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The development of elementary teacher identities as teachers of science

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ABSTRACT

The purpose of this qualitative study was to investigate the contributions of pre-service teachers' memories of science and science education, combined with their experiences in a STEM-focused teacher preparation programme, to their developing identities as elementary school teachers of science. Data collected over three years include a series of interviews and observations of science teaching during elementary teacher preparation and the first year of teaching. Grounded within a theoretical framework of identity and using a case-study research design, we examined experiences that contributed to the participants' identity development, focusing on key themes from teacher interviews: *memories of science and science instruction, STEM-focused teacher preparation programme, field experiences, first year of teaching,* and *views of effective science instruction.* Findings indicate the importance of exposure to reform strategies during teacher preparation and are summarised in main assertions and discussed along with implications for teacher preparation and research.

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Elementary/primary school; qualitative research; science teacher education; identity

Elementary teachers hold the responsibility to prepare students in all school subjects, including science. Elementary teachers' low self-efficacy in teaching science is well documented (Cakiroglu, Capa-Aydin, & Hoy, 2012; Kazempour & Sadler, 2015; Mintzes, Marcum, Messerschmidt-Yates, & Mark, 2013; Schoon & Boone, 1998), and low confidence in teaching science has been linked to weak models of science teaching when pre-service teachers were in school (Bleicher, 2007). These limited science backgrounds of many pre-service teachers increase demands on teacher preparation programmes responsible for preparing elementary teachers to teach science content and practices. Meanwhile, reform efforts for science education in the U.S. and Europe have called for improving science instructional approaches (National Research Council [NRC], 2007; Osborne & Dillon, 2008; Roth, 2014); yet, school cultures and administrators who value science as a core and inquiry-focused subject are 'all too rare' (Berns & Swanson, 2000, p. 11). The *Framework for K-12 Science Education* (NRC, 2012) in the U.S. established a vision for science learning beginning in Kindergarten that prepares all citizens to be informed decision-makers, including, but not limited to, those who will choose a career

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in science. Furthermore, cognitive researchers have identified the capacity of young children to reason scientifically and engage in a wide range of complex reasoning processes (Michaels, Shouse, & Schweingruber, 2008; NRC, 2007). These research findings and NRC recommendations, coupled with challenges like pre-service teachers' science backgrounds and school culture around science, point to the need for more research on elementary science teacher development. The current study addresses this need by examining novice teachers' identity development as elementary teachers of science during teacher preparation and the first year of teaching.

Teacher preparation programmes vary in the volume of science coursework and methods required for pre-service elementary teachers, and researchers have explored the impact of various science teacher preparation efforts on pre-service teachers' development as teachers of science. Appleton (2013) synthesised contributions of science educators and researchers from many countries by presenting issues that impact elementary science teacher preparation such as teachers' pedagogical content knowledge and field experience challenges. Avraamidou (2013) and Zembal-Saul (2009) examined the role of science talk and discourse in teacher preparation. Eick and Reed (2002) examined the influence of pre-service teachers' personal histories on role identities, and Hollins (2011) described the challenges teacher educators face in providing pre-service teachers with opportunities for learning to teach. Other research has examined the role of curriculum in teacher preparation (Beyer & Davis, 2012; Forbes, 2013). As researchers seek to identify effective models for preparing teachers to help young children learn science, these efforts highlight the complexity of teaching and teacher development.

Aligned with other researchers' attempts to inform best practices for teacher preparation, we strive to reveal complex factors that influence pre-service elementary teachers' developing identities over time as teachers of science throughout and beyond their teacher preparation. Because few studies have examined the longitudinal effects across the teacher preparation experience (Swars, Smith, Smith, & Hart, 2009) and into the first year of teaching (Mewborn, 2000), we present case studies of two teachers, describing their experiences in a STEM-focused teacher preparation programme and through their first year of teaching. Thus, the present study adds to the field's understandings of elementary teacher preparation as we further identify elements at play when learners of science become effective teachers of science.

Theoretical perspectives and relevant literature

Teacher identity

Teacher professional identity, how teachers define themselves internally and to others, is a construct of self that evolves over time, contributes to individual teacher capacity, and has multiple influences (Lasky, 2005). Several components of teacher identity include their knowledge, beliefs, self-efficacy, and social membership (Collopy, 2003; Drake, Spillane, & Hufferd-Ackles, 2001; Lave & Wenger, 1991). Sachs (2001) describes teachers' professional identities that are positioned as both retrospective and prospective identities (Bernstein, 1996). Retrospective identities use resources from teachers' experiences inside and outside of schools about what it means to be a teacher as models for

professional behaviours. Prospective identities are positioned in the future and provide personal narratives about the type of teacher they aspire to be.

As Avraamidou (2014a) pointed out in her review of science teacher identity research, the last decade of research studies has provided theoretical underpinnings for the study of teacher identity; yet, she called for more research in the area of science teacher identity. In the present study, we address Avraamindou's recommendation that science education researchers agree on identity development as a *process* and examine the factors that contribute to identity development such as personal histories and interactions within institutions. Forbes and Davis (2008) examined how teachers fashion a sense of self as teachers and the role of institutional discourse and shared experiences with other teachers. These contributing factors can impact pre-service teachers in multiple ways depending on the players and contexts.

In a review of challenges of beginning teachers, researchers found that pre-service teachers have demonstrated underdeveloped knowledge of science content as well as unsophisticated beliefs about the nature of science (Davis & Smithey, 2009). Furthermore, they identified the social support that cohort models, as experienced by the pre-service teachers in our study, contribute to their developing identities as science teachers. Avraamidou (2014a) further offered recommendations for researchers to explore longitudinal life history studies to reveal experiences that contribute to science teacher identity development and enactment. We address these recommendations by examining pre-service teachers': family backgrounds; memories of elementary science instruction and feelings of competence during that critical period; and school and life experiences through teacher preparation and into their first year of teaching.

