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Preservice Elementary Teachers' Identity Development in Learning to Teach Science: A Multi-site Case Study

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Abstract

The purpose of this qualitative study was to investigate preservice elementary teachers' science teacher identity development during their participation in the field-based science methods course and a year after. Grounded within the Feiman-Nemser's thematic framework of learning to teach, this study utilized a case study approach aimed to examine the experiences that contributed to formation of science teacher identities of two participants uniquely positioned in the teacher education programs at the two sites, USA and Canada. Data collected over a year included science autobiographies, reflective journals, interviews, classroom observations, and artifacts. The analysis of the data revealed that experiences and interactions within prior science courses, science methods course and classroom teaching, and the

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program itself (a year after), accounted for the changes in how and in what the ways the two preservice teachers *think, feel, know*, and *act* as a teacher of science. Findings indicate the importance of the framework of learning to teach in shaping preservice science teachers' identities. The study includes implications for preservice teacher education programs and research.

Keywords: Science teacher identity, preservice science teacher education, learning to teach

Introduction

As science and technology continue to advance, it is imperative that today's youth develop a firm understanding of science concepts and apply conceptual knowledge to solve real-world problems (Next Generation Science Standards [NGSS] Lead States, 2013; National Research Council [NRC], 2012). Recent reforms in science teaching and learning across the globe call for preparing high-quality science teachers who have the foundational knowledge of science and the confidence to teach it (Australian Curriculum, Assessment and Reporting Authority [ACARA], 2015; Newfoundland and Labrador. Department of Education, 2015; NGSS, 2013). Despite numerous calls, research suggests that science is generally neglected in elementary classrooms (Kelly, 2000). Past literature documents that many elementary teachers "shy away from science and science teaching" because of fewer and more often negative experiences with science (Gunning & Mensah, 2011, p. 172). Given the challenge, there is an increasing demand for teacher preparation programs to find ways to provide experiences that help preservice teachers to gain an interest in science to develop their identities as teachers of science (Katz et al., 2011). Teacher identity refers to a teacher's sense of *self*, leading to how a teacher represents oneself and performs actions within a teaching context (Avraamidou, 2014a).

Prior studies suggest that the development of teacher identity is a complex process, and a variety of life-experiences influence the formation of teacher identity over time (Hancock & Gallard, 2004; Kier & Lee, 2017). Such life experiences collectively influence how preservice teachers connect with science and perceive themselves as science teachers personally and professionally (Carrier et al., 2017). Identity is an interplay of self and the social context, and both personal and contextual factors work together toward the construction

of one's professional identity (Arvaja, 2016). Considering that the development of teacher identity is a dynamic process (Gee, 2000), studies on teacher identity need to take into account preservice teachers' unique backgrounds, which impact their motivation to enter into the teaching profession as well as ways in which they interpret the information with the teacher preparation courses. In that sense, multi-site studies on teacher identity could offer a broader perspective that allows teacher educators to support and develop science teacher identities.

While teacher identity has been explored considering experiences within teacher preparation programs, more longitudinal studies are needed to explore how the range of experiences and interactions shape the development of science teacher identity. It is argued that a comprehensive understanding of teacher identity may be better achieved by investigating the interplay between personal and contextual factors that shape preservice teachers' science teacher-self over a longer period (Avraamidou, 2014a). This research focuses on understanding how and in what ways preservice teachers interpret, develop, and learn to use the knowledge and skills required for science teaching as they participate in science methods courses and practice teaching. We explore and present cases of two preservice elementary teachers' identity development, one in the United States and the other in Canada. The development of science teaching identity is informed by preservice teachers' personal histories, particularly their experiences with science teaching and learning. Therefore, we collected data at three points of time (1) beginning of the science methods course (investigating prior science experiences), (2) as they participate in their science methods course, and field-experiences, and (3) in their final year of their teacher preparation program. The following research questions guided this study:

(1) How do preservice teachers' life-experiences, science backgrounds, and college teacher preparation influence science teacher identity development?

(2) How are science teacher identities of the two preservice teachers shaped in the process of learning to teach science (at three time points—beginning of the science methods course, immediately after the course, and at the end of the preservice teacher preparation program)?

Theoretical framework and background literature

Teacher identity

Teacher identity is a valuable construct in educational research and is conceptualized and interpreted in many ways (Gee, 2000). One line of research positions teacher identity as central to an individual's belief system encompassing values and beliefs regarding science teaching and learning influencing one's positioning as a science teacher (Carlone & Johnson, 2007; Helms, 1998; Kier & Lee, 2017). The personal dimension of identity includes personal interests, beliefs regarding how one recognizes oneself as a science teacher, values they hold regarding teaching practices, what is important to them, and self-efficacy and confidence in science teaching (Appleton & Kindt, 2002; Avraamidou, 2014a; Helms, 1998). This dimension also centers on individuals' personalities including the choices they make, conscious or unconscious, to engage or disengage with science (Shanahan, 2009).

