching.

Motivation Taylor's memories of hands-on activities as a student contributed to her ideas that active learning motivates students to learn. These notions were reinforced in field experiences during her junior year methods course where she and a fellow pre-service teacher taught an integrated lesson on sound to grade 2 students that included activities where the students interacted with sound properties. She was impressed with students' excitement and the recognition of her impact on their learning. "I think it's so exciting when kids are discovering…and it's just so rewarding and especially when you see the 'aha' moment where they get it." Taylor described how students continued their interest and discussions about sound waves even two weeks following their participation in sound activities. Taylor's early vision that effective science teaching includes activities to motivate students was likely based on her memories of science activities and reinforced by her experiences as a pre-service teacher as she actively engaged students with science in schools. Taylor's recognition of students' enthusiasm for science and positive attitudes about science clearly influenced her valuing of science teaching.

Prior Knowledge During Taylor's junior year science methods course, pre-service teachers were asked to research the issue of students' alternative conceptions in order to develop strategies of teaching for conceptual change. These strategies begin with identifying students' current notions about target ideas. As Taylor prepared for her lesson on sound, she planned to begin by identifying students' prior knowledge. When she discussed this with her mentor teacher, she told Taylor that the students would not have any prior knowledge on sound, illustrating the teacher's lack of understanding that students form ideas about concepts even without formal instruction. Later, when Taylor asked students questions about the topic of sound, she was amazed at the level of students' prior knowledge, which contributed to the development of her vision of effective science teaching. Through this experience, Taylor's vision expanded to embrace the notion that teachers must assume students have accurate and inaccurate background knowledge on a wealth of scientifically oriented topics.

As a second example, Taylor decided to evaluate students' knowledge about the term "STEM" during her senior year science methods course for an independent field-based inquiry project in a school where "STEM" had been identified as the theme of the school. Upon questioning students and teachers about the meaning of STEM, she discovered that the majority were unaware that STEM is an acronym that stands for science, technology, engineering, and mathematics. The acronym was typically used at the school in reference to design and building (e.g., straw bridges). She realized that without asking questions to identify students' prior knowledge, she would have continued to use the term STEM without realizing that students lacked a full understanding of the interdisciplinary connections. With this experience, her vision of effective science teaching began to include that teachers ensure their students have common understandings of basic concepts.

Using Evidence In her methods courses, Taylor learned that an effective teaching strategy to encourage student learning in science is asking them to provide evidence to support their claims (Michaels et al. 2008). Her vision for this strategy transitioned during her teacher preparation experience and again when teaching in her own classroom. Initially, during her junior year methods course, Taylor explained that student use of content area vocabulary served as evidence, explaining that her students would use the words "high-pitch humming sound" and "high frequency" to describe a sound. Later, in her senior year science methods course, Taylor continued to focus on the vocabulary knowledge over science content. Following a lesson on force and motion she explained, "They didn't really have to use that much evidence. After they did the cannon ball activity, they had to, I guess, kind of use evidence from the game of what was science, what was technology, what was engineering…".

As a first-year teacher, Taylor identified students' observations about features of plants to "tell me what process of the cycle their plant was in" as students providing evidence of the plant's life cycle stage. Over the series of interviews, Taylor's strategies for students' use of evidence to critique claims began with students' use of content area vocabulary words as evidence, then to accuracy of student language, and as a new teacher she used students' descriptions of observational data as evidence to support their claims. Her documented learning about students' use of evidence contributed to her developing vision of effective science teaching.

Intellectually Engaging with Relevant Phenomena In her sophomore year, Taylor took an entomology course where she learned about relationships between insects and humans. During an early interview in her junior year, when asked about intellectually engaging her future students with relevant phenomena, Taylor described how learning the relationship between humans and insects might also help elementary students intellectually identify with the role of insects in their world. "When kids can see the connections, they will learn more about insects in our world."

While discussing how she learned, through her methods courses, the importance of student discourse and intellectually engaging students, Taylor expressed that she had not previously considered "asking students why and asking them to explain their thinking." She elaborated:

> Making sure that the kids are thinking about what they're doing, not just regurgitating answers and answering questions that have one answer, make sure that they're discussing it and agreeing and disagreeing on things, so not only teacher-made questions but also student questions that they can ask one another and ask their (sic) self.