Teacher development: a situative perspective

Lave and Wenger (1991) described learning as a social practice that helps to define who we are and our identity; therefore, it is important to uncover the influence that participation in communities of teacher preparation programmes and the education community have on elementary teachers' developing visions of themselves as teachers of science. Pre-service teachers begin on the periphery of the community of teachers and move towards the centre as they gain experience. As pre-service and beginning in-service teachers gain more experience with the school community, they begin to develop an identity within that community that changes over time as they move from novice towards expert and as they incorporate the mannerisms, language, and customs of that community into their identity. We next present the theoretical models on identity development that informed the current study's conceptual framework, and we introduce our framework, specifically how we examined identity development from a situative perspective.

Conceptual framework

Avraamidou's (2014b) identity trajectory model combined elements from Gee's (2000) views of identity with Clandinin and Connelly's (2000) three-dimensional narrative inquiry space model. The three dimensions of Clandinin and Connelly's model and incorporated in the present study are: interaction – both personal and social; continuity – past, present, and future; and situation – representing the context. Avraamidou's combined

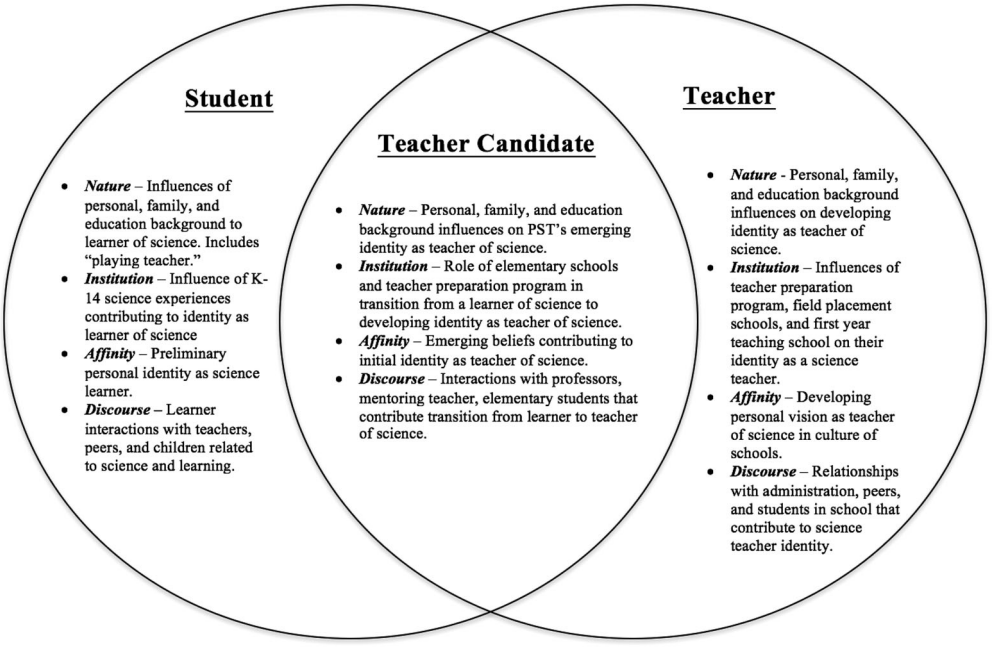

Figure 1. Identity dimensions and trajectory (adapted from Avraamidou, 2014b and Gee, 2000).

model provides a rich tool for analysing identity trajectories. We position our case studies' three-dimensional narratives in their trajectories as students, pre-service teachers, and first-year teachers. We acknowledge Avraamidou's (2014a) recommendation to capture time and space of teacher development by structuring our analyses and findings in the following stages: (a) *Student* – individual's personal and social interactions as a student and learner of science, (b) *Teacher Candidate* – individual's past, present, and projected future in the transient or transition process moving from a learner to envisioning him- or herself as also a teacher of science during teacher preparation, and (c) *Teacher* – experiences as a first-year teacher.

We further examined Gee's (2000) identity constructs of nature, institution, discourse, and affinity. *Nature* identity explores background influences such as family and upbringing. We use Gee's *institution* identity to examine the influences of institutions on case studies' personal identification as teachers of science and *discourse* identity to examine influences from discourse or dialogues with instructors, teachers, or students. We connect Gee's *affinity* identity to the influence of communities on case studies' developing identities. Each of Gee's framework constructs emphasises the influences of others on identity development. Figure 1 represents the data collection and analysis frame of the current study to capture time and space in the three aforementioned stages (Student, Teacher Candidate, Teacher) and to examine Gee's identity constructs within each stage to address our research questions.

The present study was guided by the following research questions:

(1) What factors contribute to the development of elementary pre-service teachers' identities as teachers of science?

(2) How do pre-service teachers' personal backgrounds, K-12 and college memories of science, and science instruction influence their developing identities as elementary teachers of science during their teacher preparation and into their first year of teaching?
(3) What are the influences of a STEM-focused teacher preparation programme on pre-service teachers' developing identities as teachers of science?

Programme description

The participants in the current study were teacher candidates enrolled in a STEM-focused teacher preparation programme, offering them extensive preparation in science, mathematics, and engineering with technology infused throughout the programme. They were required to take 27 credit hours of mathematics, science, and engineering design coursework in their general education requirements during their freshman and sophomore years. These course expectations in mathematics and science are beyond those of most elementary teacher preparation programmes as identified in a recent national survey in the U.S. (Trygstad, 2013).

Following candidates' general education and in the fall of their junior year, the teacher candidates took the first of two mathematics methods and science methods courses as well as an engineering methods course. The courses and field experiences in this semester focused on K-2 classrooms and instruction. Through the coursework and field experiences, the teacher candidates evaluated a range of curricula, examined the role of informal education in student learning, analysed factors that contribute to teachers' developing pedagogical content knowledge, and explored the important role of providing opportunities for rich student discourse.

In the initial science methods course, one early project asked the teacher candidates to reflect on their memories of science when they were in elementary school. Beijaard, Meijer, and Verloop (2004) described the importance of exploring teachers' biographies as important elements when evaluating the formation of their professional identities. Other science methods course experiences introduced the candidates to various curricular programmes as they examined models of science inquiry opportunities for children on topics related to elementary standards (e.g. magnets, water cycle, particulate nature of matter).