Several others in the field emphasize the social dimension of identity that is shaped and negotiated through social interactions (Avraamidou, 2014b; Carrier et al., 2017; Enyedy et al., 2006). There is a consensus in the literature that contextual factors affect teacher identity and takes into account ways in which individual teachers negotiate their identities as part of the broader school culture (Luehmann, 2007), interactions leading to being recognized by colleagues, supervisors, administrators, parents, and students within the classroom. In a nutshell, teacher professional identity holds high emphasis due to its focus on how an individual situates oneself within the teaching profession (Beijaard et al., 2004), which further influences their decision making regarding teaching processes and teacher practices (Bandura, 1986; Kier & Lee, 2017). Researchers noted teacher professional identity as discipline-specific and related to professional self-image (Enyedy et al., 2006; Volkmann & Anderson, 1998). Within the context of preservice teacher education, developing a professional identity includes how preservice teachers make sense of their *roles* as science teachers (Luehmann, 2007; Sutherland et al., 2010). Others have linked professional identity to being a *reform-minded* teacher—indicating teachers' thought processes and instructional practices are in-line with the vision and efforts for reforms in science education (Avraamidou, 2016; Luehmann, 2007; Saka et al., 2013).

Preservice science teacher identity

Researchers have studied preservice teacher identity in a variety of contexts such as science methods courses (Kier & Lee, 2017), field experiences (Settlage et al., 2009; Siry & Lara, 2012), informal contexts (Avraamidou, 2014b; Katz et al., 2011), science education reforms and science curriculums (Avraamidou, 2014b; Eick & Reed, 2002), and in the beginning years of teaching (Avraamidou, 2016; Kier & Lee, 2017; Madden & Wiebe, 2015). Studies that investigate the formation of science teacher identity over time provide some interesting findings. Avraamidou (2014a) studied the development of a beginning elementary teacher's identity over five years, through her preservice teacher education program and the first year of teaching. The analysis indicated the presence of the four dimensions of identity, as suggested by Gee (2000) (nature identity, institution identity, discourse identity, and affinity identity), indicating that the beginning teacher's identity was multi-faceted and complex in nature. Hsu et al. (2017) explored preservice teachers' science teaching identity as "manifested in their philosophies of science learning and teaching" (p. 179). Rodrigues et al. (2018) investigated preservice teachers' decision-making process to become a teacher and formation of their science teacher identity within the context of a teaching practicum in a science teacher education program in Brazil. Preservice teachers' narratives showed several elements contributing to their decision-making and formation of their science teacher identities, including the nature of the undergraduate program, representational models of teaching/teachers, the possibility of being an agent for social transformation, and an affinity toward natural sciences and education.

Preservice teachers' development of science teacher identity is informed by their personal histories when they arrive teacher education program (Avraamidou, 2014a; Beltman et al., 2015; Eick & Reed, 2002). Preservice teachers experience new discourse during their teacher preparation programs that may challenge their prior views of science and science teaching. While preservice teachers' may encounter conflicting ideas, they negotiate science teacher identities as they engage in discourse within their coursework and school placements (Danielsson & Warwick, 2014; Melville & Bartley, 2013). Several questions arise: Do science teacher identities continue to re-construct after the completion of college coursework? Is the nature of the

developing science teacher identity progressive, or can there be falling back for some preservice teachers in light of new events? What kinds of supports do preservice teachers need in order to continue progressively in developing science teacher identities after their regular coursework? In this case study, with an attempt to seek answers to some of the questions, we focus on understanding the nature and development of preservice teachers' science teacher identities a year after the science methods course is concluded.

Learning to teach

Preservice teacher preparation programs provide a variety of "intentional learning opportunities" that can collectively constitute experiences helping preservice teachers become more effective teachers Feiman-Nemser (2008). Such "learning-to-teach" experiences (Darling-Hammond & Bransford, 2005; Zembal-Saul, 2009) are useful in re-shaping existing teacher identities because these experiences are spread over time during preservice teacher preparation courses and allow them to develop a vision for teaching. To investigate preservice teachers' identity development as they are learning to teach science, we utilize the thematic framework of "learning to teach" proposed by Feiman-Nemser (2008). Feiman- Nemser (2008) conceptualization of learning to teach consists of four themes: (1) learning to *think* like a teacher, (2) learning to *know* like a teacher, (3) learning to *feel* like a teacher, and (4) learning to *act* like a teacher (see **Figure 1**). The first theme, learning to think like a teacher, takes into account teachers' awareness of their existing beliefs, thoughts, and experiences. Extending the notion to preservice teacher education, learning to think like a teacher allows preservice teachers to examine their existing beliefs critically in light of new experiences and understandings as they take science methods courses to learn how to teach. Learning to think like a teacher will help preservice teachers challenge their preexisting beliefs and recognize any changes in their pedagogical thinking they need to make to adjust their current practices.