As a first-year teacher, Taylor described her developing ideas about intellectually engaging students with relevant phenomena:

> I think a huge part of science is giving students a chance to explore something for themselves. So, if you're talking about spring, don't sit in your classroom, go outside during springtime and talk about spring instead of like looking at picture of pollen ...go look at some pollen outside...make it purposeful. Make it meaningful.

Taylor's explanation of helping students engage with science through lived experiences, rather than in a textbook, as well as explaining their thinking led to the development of her vision for effective science teaching, relevant to student engagement.

Sense-making During the junior year science methods class, Taylor described her own initial learning about the importance of sense-making during an activity in the course that physically modeled the relative distances of the planets from the sun. After participating in the outdoor activity illustrating scale distances between planets in our solar system, she said "that makes so much more sense now" as she recognized new learning about key ideas herself.

When asked how she helped her students make sense of science concepts, Taylor contrasted her memories of science when she was in school with the research she encountered in her methods courses. She explained her memories:

> The teacher presenting what the answer should be and then the kids are just looking for that one answer and they don't really get the science behind it…because when we did those activities we didn't actually understand the science behind them, so I guess the research kind of helps gauge how effective the instruction is and then it's used to revamp how it's taught.

Taylor's vision of effective science instruction was clearly influenced by her memories of science activities when she was an elementary student but also from learning about research-based strategies in her methods courses. While Taylor's initial vision of effective science teaching was grounded in her comfort with familiar memories, these memories conflicted with the effective teaching strategies she learned in her teacher preparation program (e.g., using evidence to support claims and intellectually engaging young learners with phenomena). When novice teachers' past experiences as students conflict with their new learning about teaching, they must negotiate their visions of effective teaching. Taylor's recognition of students' enthusiasm for science in her field placement classrooms and their positive attitudes toward science as they worked to make sense of what they were learning reinforced her developing visions about effective science teaching.

Cameron—the Developing Science Teacher

Like Taylor, Cameron's initial visions of effective teaching were also based on her memories and experiences as a student. She fondly remembered teachers who "were nice" and who joked in class. This supported one of Cameron's initial goals for herself to become a "fun" teacher. Her image of science in particular when she entered the program was a school subject that was often "boring" because of note taking, writing, and memorizing definitions, and reading textbooks. She had few memories of science in elementary school but expected that teaching elementary science would be "easier" than the science she remembered from middle or high school. By the end of her junior year in college and after two science methods courses, Cameron described science as important and especially emphasized getting girls interested in science. From this point, the trajectory of Cameron's vision for effective science instruction plateaued when compared to Taylor's.

At the beginning of her senior year, Cameron described an effective science lesson as one that is hands-on, fun, and engaging for students. Despite readings and discussions in her methods courses, Cameron often labeled students having fun as evidence of a successful lesson and she used student engagement as a measure of lesson effectiveness, pointing out that the students' interest in science motivated them to learn. By the end of student teaching, Cameron said that she enjoyed teaching science more than other subjects because the students enjoyed the activities, yet her interviews included descriptions of activities with hands-on, but not minds-on, emphasis. Cameron's limited emphasis on students' sense-making at this stage is captured in her description of a lesson about weather. "The students enjoyed playing with the different materials, so I think the lesson was a hit."

During her first year as a teacher, Cameron taught 2nd grade which comforted her because she felt she was not prepared to teach science content in upper elementary grades. Her grade level team shared planning of various subjects and she planned the science lessons. She was frustrated with *institutional policies* limiting teaching materials in science because she was exposed to the use of science kits during student teaching, but the school where she got her first teaching position did not supply science kits or other instructional materials. As a result, she asked students to create a book on the science topic of study and she identified student research on a computer as their use of tools. When asked about how she assessed student learning, she said she would "just go over the page of the project." When prompted about what students learned from her lesson on weather, she said "they were really excited; tsunami is a cool word." She also expressed frustration with the emphasis on mathematics and reading time usurping time for science. Her descriptions of these *institutional policy* barriers clearly interrupted her developing visions of effective science teaching.