In the spring of their junior year, the teacher candidates were required to complete a second mathematics methods course and science methods course focused on grades 3–5 instruction with field experiences in local 3–5 classrooms. One course assignment asked the candidates to demonstrate a discrepant event they might use to 'engage' students as they incorporate the 5E model of instruction (Bybee et al., 2006), an instructional design introduced in the first science methods course the previous semester. The extensive fieldwork in local elementary schools in the candidates' senior year began in the fall semester and continued in the same classroom for the student teaching semester in the spring. This continuity in the field placement provided an entire year's experience with comprehensive and in-depth exposure to classroom teaching. Across the entire programme, participants complete over 920 hours in field placements in elementary school classrooms.

Because STEM-focused elementary teacher preparation programmes are uncommon, few studies have examined the longitudinal effects of this model across the teacher preparation experience and into the first year of teaching. To that end, the present study

addresses the dearth of research by examining the influences of backgrounds, memories of science and science instruction, features of the STEM-focused elementary teacher preparation, and experiences as beginning teachers on the participants' developing identities as elementary science teachers.

Method

Participants and context

The present study is part of a larger research project designed to evaluate the STEM-focused teacher preparation programme. The larger research project involved 245 participants across four cohorts of graduates of the STEM-focused programme. The majority of these participants represented the common demographic for beginning elementary teachers (white and female) as identified in the National Survey of Science and Mathematics Education (NSSME) (Banilower, Trygstad, & Smith, 2015).

For one cohort ($n = 55$), participants were recruited to be a part of an in-depth case-study component at the start of their junior year and into their first year of teaching. Sixteen of 36 volunteers were selected to participate based on stratified sampling (with three strata) using GPA as the variable. Data collection included interviews and video recordings of lessons while they were engaged in coursework, field experiences, and their first year of teaching. The interviews included questions about their backgrounds and memories related to science and science learning, their experiences in teacher preparation and field experiences in schools as pre-service teachers, their projections of their future as a teacher of science, and analyses of decisions in lesson planning and implementation. One of the researchers taught the science methods course during the first semester of methods coursework.

Here, we describe case studies of two elementary teachers – Peyton and Morgan (pseudonyms) – now graduates of the STEM-focused teacher preparation programme. In order to protect the anonymity of our case studies and because there were few males in the programme, we use gender-neutral pseudonyms but use the pronoun 'she' for ease of discussion, following our approved research ethics protocol. The two cases were purposefully selected using case summary data of the 16 participants who were followed for three years. A research assistant created case summaries of each participant that included background information (e.g. motivation for being an elementary teacher; elementary school experiences in science; parent science interest) collected during the junior-year interviews.

The case summaries were reviewed by four researchers and organised in patterns regarding attitudes about science and science teaching that they brought to their teacher preparation. Researchers purposefully selected one teacher with strong and one with mixed initial images of science and science instruction who were representative of the larger group of 16 participants. Patton (1990, 2002) described the power of purposeful sampling as selecting information-rich cases for in-depth study. Specifically, intensity sampling was used in this study to present two stories that represent the multiple influences that contribute to their developing identities as teachers of science. Patton described intensity sampling as 'excellent or rich examples of the phenomenon of interest, but not highly unusual cases … cases that manifest sufficient intensity to illuminate the nature of success or failure, but not at the extreme' (Patton, 2002, p. 234). Our multiple case-study

design presents two participants who are 'representative or typical case' (Yin, 2009, p. 48) of profiles of pre-service teachers entering teacher preparation. Here, we present multiple cases and 'then draw a single set of "cross-case" conclusions' (p. 20).

While some pre-service teachers enter their teacher preparation with limited or negative memories of science instruction, here we present one case, Peyton, with initial positive memories and another, Morgan, with mixed impressions of science as both offer data-rich stories of their developing identities and the role of their teacher preparation. We present descriptions of each case study's developing identity as a teacher of science using the space and time lenses adapted from Avraamidou (2014b), Connelly and Clandinin (1999), and Gee (2000).

Data sources and analysis

A longitudinal case-study design was employed in the current study. Over a period of three years, each case study participated in a series of interviews during their junior year, senior year, and first year of teaching. To establish the trustworthiness of data interpretation, we used several validation and reliability procedures suggested by the literature (Creswell, 2013), described next.

Study researchers established long-term contact with participants in order to build trust and learn about the study context; all researchers were involved for the three years of this study, thus establishing strong relationships with the case-study participants. Each researcher took notes during the interview process and memos were kept during the interview process; researchers further took self-reflective notes during data analysis and coding. This strategy allowed all coders to reflect more deeply in order to make sense of the data (Creswell, 2013).

A list of interviews and data collection timeline, along with a short description of interviews is presented in Appendix A. A total of 34 interviews across the two case-study participants (17 interviews per participant) were conducted during the three years, and the transcribed interviews were the focus of data analysis in the current study with field notes supporting interview data. We also interviewed principals at schools that employed the participants as first-year teachers; the principal interview data were used in comparison to case studies' impressions of institutional influences on their practices and developing identities as teachers of science. We provide rich and thick descriptions of the interviews, allowing the reader to understand more about data interpretation and help make decisions about study transferability.

All transcribed interviews and field notes were first uploaded in NVivo 10 software, and four coders performed data coding in several phases using an inductive process (Creswell, 2013). In an initial phase, each of the four coders (researchers from the current research project) read the transcribed interviews for one randomly selected case study and together developed a coding scheme capturing open coding categories and aligned with Gee's (2000) identity frames during each stage: *Student*, *Teacher Candidate*, and *Teacher*. In order to provide trustworthiness, the coding procedures and scheme were discussed constantly by the coders in all phases of data analysis and revised by the coders until agreement between all coders was reached. In the final phase, two coders coded all interviews from the same case study independently, while ensuring consensus through ongoing discussions with other coders. Additionally, in order to address potential bias, all identifying

factors were removed from data by first replacing participant names with identification numbers that were then assigned pseudonyms by the research team following ethics guidelines to blind the researchers to case study identity. Appendix B provides an overview of the coding process and sample data.