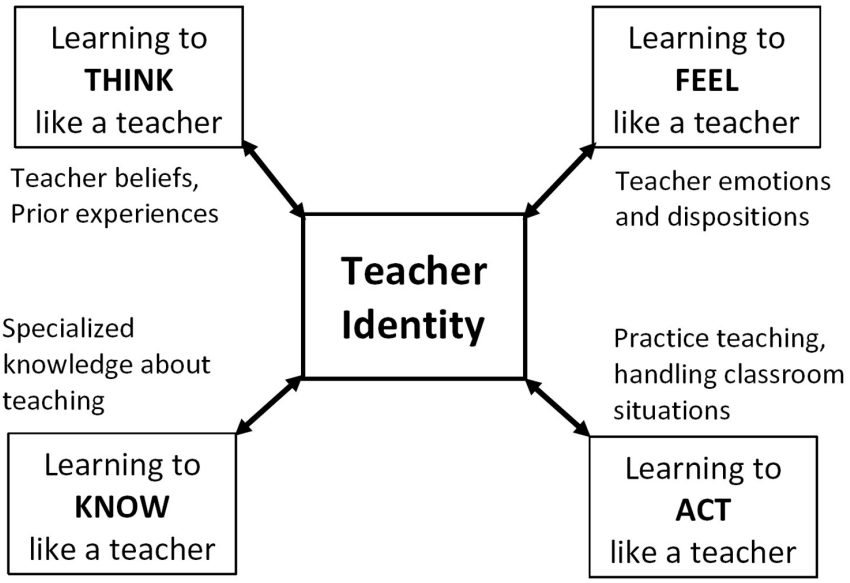

Figure 1. Representation of four themes of "learning to teach" (Feiman-Nemser, 2008).

Teacher Identity

The second theme, learning to know like a teacher, considers the various knowledge-base that teachers require to teach effectively. Preservice teachers acquire knowledge bases about science and science teaching during science content and pedagogy courses. While a sound understanding of content is critical for teaching science (Menon & Sadler, 2016), specialized knowledge about teaching science, including knowledge about their learners, curriculum, instructional practices, and assessment, is important to enhance student learning outcomes (Grossman, 1990; Shulman, 1987). In addition, preservice teachers need to understand how to adapt instruction to attend to *all* learners considering the diverse interests and abilities of learners (Menon & Sadler, 2018).

The third theme, *feel* like a teacher, highlights teacher emotions and dispositions associated with one's teacher professional identity. Professional identity includes an affinity for a role, making sense of the responsibilities and realities associated with the teaching

profession, and recognizing the challenges and rewards attached to the teaching profession (Gee, 2000; Settlage et al., 2009). The fourth theme, act like a teacher, focuses on the practice of teaching, which involves using knowledge, skills, and dispositions together in a personalized manner within a specific context. During field teaching, preservice teachers are involved in a variety of activities, including planning a science lesson through a collaborative effort, organization, material and classroom management, and lesson implementation in a classroom. Classroom implementation often puts preservice teachers in situations that vulnerable and challenging and require preservice teachers to *act* and *react* to those situations in real time. Learning to act like a teacher requires a constant judgment on the teacher's part to take necessary actions to handle unanticipated situations that may arise in classrooms.

Learning to become an effective science teacher is an ongoing and complex process, which is similar to how teacher identity is shaped over time. The "Learning-to-teach" framework offers a powerful and multi-dimensional lens embedded within the context of life experiences, preservice programs, and school culture (Flores & Day, 2006). The dimensions of Learning-to-teach framework (think, know, act, and feel like a teacher) are closely related to personal (beliefs and emotions), social interactions, and professional aspect of teacher identity. Teaching is a complex process as it demands teachers to engage in a range of activities including planning for classroom teaching and social interactions with colleagues, parents, and administrators. The goal of the teacher preparation programs is that preservice teachers are able to integrate thinking, knowing, feeling, and acting into their everyday decision-making and classroom practice. The integration of the four aspects of Learning-to-teach work together to support in the development of teacher identity as they conceptualize new knowledge and translate into practice. We draw on the framework of "Learning-to-teach", which served as a lens to examine and understand the development of preservice elementary teachers' identity to teach science (see Figure 1).