Motivation Cameron identified actively engaging students as motivational and as a first-year teacher, she described that her students often valued science more than recess. She stated:

> Because they just enjoy it so much, it makes it easy to teach, even if I didn't know everything, it's fine because it's science and you know, that's what you talk about; that's why we do experiments. I don't know everything, you don't know everything, but we'll figure it out together. I became much more comfortable at teaching science.

Here, Cameron's vision of effective science teaching included a reciprocal relationship between students' enthusiasm for learning science and her motivation to teach science.

Cameron's developing vision for motivating students included student autonomy that she learned about in her methods courses. During an interview following one of her lessons, she explained:

> One of the main things in my methods class is letting students take charge of their own learning, and, you know, finding out stuff for themselves. It was way more interesting for them to find out something than for me to tell them. So, as much as I can, I let them explore and discover. It takes away the fun if I'm the one telling them the facts. You know, so I really was trying to just scaffold their learning and let them take charge.

Notably, through her field experiences, Cameron's vision of effective science teaching recognized the importance of providing students with opportunities to discover and explore science concepts.

Prior Knowledge During Cameron's junior year science methods course, she was introduced to the concept of conceptual change and the need to first identify students' prior knowledge to launch instruction. She attempted to identify students' prior knowledge in her junior year field placement lessons using strategies she had learned in readings for eliciting students' prior knowledge:

> I think it's really important before you start talking about whatever topic you're talking about to maybe do a KWL chart, what you *know*, what you *want* to know, what you want to *learn*, like your prior information.

Cameron recognized early in her teacher preparation that identifying prior knowledge is important, yet her statement about including a KWL chart revealed partial understanding. Cameron had not connected incorporating students' ideas to identify potential alternative conceptions or strategies for building instruction on students' prior knowledge. With this in mind, Cameron's vision of effective science teaching had room to grow.

Using Evidence During one of her junior year field experiences, Cameron described her mentor teacher's lesson on chemical change and recognized that students were not required to provide evidence of chemical change. She noted the absence in students' science notebook entries and explained, "They're saying that they see bubbles but...what is causing the bubbles, why do you think you're seeing that?" During her senior year, Cameron was able to further elaborate on having students use evidence to critique claims. She explained, "I think it's important for students to be able to make predictions…then see the actual results and see the differences and then be able to summarize and conclude what they learned." Cameron's developing vision of effective teaching included supporting students to provide evidence during science lessons.

Intellectually Engaging with Relevant Phenomena Cameron's vision of effective science teaching was influenced by one of the projects she worked on during her senior year science methods course that focused on the use of science notebooks. Digging deeply into the use of science notebooks as a tool for student communication and intellectually engaging students, she described her mentor teacher using science notebooks ineffectively and in isolation. She described her frustration:

> I think they're a really great tool and I think teachers don't utilize them to the best of their abilities. A lot of teachers just say okay, write this in your science notebook and that's it, you never look at it again… It can be combined into so much more than just write your observations.

Cameron felt she was "very good at relating things to real-world" situations. She described how her vision of effective science teaching reflected the importance of making the most of learning opportunities, "When you're walking outside for recess or just basic common things that aren't necessarily in the curriculum, it's good to take a moment to talk about that." As a first-year teacher, Cameron used state standards to guide her science instruction, yet she described making connections to students' lives by "adding on a real-life example." For example, when she introduced a unit on natural disasters, she took her students outside to collect weather data to provide a context for instruction. Thus, acting on her vision as she described it previously, she attempted to intellectually engage students with relevant phenomena.

Sense-making Cameron saw the benefits of continuity and helping students make sense of experiences. "I think it shouldn't just be something that you do in a 50-minute activity and then you're done with it forever. I think it's something you should be able to connect to other things and build upon." As a beginning teacher, she relied on science notebooks to structure student engagement with activities by asking students to make and record predictions and observations, and include diagrams with labels.