Limitations

The findings from this study are limited to patterns identified in the two cases presented in this paper. Although the sample size is small, patterns emerged within the original 16 case studies that show similar science attitudes and memories to the two case studies presented here. We acknowledge the limitation of memory retrieval, both the potential for selective retrieval of memories and the difficulty of remembering science instruction from childhood. The use of a case-study design limits the generalisations beyond the present study. Additionally, these two case studies were chosen from a STEM-focused teacher preparation programme, which heavily emphasises science methods and experiences. Many teacher preparation programmes do not have such foci; therefore, these experiences may be limited to the participants who were part of the STEM-focused preparation programme. Finally, because we are primarily focused on the teachers themselves, additional factors such as school demographics and chosen curriculum are not the main focus of this paper.

Findings

The two case studies presented here provide stories of individuals' development as elementary teachers of science coming from different backgrounds and contexts. Each case study is first presented separately and begins with an overview followed by each 'story' as she transitions through the role of learner to her development as a teacher. Table 1 synthesises key findings for the two case studies followed by full descriptions of each.

Peyton

Peyton represented a pre-service teacher who entered teacher preparation with a positive impression of science and science teaching. She brought with her positive memories of science in school. Her teachers in elementary school were enthusiastic, providing Peyton with a positive impression of science. During her teacher preparation programme, Peyton faced obstacles that led to the waning of her enthusiasm, yet by the end of the programme, she was able to learn from all of her experiences and rekindle her passion for teaching. Her first year of teaching was a mix of trial and triumph, but her personal background in science combined with her experiences in her STEM-focused teacher preparation contributed to her resourcefulness for teaching science with few supplies and little support.

Peyton: Student. Peyton is the oldest of four siblings, with a younger sister and two brothers much younger than she is. Her father was in the military, which required that her family move frequently. When Peyton's family lived on military bases, this shared experience contributed to Peyton's *affinity* identity with other military families. When Peyton's family moved off the base, she felt like an outsider. Moving to different

Table 1. Key developmental findings of Peyton and Morgan.

	Peyton	Morgan
Student		
• Nature identity	• Came from a family that moved around due to her father being in the military.	• Came from a close-knit family that talked about science and math frequently due to her father's job as an engineer.
• Institution identity	• Had positive experiences in science throughout K-12 school and college.	• Had both positive and negative experiences in science throughout K-12 and college.
• Affinity identity	• Did not feel that science content courses were directly applicable to her future teaching.	• Did not connect with science growing up because they were not investigation focused.
• Discourse identity	• Moved to different schools and was a new student often, which impacted her social encounters with peers and teachers.	• Felt encouraged by her teachers, especially her 4th grade teacher.
Teacher Candidate		
• Nature identity	• She spent time helping her siblings with schoolwork.	• She always had the desire to be a teacher and would spend time teaching her younger brother during the summer. This may have provided the patience she needed to work with children.
• Institution identity	• Attended two different high schools, in two different states. She participated in a teacher cadet programme, which helped prepare her for her future career.	• Methods courses helped to guide Morgan to view teaching in a different light. She had a newfound respect for teaching and was influenced by the alternative conceptions students bring with them into the classroom.
• Affinity identity	• Believed that science would play a prominent role in her future classroom. Felt that students in elementary schools do not get the science instruction she received as a student. Her confidence waxed and waned over the time as a preservice teacher, but she felt that she grew as a teacher.	• She felt challenged by what she learned in her methods classes and what she was seeing in her field experiences. In the classroom, students would have little time to engage in science after recess and would spend most of their time taking notes or doing something on the computer.
• Discourse identity	• Interaction with students in field placements and student teaching fuelled her desire to teach science. Felt as though she did not belong with her peers due to her time spent as a member of the college track team.	• Interactions with her students during her senior year strengthened her vision of herself as a teacher. She had students who had little interest in science telling her their favourite things with great detail and excitement.
Teacher		
• Nature identity	• Viewed herself as an outsider growing up, which led to her independence and ability to teach at a school without an instructional history.	• Her family's support of her brother with autism and their life overseas helped her to develop the strength and organisation needed to transition quickly into her new role as a full-time substitute teacher upon graduation.
• Institution identity	• Took a position at a newly opened school, which led to her struggle with the disconnect between what she believed were effective science teaching practices and the lack of resources and support from her school.	• Graduated from college and immediately took on a 5-week substitute teaching role, where she was later hired on at the same school. Her principal supported her decision to include science despite her colleagues' own practices.
• Affinity identity	• Felt supported by her 4th grade colleagues and planned the science lessons for the whole team.	• Continued to feel a disconnect between what she learned in methods coursework and what was being taught in her grade level.
• Discourse identity	• Her interactions with administrators who set unrealistic goals for teachers, coupled with the wide variety of socio-economic status and parental support had Peyton negotiating her initial enthusiasm for teaching science.	• Felt support by some of the members, including the principal, at her school. This led her to strengthen her beliefs of presenting consistent and rich science practices within her classroom.

schools and often being a 'new student' illustrated the impact of *discourse* identity through social encounters, contributing to her potential to build self-reliance and independence.

Peyton's *nature* experience growing up helping her siblings led her to begin to identify as a teacher. In addition, her positive experiences in science classes as a student further supported her formulating a vision of her future classroom where she imagined that

science would play a prominent role. In high school, Peyton participated in a teacher cadet programme, spending time in elementary classrooms, providing *institutional* support for her identity as a learner/teacher.

School *institutional* influences impacted her vision of herself as a learner of science in school. Peyton held positive memories of her elementary school teachers that she described as 'really excited about [science] and I think when someone likes something and they can really show that and be enthusiastic about it, then the kids really feel that same way.' During middle school, she excelled in science activities, especially 'dissecting stuff,' and Peyton's teachers praised her writing, thus providing *discourse* for building her confidence as a student.