Cameron's vision of effective science teaching thus progressed from her early descriptions of the teacher providing students with fun activities to her descriptions as a first-year teacher, facilitating student-centered learning and sense-making. She further expanded her use of tools and focused on the importance of aligning science instruction with students' lives.

Skyler—the Emerging Science Teacher

In contrast to Taylor and Cameron, Skyler felt intimidated by science mostly because she had limited memories/models of science from when she was in school. Many of the field experiences she had in her teacher preparation program reinforced the institutional marginalization of science, contributing to her insecurities. She was challenged by the science content in upper elementary grades and expressed little interest in building her science content knowledge through her own research of topics. Skyler's confidence trajectory started low and while it increased at certain points, it ended well below the group mean.

Skyler's interview responses throughout the three years remained generally static, generating minimal evidence of growth in her vision of science teaching. Upon entering the teacher preparation program, she described being nervous about its STEM focus and about the prospect of teaching science because she had few memories of science instruction when she was in elementary school. Her early vision of effective science teaching was a teacher-led demonstration or the show-and-tell of science artifacts that she described as “having the example in the front of the room” as opposed to “just teaching from a textbook.” She further described her ideas about demonstrations and reading about science, “so maybe having both, because you are going to have some visual learners and some learners that actually just can read it and understand it, so being able to reach each type of learner can help.” This statement that some students are strictly visual learners illustrates Skyler’s own misconceptions that students have distinct learning styles (Curry 1990; Garner 2000; Riener and Willingham 2010). Skyler went on to ponder how she would decide what to teach as choosing lessons that are “fun” for students with the caveat that her comfort level would determine what she teaches. “If I don’t think I can teach it well, I don’t think I want to teach it to my students because if I don’t think I can teach it well it may not come across well enough to them.”

Skyler often referred to her weak science background. “In elementary school, we really didn’t do a lot of science. It was mostly math and reading. I barely remember anything about science and science from my memory was reading out of a textbook.” By the end of both science methods courses, Skyler had expanded her view of effective instruction. She described the importance that teachers support student-to-student discourse and avoid structured activities seeking one answer. She described from her senior field experience, “In science we’re not doing enough inquiry based, it’s simply students trying to figure out the right answer.”

When asked how she would facilitate classroom discourse, her impression of student discourse focused on vocabulary instruction:

> …a lot of it will be me frontloading the vocabulary that I want them to be using and by that I mean I just use it myself, like I teach them the vocabulary and then if they say something, I restate it using the vocabulary.

At end of her first year of teaching, Skyler described effective science instruction as giving students chances to explore for themselves, and making experiences “purposeful and meaningful,” yet she recounted relying on videos to engage students in content and guide class discussions about the science content.

Motivation During her junior year, Skyler used her body to model movement in a lesson on force and motion to supplement her use of videos to motivate students. Skyler pondered ways to encourage students to record information in their science notebooks as emphasized in her second science methods course. She explained, “Maybe having questions for the students and having them write more about what their opinions are, they would be more motivated to write…having them draw and doing different representations will break up the monotony of strictly writing.” Skyler interpreted the concept “motivation” as motivating students for writing tasks rather than engaging them in science activities, which demonstrated her limited vision of effective science teaching when strategies to motivate students are concerned.

Prior Knowledge During her senior year interviews, Skyler identified her understanding that student learning should build on prior knowledge that teachers must first identify. Skyler planned to use science notebooks to identify students’ prior knowledge and diagnose students’ alternative conceptions by asking them to include a KWL chart in their notebooks to identify their existing knowledge about science content prior to instruction. She explained, “Knowing what students know is important for you as a teacher because you have to hold their expectations based upon what they can do.” As a beginning teacher she elaborated:

> I think it’s really important that you don’t take for granted what your kids know and what they don’t know…one thing we talked about in our methods course is when students have ideas like ‘clouds are cotton balls,’ when they build these misconceptions and how to get rid of misconceptions.

This recognition of the need to build instruction on students’ prior knowledge indicated Skyler’s emerging vision of reform-minded science teaching. In her first year as a kindergarten teacher, Skyler continued to work toward becoming an effective teacher but was stifled by her lack of confidence in teaching science.

> I’m still trying to work with how to teach science and how to get it exciting and engaging again. Not telling the students so much of what they need to know in kindergarten is hard because they don’t have a lot of prior knowledge to build upon. It’s kind of hard not to tell them…it’s not that I’m not competent, it’s just that I know that there’s definitely a lot of room for growth in this area.

Using Evidence During her second methods course, Skyler discussed students’ use of science notebooks as a source of evidence. “Science notebooks are more than just handwriting, they involve pictures and diagrams and notes about investigations.” She elaborated:

> A lot of them would turn to evidence in their science notebooks…when we were studying the solar system we did this, so they were remembering what they had previously written, so they were using evidence, and they wouldn’t call it that, but I was able to see that they were using evidence and they had gone back to what they had done to support their answers.

Because Skyler had previously described these students’ solar system instruction as watching videos and taking notes, her interpretation of students’ using evidence to support claims was focused on students’ notes about the videos rather than their personal engagement with science phenomena. This limited identification of evidence illustrated Skyler’s emergent vision of effective science teaching as aligned with traditional instruction practices.

Intellectually Engaging with Relevant Phenomena In the interview at the end of her senior year, Skyler’s description of supporting students’ intellectual engagement was providing them with tools. While Skyler recognized that tools may be used to extend student observations, she did not connect these with students’ processing information. She further interpreted teacher facilitation by teachers having “a cute little recording sheet,” for recording observations for young students. Her teaching emphasized the use of visuals, whether videos or photo images, which were resources widely used during her student teaching experience. At this point, Skyler’s interpretation of teachers intellectually engaging students limited her vision of effective instruction.

Skyler's first year of teaching was in a kindergarten classroom, and she described alternating between science and social studies every three weeks. She explained that she followed her school's *institutional policies* that kindergarten teachers not teach science during the first quarter of the school year. In the second quarter of the school year, Skyler described her initial science instruction as helping students learn about science practices including observation and providing opportunities to communicate their observations. In the middle of the school year, she asked students to compare and contrast apples and pumpkins as a representative science lesson. Skyler's principal gave her the flexibility to determine her schedule and instructional goals in science, so rather than following the state standards for science, she used weekly themes to guide her instruction. She felt kindergarten science lessons should reinforce collaboration, helping students learn to work together and get along. She expressed surprise with how engaged students were in lessons such as learning about their senses saying, "I could not believe how excited and involved they were during the activities" and concluded that science was the subject the students enjoyed the most.

In the middle of the school year, rather than choosing a lesson aligned with science standards, the lesson she prepared for an observation of a science lesson was one that she found on the internet about the 100th day of school. Students explored the capacity of containers by counting the drops of water they placed in the container. She considered this a science lesson because students made predictions about the number of drops and were introduced to eye droppers as tools of science. Later in the school year, Skyler planned her instruction loosely aligned with state science standards by following the district pacing guide to teach about animals. She presented a lesson on ocean habitats, maintaining consistency over time with her vision of effective teaching by using videos and images in non-fiction books to intellectually engage students. Skyler recognized her science teaching contrasted with strategies she learned about in her methods courses, because neither the school where she was a student teacher nor the school where she worked as a beginning teacher emphasized science. Yet Skyler described science as an important subject and, unlike other teachers at her school, she chose to dedicate at least some time for science in her school day.

Sense-making One of Skyler's mentor teachers when she was a PST used videos in his instruction. In many of Skyler's interviews, she described how videos could support the deficits in teachers' science knowledge and help students learn and make sense of science concepts. She recounted how her mentor teacher struggled to explain to students about the size of the sun and planets, so he showed them a video. She described supporting students' sense-making as she recounted their reactions as they watched a video:

> …that really hit home with them and as I was looking around the classroom, they had this really bug-eyed look and they were all really amazed by it, so I think just being prepared and showing students more than just words out of a textbook is one thing. I think having appropriate teacher background knowledge (is necessary) because students will have millions of questions.