Peyton entered college with an appreciation for science due primarily to her experiences in core science content classes. While Peyton's *affinity* for science influenced her experience as a student, she did not feel that the content was directly applicable to her future as a teacher of science. During her initial classroom observations in her sophomore year in college, she saw little science instruction and realised that many children were not getting the kind of science instruction she had experienced as an elementary school student.

Peyton: Teacher Candidate. Peyton's science methods courses helped her to begin to connect science content to teaching because 'now we're actually doing stuff that's relatable and interesting and things that will propel me into my future career.'

Peyton's *discourse* with children fuelled her desire to teach science. She explained, 'Kids are so curious … they want to know how things work, they want to know the science behind things.' While Peyton was frustrated by the lack of science instruction she saw in field placement classrooms, she was becoming more aware of herself as a teacher and her actions with the students.

At the beginning of her senior year, Peyton felt the 'roller coaster of emotions … since entering the program.' She felt that her passion was her biggest strength at this point in time but still struggled with the feeling that she was 'in over my head.' She was having a hard time coming to terms with the fact that teaching would be much harder than she thought. Her enthusiasm waned during this time, and she did not feel ready for student teaching. Peyton witnessed the multitude of stressors that teachers face and was feeling discouraged about how teaching is 'so underestimated.' While Peyton described her senior year as a difficult year of 'personal growth', she described rediscovering her passion for teaching and felt she had ' … come full circle. I'm heading in the right direction.'

Peyton: Teacher. Upon graduation, Peyton took a fourth-grade teaching job at a newly opened school without an instructional history. Her *nature* background as the eldest sibling and her multiple school experiences influenced a clear independence. Peyton felt positive at the beginning of her first year of teaching, pointing to the role of the teacher preparation *institution* in building her confidence and readiness as a first-year teacher. She explained the institutional support, 'I don't know about other elementary education programs, but I can't imagine one that instils companionship … I always felt a part of something.' Peyton participated in professional development at her new school; yet, some of the presented techniques, such as use of strict homogeneous ability grouping, contradicted the heterogeneous grouping models she learned in her teacher preparation *institution*. Peyton struggled with the disconnect between what she believed were effective science teaching practices and those promoted at her new *institution.* Peyton complained

about the school administration's limited support. The school had no resources or supplies for teaching science but Peyton still felt excited initially about creating her own classroom.

In the mid-year interview, she expressed frustration with the long hours and few resources for teaching science. As identified in field notes, Peyton worked to balance reform-based science teaching with expectations communicated by her administrator such as practice drills and rote learning. Peyton's *affinity* with her fourth-grade colleagues provided support as she assumed the role of lesson planner for her team, building on skills Peyton had learned during her science methods courses. Peyton's peer teachers at her school were encouraging, and she felt supported by them, explaining, 'I got some really good feedback from the other teachers, [who] couldn't believe I hadn't worked in a classroom before. Who doesn't love to hear that?!'

By the end of the year, there was much tension among teachers and administration. Peyton stated that faculty meetings were stressful, and everyone left them 'feeling spanked.' The influence of *discourse* identity was impacted by her interactions with administrators as she negotiated the limitations imposed by the *institution* of her school. Peyton had accepted that she would need to create her own resources for teaching science and expressed comfort from feeling connected with teachers in her grade level.

In an interview with Peyton's principal about the school, the principal described her task of starting a new school and attending to parents. When asked about the resources for STEM, the principal acknowledged limitations of the commercial science curricula, explained that they were seeking to build their science programme, and articulated the need to find more and better support for teachers.

Summary. Peyton's initial enthusiasm for science and science teaching was based on her experiences as a *Student* of science that began early and continued with strong *nature*, *institutional*, and *discourse* contributions to her identity in this dimension. As she transitioned to a *Teacher Candidate*, her trajectory wavered as she began to learn about the complexity of effective teaching. Combined with the marginalisation of science she witnessed in her field experiences, Peyton's image of science and science teaching followed her 'roller coaster' description of her developing identity as a teacher of science. As she began identifying as a *Teacher*, Peyton continued to struggle with the *institutional* marginalisation of science and lack of administrative support for science instruction. Yet, Peyton drew from her memories as a young *Student* and from strategies, research, and resources gleaned in her STEM-focused teacher preparation to persist in her goals to become an effective science teacher. The role of the *nature* and *institution* influences from her time as a *Teacher Candidate* encouraged Peyton's tenacity as her identity as a teacher of science continued to develop.

Morgan

Morgan was representative of those entering teacher preparation with both positive and negative or unclear views of science education. She had mixed experiences with science in elementary school, and she felt competent but disconnected in many of her college science courses. As Morgan moved from a *Student* to envisioning herself as a *Teacher Candidate* during her science methods courses, her developing identity as a *Teacher* of science waxed and waned. Like Peyton, Morgan realised during her teacher preparation that teaching was a much more complex practice than she previously envisioned, and

Morgan's initial year as a Kindergarten teacher provided her opportunities to explore science with her students.

Morgan: Student. Morgan came from a close-knit family, strongly representing both personal and social *nature* influences. She explained, 'My brother who's a freshman in college has autism so that kind of shaped our family. We were very routine and scheduled in everything … .' Morgan's father's interest in engineering guided her family memories related to science.

Morgan's initial elementary school experiences were mixed. 'I was never very sciencey growing up, I didn't really connect with science lessons maybe because they weren't really investigation focused.' Morgan worked in after-school programmes and with the YMCA, which contributed to her desire to teach. 'Since I was little I have always wanted to be a teacher … and at the YMCA and afterschool program, those experiences really led me to know for sure that I wanted to be a teacher and be around kids.'

When she was an elementary school student, Morgan gained support from her teachers' *discourse.* 'My fourth-grade teacher was one of my favorite teachers, she was very encouraging all through the year, we did a lot of, now that I think of it we did a lot of science.' While Morgan had few memories of science in elementary school, the few she held were activity-based.

Morgan: Teacher Candidate. As Morgan entered her methods courses, her confidence was initially high; yet, she brought both positive and negative memories of science instruction from elementary school. Morgan described her role as a learner/teacher, 'I had to look up how to teach first graders about magnets and I had to review myself how magnets actually work.' During Morgan's senior year, her continued interactions with students illustrated their engagement with science. Morgan described how the students' enthusiasm strengthened her vision of herself as a teacher of science:

> I was nervous about science just because growing up, I was never that interested in science but now I think it's one of my favorite subjects to teach just because the wonder that it brings in, especially with these kids.

Morgan's *affinity* as a teacher of science was challenged by the disconnect between the practices she saw in her field experiences and those presented in her methods courses. She explained her personal negotiation, 'There's 30 minutes after recess before the bell rings to quickly go through science and so they don't really learn anything … so I see that it's very challenging.'

Morgan: Teacher. Morgan's first teaching job was in a Kindergarten classroom. The *institution* influence of Morgan's STEM-focused teacher preparation programme was evident through her resisting the practice of her fellow Kindergarten teachers who taught no science during the first six weeks of school. Field notes from an early observation described the Kindergarten students as clearly accustomed to going outdoors to collect weather data. She confirmed that her principal supported her decision to include science, thus having *institutional* support. She explained, 'Eventually I [discussed with] administration … when I talked to them, they made me feel a lot better.' As the year progressed, Morgan pointed to the role of her STEM-focused teacher preparation programme as she 'definitely felt prepared in teaching math and science' because she had 'experience planning lessons and implementing lessons' during the programme.

Morgan's developing identity as a *Teacher* of science was confounded by *discourse* with teachers at her school marginalising science that countered those learned during her teacher preparation as a *Teacher Candidate*. This intersection of the *institution* and teacher *discourse* further revealed Morgan's transition identifying as a *Teacher* extending beyond her teacher preparation to her first year of teaching.

Morgan's developing identity as a *Teacher* was also strengthened by her students' growth. By the middle of the year, she was able to see students making connections with their ongoing weather data collection. She explained that her students were 'not just noticing the trees are moving, but *why* are they moving.' At the end of her first year as a teacher, Morgan described her impression of teaching in general, 'It is a lot harder than what I thought it was.'

Summary. As a *Student*, Morgan's family discussions about science highlight the *nature* influence in her young life; yet, she had mixed experiences with science in elementary school. The mixed *institutional* experiences contributed to her ambivalence for science; yet, her strong *affinity* and desire to become a teacher persisted. Morgan's transition from *Student* to *Teacher Candidate* to *Teacher* mirrored Peyton's as she began to learn about the complexity of teaching. The role of *discourse* with students in Morgan's field experiences during her time as a *Teacher Candidate* had a strong and positive impact on Morgan's vision of science as she witnessed the students' enthusiasm and hunger for science lessons. Morgan's science experiences as a *Teacher Candidate* and *discourse* with professors and students further influenced her development of goals to present science inquiry experiences for students. As she began to identify as a *Teacher*, Morgan was able to build upon her experiences as a *Student* and *Teacher Candidate*. Despite an institutional culture of science marginalisation, Morgan leaned heavily on her STEM-focused teacher preparation as she strategically attempted to provide her Kindergarten students with continuous and rich science experiences.

Discussion

The findings of this study illustrate the challenges and factors that influence teacher identity formation. Teachers' experiences as students in science classrooms, teacher preparation courses and field experiences, and the continued marginalisation of science in schools all influence teachers' developing identities as science teachers. Our findings indicate the importance of exposure to reform strategies during teacher preparation (Avraamidou & Zembal-Saul, 2010; Davis & Smithey, 2009; NRC, 2007). As Avraamidou (2014a) described, science teacher identity formation is a dynamic process, and teacher education programmes help initiate an awareness of the importance of developing an identity (Beauchamp & Thomas, 2009). We positioned our research to capture the stages that describe the path from *Student* to *Teacher* (Avraamidou, 2014b; Erickson, 1968). As Gee (2000) pointed out, people have multiple identities, and we recognise that our exploration describes malleable and developing science teacher identities.

Our research questions sought to determine factors that contribute to our case studies' identities as elementary science teachers, highlighting their backgrounds and memories of science and science instruction and the influences of their STEM-focused teacher preparation programme. In the following, we structure our discussion by focusing on the similarities and differences among the two case studies around the key themes: *memories of*

science and science instruction, STEM-focused programme, field experiences, first year of teaching, and views of effective science instruction.

Memories of science and science instruction

The stories we live by, as described by Connelly and Clandinin (1999), build on early memories as teachers paint their professional self-portraits. Family backgrounds and elementary school memories related to science provided a canvas for Peyton and Morgan within their *nature* identity. Peyton's and Morgan's positive early images of science from their family backgrounds and Peyton's positive early school experiences contributed to their intentions to offer authentic science experiences for their students. The longitudinal influence of early science experiences supports calls for improving science instructional approaches (NRC, 2007, 2011; Osborne & Dillon, 2008; Roth, 2014) beginning in Kindergarten.

STEM-focused teacher preparation

Both Peyton and Morgan were influenced by their STEM-focused teacher preparation. As learners in the process of envisioning themselves as teachers, they initially felt challenged to connect content of core college-level science content courses with the science they would communicate with children. As Feiman-Nemser (2012) explained, many pre-service teachers fail to see the benefits of content knowledge contributing to their ability to teach and instead 'want recipes' (p. 34) for teaching. The transition from passive learner to active participant in the learning process began with methods coursework and required a shift from their previous experience as learners of science. Furthermore, Peyton's and Morgan's initial simplistic perceptions of teaching contrasted with the complexities of teaching as discussed in their methods courses and illustrated in their field experiences. Thus, the university and elementary school *institutions* along with professional *discourse* at each institution played critical roles in their personal negotiations with identity as teachers of science.