While Skyler most commonly pointed to the use of videos for communicating science content to students, during one interview near the end of her senior year, she said that effective instruction should include students actively engaged in learning. "If you're going to be doing a lesson about plant growth, actually having students grow plants instead of just talking about it." Skyler's lack of confidence in her own content knowledge perpetuated her reliance on videos; however, her emerging science teaching introduced students to science practices of classification and comparison of common objects. Thus, Skyler's vision of effective science teaching was directly aligned with teachers' knowledge of science content.

Discussion

In order to answer our research questions, we examined across cases (Yin 2017) to synthesize the developing visions of the three novice teachers in this study as they described their respective experiences during teacher preparation and into their first year of teaching.

Research Question 1

The first research question asked, "How did participants' visions of effective science teaching align with the five learning theory elements of effective science teaching?" The participants' interviews and observation data illustrated the challenges of translating theory to practice (Korthagen et al., 2001). While each of the participants' views transitioned over the three years, interview data illustrated their challenges of weaving memories and past experiences with new learning and experiences into visions of effective science teaching. As Kennedy (2006) described, teachers often limit their focus to one or two lesson goals. This focus is especially necessary for novice teachers who have memories and models of traditional science teaching. Here we discuss our findings organized by markers of effective science teaching: motivation, eliciting prior knowledge, intellectual engagement with relevant phenomena, using evidence, and sense-making (Banilower et al. 2008, 2010) to identify their developing visions of effective science teaching during this study.

Motivation Each of the three identified the role of *student motivation* in learning. Taylor, the science enthusiast, and Cameron, the developing science teacher, described students' engagement in activities as key *motivating* factors, and the depth of their attention to student motivation developed over time with the notion that motivating students to engage in science activities would contribute to their motivation for learning (Duschl et al. 2007; Schunk and Pintrich 2002). Cameron described how concept continuity that connects to students' lives helps students' sense-making. Her recognition that concept development should not be limited to isolated presentations is supported by Schunk et al. (2012) who explained the role of sustained activities to encourage students to persist toward learning. In contrast, Skyler, the emerging science teacher, whose interview responses over the three years remained fairly static, maintained her focus on showing videos to motivate students, a form of extrinsic motivation (McInerney et al. 2004). Skyler remembered using videos for learning about science when she was an elementary student, and this practice was further modeled by a mentor teacher in a field placement classroom. Skyler interpreted motivation less as students' motivation to learn science but rather motivating students for tasks and did not include students' actively engaging in science concepts.

Eliciting Prior Knowledge These PSTs described attending to students' *prior knowledge* as a new concept, and their learning about teaching for conceptual change introduced them to the notion that learning should begin with existing student knowledge rather than simply following lesson plans. Researchers have identified a small fraction of lessons that consider students' prior knowledge (Banilower et al. 2006; Roth and Garnier 2006; Weiss et al. 2001), thus reinforcing the novelty of this concept for the teachers in this study. Cameron recognized that students' existing ideas are important when she decided to use a KWL chart to identify their prior knowledge. Yet, Cameron neglected to fully consider KWL data to identify students' potential alternative conceptions or to inform her instruction decisions. Cameron was clearly developing in her own intellectual engagement with effective instruction practices.

Intellectual Engagement with Relevant Phenomena Across the three years, the participants launched their visions of *intellectual engagement* connecting science to students' lives. Taylor's, the science enthusiast, early ideas about intellectually engaging students drew from an entomology course that she felt connected to her life experiences. During her methods courses, Taylor described learning that teachers need to connect science experiences with student discourse for intellectually engaging students. As a beginning teacher, she provided lessons on seasons by taking students outdoors on regular basis to observe seasonal weather conditions and asking students to discuss the patterns. Her decision to move beyond the classroom walls strayed from instructional norms (Carrier et al. 2014; Cronin-Jones 2000), distinguishing her from other teachers and potentially risking alienation from the institutional culture. Cameron, the developing teacher, relied on science notebooks to document student engagement with science content and practices, and she recognized the importance of connecting concepts to students' lives. As a first-year teacher, she also took students outside to introduce them to weather concepts as an introduction to her unit on natural disasters. While Skyler, the emerging teacher, described the role of tools and models to engage students, upon graduation and as a beginning teacher, she resorted to relying on videos to intellectually engage students.