Field experiences

Although the STEM-focused teacher preparation programme is diligent in the monitoring of quality of field experiences, many of the field placement schools mandate major emphases on reading and mathematics at the expense of other subjects, including science. These instructional guidelines are typical of those reported in the NSSME (Banilower et al., 2015) where elementary teachers taught science much less frequently than language/reading and mathematics. Administrative guidelines of instructional time in many field placement schools sequestered science instruction to short time periods, requiring teachers to present science in mandated short blocks or infuse science within other disciplines. The influences of *nature, institution,* and *discourse* frameworks during *their stage as Teacher Candidates* provided Peyton and Morgan conflicting models of elementary science instruction. They each negotiated the relationship between their personal science experiences as elementary students, models in methods courses, and the science instruction practised in their field placement classrooms. Each of these experiences contributed to the process of developing their personal identities and their *affinity* identity as a science teacher. In addition, the role of *discourse* with children in field experiences

positively contributed to personal teaching identities as each described children's interest and enthusiasm for science. The peaks and valleys of identity development form an identity path that is different for each teacher, yet has common challenges (e.g. negotiation of conflicting images of science teaching; realisation of the complexity of teaching).

First year of teaching

Each of the cases at some point described Gee's (2000) *institution* identity as 'authorising' the position of a *Teacher* and a long-term desire to be a teacher or teaching seen as a 'calling' (p.103). It is possible that their early experiences, along with their teacher preparation, contributed to Peyton's and Morgan's persistence in trying to include science for their students despite peer practices and school cultures marginalising science. Connelly and Clandinin (1999) describe schools as 'a landscape of interacting stories that bear directly on teacher identity, and by association, on teacher satisfaction with their work' (p. 100).

Using NSSME data, Banilower et al. (2015) reported that 80 per cent of K-3 classes taught by novice teachers receive science instruction three days or fewer each week or only some weeks during the school year, and both novice and experienced teachers report spending little instructional time on science compared to reading/language arts and mathematics. Peyton complained about the lack of resources for teaching science, exemplifying NSSME (Banilower et al., 2015) survey data that found that novice science teachers in elementary grades 'generally cobble together their materials from multiple sources, some of them commercial, some not' (p. 24). Peyton perceived her challenge with resources as a lack of administrative support for science teaching at her school. According to NSSME data, principal support is the strongest influence on science instruction when compared to all other factors including state standards, parent expectations, teacher evaluation policies, and student reading abilities, thus providing a challenge for first-year teachers to act in conflict with administrators who do not prioritise science. In contrast to Peyton, Morgan felt supported by her school administration when she taught science when her grade-level colleagues did not.

Views of effective science teaching

Each participant in this study brought different visions of effective science teaching based on their backgrounds as students. While Peyton and Morgan initially relied on memories from elementary school as models of science teaching, their methods courses introduced them to the importance of activities that promote science inquiry and the need to identify and build upon students' prior knowledge. The conflicting messages between teacher preparation and field placement *institutions'* visions of effective instruction created personal struggles with these visions. The role of the *institutions* and *discourse* with key players interacted in the *Teacher* stage as they began teaching and searching for their personal identities as teachers of science.

Implications

The findings of this study provide implications for policies that influence elementary science. The time mandates and marginalisation of science instruction is a cycle that

must be interrupted. We clearly know that young children are not only enthusiastic about science, but they also have the potential to learn rich science (NRC, 2007). In addition, for those who will become teachers of science, weak models during elementary school challenge their development as teachers (Feiman-Nemser, 2012). Using identity as a lens to examine teacher learning can guide teacher preparation programmes to address individual teacher candidates' experiences through exploration of their retrospective and prospective identities (Bernstein, 1996).

When pre-service teachers enter an elementary teacher preparation programme, they enter the 'community of practice' as teachers (Eckert, 2006; Lave & Wenger, 1991), but in actuality, they have been associated with this community for a long time, only as students. The consequences of this 'long apprenticeship of observation' (Feiman-Nemser, 2012, p. 201) begin to appears within the *Teacher Candidate* stage when dissonance occurs if the type of instruction the pre-service teacher experienced as a student is disharmonious with what they learn in the methods courses. Therefore, it seems important for teacher educators to have explicit conversations with pre-service teachers about the degree of alignment between their past and present experiences and how to continuously reflect on their views of effective science teaching.

Elementary teachers are generalists and the expectation for elementary teachers to become masters of all subjects requires support. Teacher perceptions of limited principal support for science instruction influence teachers' beliefs (Johnson, 2007) and can impact instruction. Principal support may come in the form of the purchasing high-quality curriculum resources or developing a school schedule that prioritises science. In many schools and districts, science has been relegated to the back burner due to a focus on reading and mathematics. This unintended implication of accountability and testing policies runs counter to national and international calls for improving and encouraging STEM preparation. Therefore, it seems important for principal preparation programmes to emphasise the importance of early, rigorous, and regularly implemented science instruction. One recommended strategy to support science instruction is to hire science specialists in elementary schools who work with classroom teachers and students to implement inquiry-based instruction (Banilower et al., 2015; Jones & Edmunds, 2005).

Additional research is needed that examines other factors that contribute to teachers' developing identities as science teachers. Teacher preparation programmes and professional development programmes, particularly as part of induction for novice teachers, with attention to science teacher identity development can build and strengthen a solid force of elementary science teachers who strongly identify and embrace their roles as effective science teachers.

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Appendix A

Study Measures and Timeline

Data Sources	Timeline		
	Junior year	Senior year	1st year of teaching
Fall semester	*Introductory Interview*	*Beginning of Senior Year Interview*	*Introductory Interview 1st Year Teaching*
	STEM Cognitive Interview	*Pre-Student Teaching Interview*	*Science Lesson #1 Interview 1st Year Teaching*
	Getting to Know You Interview	*Science Student Teaching Interview*	*Mid-Year Interview 1st Year Teaching*
Spring semester	*Field Based Science Inquiry Assignment Interview*	*End of the Senior Year Interview*	*Science Lesson #2 Interview 1st Year Teaching* *Science Lesson #3 Interview 1st Year Teaching*
	End of the Junior Year Interview		*End of 1st Year Teaching Interview*

1. The *Introductory Interview* was conducted in the very beginning of their junior year, capturing initial views on teacher preparation, efficacy beliefs and planned instruction;
2. The *STEM Cognitive Interview* conducted during the Fall semester after participants' first STEM lesson was taught to elementary students in the participants' field placement classrooms to capture participants' reflections on science teaching;
3. The *Getting to Know You Interview* was conducted at the end of Fall semester to learn more about participants' background;
4. The *Field Based Science Inquiry Assignment Interview* conducted during Spring semester after participants' science lesson was taught to analyze the course of the lesson and their science teaching;
5. The *End of the Junior Year Interview* was conducted at the very end of their junior year, capturing views on teacher preparation, efficacy beliefs, and changes in their thinking during the year;
6. The *Beginning of Senior Year Interview* was conducted in the Fall semester at the very beginning of their senior year, capturing initial views on teacher preparation, efficacy beliefs and planned instruction;
7. The *Pre-Student teaching Interview* was conducted in the Fall semester at the end of their senior year, capturing changes in instructional beliefs, efficacy beliefs and planned instruction;
8. The Science Student Interview was conducted during the Spring semester of their senior year, capturing participants' reflections on their science lesson teaching;
9. The *End of the Senior Year Interview* was conducted at the very end of their senior year, end of Spring semester, capturing changes in their views on teacher preparation, efficacy beliefs, and changes in their thinking during the year;

10. The *Introductory Interview 1st Year of Teaching* was conducted in the very beginning of their 1st year of teaching (Fall semester) capturing views on teacher preparation, changes in instructional beliefs, efficacy beliefs and planned instruction;
11. *Science Lesson Interview One 1st Year Teaching* conducted during Fall semester after participants' science lesson was observed to analyze the course of the lesson and their science teaching;
12. *Mid-Year Interview 1st Year Teaching* was conducted mid-year of their 1st year of teaching (Fall semester) capturing views on teacher preparation, changes in instructional beliefs, efficacy beliefs and planned instruction;
13. *Science Lesson Interview Two 1st Year Teaching* conducted at the end of Fall semester after participants' science lesson was observed to analyze the course of the lesson and their science teaching;
14. *Science Lesson Interview Three 1st Year Teaching* conducted during Spring semester after participants' science lesson was observed to analyze the course of the lesson and their science teaching;
15. *End of 1st Year Teaching Interview* was conducted in the early summer and end of the teachers' school year capturing reflections on the first year of teaching, the role of teacher preparation, changes in instructional beliefs, efficacy beliefs, and their vision of themselves as a teacher of science.

Appendix B

Overview of Coding Process

Dimension (Clandinin & Connelly, 2000)	Dimension Description	Coding Procedure	Open-Coding Categories	Identity (Gee, 2000)	Sample of Data
Student	Learner of science	The data were analyzed for instances where the case described memories of being a learner of science as well as any additional information that helped to understand their science background.	• Personal background Information (i.e. family, community, etc).	*Nature Identity*	"My dad and brother, even now, they're always talking about science or math in some form, and so I had always grown up with those conversations" (Morgan).
			• Memories of K-12 science. • Memories about general education course experiences while in college.	*Institution Identity*	" … had a lot of hands-on teachers who were really eager to get stuff in our hands" (Peyton).
			• Memories about methods courses experiences.	*Affinity Identity*	"We did a lot of fun things and I can remember going out to the pond by our school and observing things and writing reports on animals out there" (Morgan).
			• Memories of encounters with teachers, peers, family, or community members.	*Discourse Identity*	"My fourth grade teacher was one of my favorite teachers, she was very encouraging all through the year … " (Morgan).
Teacher Candidate	Transition from learner to teacher of science	The data were analyzed for instances where the case described moving from a learner of science to a teacher of science. These instances included how the PST made connections from their previous science courses to what students in an elementary classroom were learning.	• Role their family or background played in their development as a teacher.	*Nature Identity*	"No matter if it's end of year testing or not, [science] will definitely be a vital part of my classroom curriculum" (Peyton describing how her positive experiences as a student formed her vision of her future classroom).
			• Memories connecting experiences as a learner of science with their development as a teacher of science.	*Institution Identity*	"Like, I've always thought of teaching science as doing investigations and teaching the correct content, but I never really thought about how much misconceptions could play into that … " (Morgan).
			• Emerging beliefs about teaching science. • PST's confidence trajectory for teaching science.	*Affinity Identity*	" … now that we're actually doing stuff that's relatable and interesting and things that will propel me into my future career … it's becoming

(*Continued*)

Continued.

Dimension (Clandinin & Connelly, 2000)	Dimension Description	Coding Procedure	Open-Coding Categories	Identity (Gee, 2000)	Sample of Data
					more of a definitely a positive thing" (Peyton describing her methods courses).
			• Field Experiences (does not include student teaching). • Teaching practice modeled by other teachers. • Experiences that help the PST move from learner to teacher of science.	*Discourse Identity*	" … kids are so curious … they want to know how things work, they want to know the science behind things" (Peyton describing her interactions with her field placement classroom).
Teacher	Teacher of science	The data were analyzed for instances where the case described being a teacher of science during their teaching preparation program or during their first year of teaching.	• Role their family or background played in their teaching.	*Nature Identity*	I've always known since I was little that I wanted to be a teacher and how it is, teaching is so hard … " (Morgan).
			• Student teaching experiences. • School context factors (i.e. feelings, beliefs about school, etc).	*Institution Identity*	"I like it 'cause they're out of my hair … [but] it would be nice [if they] asked, you know, how it [was] going" (Peyton describing her school during her 1st year of teaching).
			• School context factors (i.e. feelings, beliefs about school, etc).	*Affinity Identity*	"I really try to make science relevant in the classroom … " (Morgan).
			• Relationship with mentor teachers.	*Discourse Identity*	"I feel like I'm pretending, but I feel like I think I know what I'm doing. Other people say I do" (Morgan commenting being a teacher).