Using Evidence None of the teachers in this study had fully internalized the role of evidence to support students' claims and inform their interpretation of data (McNeill and Krajcik 2012). Skyler's visions of effective teaching were impacted by varying images of students' use of *evidence*. Skyler recognized that data in students' science notebooks provided evidence through numbers, drawings, and narrative, yet she and others in the study demonstrated one of the "problems of practice" as identified by McNeill and Berland (2017, p. 674) of seeing data as the answer. Teachers must learn to expand their visions of effective instruction by providing opportunities for student argumentation of findings that include reasoning and interpretation of data (McNeill et al. 2006; Sandoval and Reiser 2004; Zembal-Saul et al. 2002). Cameron was able to recognize that her supervising teacher also shared this problem of practice when she failed to ask students to make sense of data by supporting their claims with evidence.

Sense-making Expanding novice teachers' visions of effective science teaching to include helping students internalize and make sense of experiences was a critical leap for each of the case study teachers. Taylor, the science enthusiast, processed the concepts of *sense-making* (NRC 2004) from her methods courses that she felt were not part of her experience as a student in elementary school. Cameron, the developing science teacher, considered using drawings and data collected in science notebooks to help guide students to make sense of their learning rather than memorizing facts (Banilower et al. 2010). While Skyler, the emerging science teacher, continued to lean on the use of videos to help students make sense of science concepts, she at one point discussed the importance of student experiences such as students growing plants to help make sense of plant life cycles. For novice teachers without strong models of science teaching from their experiences as elementary school students, teacher educators must strategically devote significant class time to presenting pre-service teachers with strategies to help students' sense-making by connecting their experiences with student discourse and reasoning. Each of the teachers in this study varied in her interpretation and enactment of effective teaching practices, and factors that may impact developing visions of effective science teaching for pre-service and novice teachers are discussed in response to the second research question.

Research Question 2

Our second research question asked "What factors influence participants' visions of the of effective science teaching?" Here we position our discussion within the selective coding themes (Strauss and Corbin 1994) that emerged from the interview data to examine how teachers' visions related to their memories, attitudes about science, field experiences, methods courses, and institutional influences. Each of these themes critically influenced the participants' developing visions of effective science teaching.

Key images of effective teaching practice originated with participants' *memories* of elementary science when they were students. Taylor's, the science enthusiast, strong memories of her science experiences when she was an elementary student influenced her positive *attitudes* about science, and as Tosun (2000) pointed out, the relationships between attitudes and beliefs influence teachers' behaviors. Interestingly, while Taylor had positive memories of science, she began to contrast some of the more traditional instruction from her memories with reform-aligned instructional practices learned in her methods classes, with the latter being preferable. The influence of both her memories and her methods class experiences allowed her to evaluate the effectiveness of both and influenced her vision of effective science instruction. Although methods courses vary greatly across colleges and universities, each of the teachers in this study illustrated learning from her methods course experiences (Rice and Roychoudhury 2003).

Cameron, the developing science teacher, had limited memories of science instruction, and the memories that influenced her goals focused on helping students have fun, but through her *methods courses* she recognized the importance of presenting science concepts in multiple ways for students. Rather than students learning concepts from an isolated lesson, she described using data to inform science concepts and connect to students' lives. Skyler, the emerging science teacher, described mostly negative memories of science instruction during middle and high school, which challenged her personal vision of herself as an effective science teacher. Connelly and Clandinin (1999) describe the influence of teachers' memories from when they were in school as influencing the stories they create of teachers and teaching. Skyler's low confidence in teaching science contributed to her relying heavily on videos for communicating science concepts as she remembered from elementary school. This practice was further reinforced in her *field experience* classrooms. Skyler's major emphasis on the use of videos for instruction counters Spillane's research (2000) emphasizing hands-on tasks or tools to help students construct new understandings, strategies that were emphasized in her science methods courses.

Each of the teachers in this study described disconnects between the vision of high-quality science instruction presented in their teacher preparation with institutional influenced visions of high-quality science instruction they experienced in schools. Many of the institutional practices and policies limiting instructional time and resources for science in their field placement classrooms and as beginning teachers communicated to the teachers a marginalization of science. This disconnect between the teachers' personal visions that developed during their STEM-focused teacher preparation and the institutional policies challenged their visions of ideal classroom practice. Shared visions of effective teaching between school administration and teachers are critical in support of teachers' practice (Hammerness 2008; Munter 2009).

Hammerness (2008) identifies these pedagogical disconnects as one reason that teachers may choose to continue to work at a school or leave the school because of policy influences that impact whether teachers believe they are effective or not. In Hammerness' (2008) study that examined four teachers' visions of effective instruction, each of the four ended up leaving their schools because the philosophical misalignment between their visions of ideal classroom practice and that of their school hindered their ability to achieve their personal goals. Because Taylor and Cameron described the misalignment between their visions and the institutional policies, one must be concerned about their intentions to continue teaching. Perhaps because of Skyler's emerging vision of effective science teaching, she may be more malleable with adopting the institutional practices that do not align with effective science instruction.

As shown throughout this study, the impact of memories formed as a learner of science impacts the visions one develops as a teacher of science. Therefore, it is a critical to increase time devoted to science beginning in elementary school to support goals for preparing a scientifically literate society. Building on learning theory (NRC 2000, 2004), models for effective science teaching (Banilower et al. 2008) help position research that can inform teacher preparation programs and institutional policies that support teachers' developing visions of effective science teaching in positive and productive ways. Institutional policies that promote increased instructional time and resources for science and expand teacher support through professional development opportunities in science are much needed.

In addition to increasing time centered around science instruction, teacher preparation and professional development programs must work to support pre-service and novice teachers to recognize the connections between their visions and practice and reconcile their visions with the realities of classrooms. Although their own experiences as learners of science did not match the reform-oriented practices they were being taught in their teacher preparation program, Skyler and Cameron were clearly impacted by their methods coursework and their field placement classroom experiences. Just as teachers must build instruction on students' prior knowledge, science teacher educators should explicitly address PSTs' experiences as students and highlight the areas in which PSTs' visions of effective science teaching align with reform-oriented instructional practices in science education. Science educators can use PSTs' "science instruction life stories" to help them examine the impact of their memories as learners of science on their developing visions of science teaching. Teachers' "professional knowledge landscapes" (Clandinin 2015, p. 189) evolve over time and experience similarly as do their visions of effective science teaching.

Limitations

This study was limited to one STEM-focused teacher preparation program and school district in the USA that positioned the pre-service teachers' field experiences and, upon graduation, the district of their employment as beginning teachers. This study was a qualitative study and thus is bounded by the specific context and participants in the study.

Concluding Remarks

In this study, we provide a snapshot of three novice teachers, and each case illustrates the complexity of teaching and preparing elementary science teachers. Teachers' visions of effective science teaching develop over time and are influenced by their backgrounds and experiences as students, and as teacher educators, we must support and inform teachers' developing visions. As we prepare pre-service teachers with science content and teaching practices, teacher educators must also help teachers learn to negotiate school policies and procedures. These policy conflicts are increasingly common in areas where high-stakes testing drives pedagogy (Jones et al., 2003). The findings in the present study and others (Hammerness 2001, 2008; Munter 2009) reveal that teachers need support as they negotiate reform-based teacher preparation and traditional institutional policies.

Research has helped us understand more about how children learn, and teacher educators can capitalize on these understandings to provide pre-service and in-service teachers with models of instruction that attend to students' motivation, prior knowledge, intellectual engagement, attention to evidence, and sense-making. Induction support (Smith and Ingersol 2004) for beginning teachers and ongoing professional development can help teachers negotiate the realities of classrooms and institutional policies and practices to develop and implement their visions of effective science instruction. Expanding teacher preparation and professional support grounded in learning theory that support practices for effective science teaching can improve teacher preparation, induction, and student learning in science during students' critical early learning years.

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