Methodology

Research context: teacher preparation program in the USA and Canada

This year-long case study was conducted at the two public universities in the Mid-Atlantic region, one participant attending the teacher preparation program in the U.S. and the other in Canada. At the U.S. research site, the elementary education program has four levels that occur in a sequence, and each level has specific courses to prepare preservice teachers for the next level. At pre-Level I (first year), preservice teachers take prerequisite content courses in science, math, language arts, and social studies. At Level 1 (second year), the focus in on literacy education and a field placement half a day each week. At level II (third year), preservice teachers take science (two specialized courses, an Earth space science, and one life science course) and mathematics courses. Preservice teachers are also enrolled in science and mathematics methods courses and field placement of two half days each week. This study began at the beginning of the science methods course and field placement (Level II, third year, Fall semester) and concluded at the beginning of Level 1 V (fourth year, Fall semester). Within the science methods course, preservice teachers are in cohorts, typically 3–4 cohorts depending on the enrollment, and each cohort consists of approximately 15–16 preservice teachers. The science methods course meets for about three hours and 50 minutes once a week for 15–16 weeks.

At the Canadian research site, the primary/elementary teacher education program is offered as a first-degree or a second-degree program. The site for this research study was the second-degree primary/elementary program, which runs for two years (72 credit hours) and is intended for candidates who have already completed a bachelor's degree. Before joining the program, teacher candidates can complete science content courses from three science areas (e.g., biochemistry, biology, chemistry, earth sciences, environmental science, ocean sciences, and physics). In addition, preservice elementary teachers need to complete six credit hours in English, six credit hours in mathematics, six credit hours in psychology, and six credit hours of optional

course from areas such as anthropology, archeology, economics, folklore, geography, history, linguistics, political science, religious studies or sociology. This program includes several integrated field experiences throughout the program and a formal 12 credit hours teaching internship toward the end of the program. While typical course enrollment in the science education course is 25–35, there were 29 preservice elementary teachers enrolled at the time of this study.

Science methods course components

The two authors (also the course instructors) held weekly online meetings during summer to discuss the features of the science methods course that served as the context for this research. During the meetings, we discussed the state and national education policies, curriculum standards (Newfoundland and Labrador. Department of Education, 2015; NGSS, 2013), and the philosophical and methodological approach to science methods course at the respective institutions. We realized that both courses strongly emphasize the scientific inquiry, reform-based practices in teaching and learning science, and engineering design. There were some differences in the course topics that each instructor emphasized in their course more explicitly as compared to the other, given the mission and vision of the national standards, such as inclusive education and impact of science on society and environment, was a component in Canadian science methods course. We made changes to the existing science methods course toward making the essential components and tasks (served as the sources of data) similar, as described in the next few paragraphs and **Table 1**.

The design of the science methods course included *five* essential components (common features): (1) practice-based science investigations that involved the integration of selected NGSS disciplinary core ideas and practices in science and engineering, (2) reform-based instructional strategies such as 5E model (Bybee, 1997; Bybee & Landes, 1990) and engineering design process (Lottero-Perdue, 2017) for student-centered science instruction, (3) collaborative science lesson planning, (4) field-experiences in a local elementary classroom, and (5) critical reflections on science learning and teaching experiences. Each class session was designed to engage preservice teachers in Science and Engineering Practices (SEPs) envisioned by the *Next*

Table 1. Science methods course activities targeting learning to teach.

Course Components	*Detailed Description of the Activities*	*Potential Sources of Learning to Teach*
Practice-based science investigations	In small groups (3–4), preservice teachers participate as learners to conduct simple hands-on science investigations.	Preservice teachers need to *know* deep knowledge of the science content specific to elementary science teaching.
Reform-based instructional strategies (5E and Engineering Design)	Science and engineering practices (outlined in the NGSS) are embedded within each science lesson using a 5E model. There are explicit discussions on and about each stage of the 5E model as well as the practices.	Preservice teachers also need to *know* pedagogical content knowledge by engaging in a specific content/topic using reform-based teaching practices and 5E learning cycle.
Collaborative science lesson planning	Preservice teachers work in collaborative teams (3–4 per group) to plan and design a practice-based science lesson for elementary classrooms.	Preservice teachers must have opportunities to brainstorm ideas (*think like a teacher*), and negotiating roles (*feel like a teacher*) while they engage in a complex process of science lesson planning
Field-based teaching in a local elementary classroom	Each preservice teacher teaches the science lesson in a local elementary school classroom to a small group of students (5–6) for 40 minutes. They also engage in discussions about their lesson with mentor teachers, peers, and course instructor (debrief sessions)	By practice teaching science through firsthand teaching experience (*act like a teacher*). Social interactions with young learners contribute toward their teacher's sense of self that allows them to bridge the gap between theory and practice.
Critical reflections on science teaching	Preservice teachers write a science autobiography (reflective narrative of prior science experiences) and reflect on their classroom teaching (reflections-on-action).	Preservice teachers must develop ability to reflect critically on the life experiences, events, situations, and classroom episodes that contribute toward their professional growth as teachers of science (*think, feel, know, and act*).

Generation Science Standards. During the course, for instance, preservice teachers conducted simple scientific investigations focused on the three disciplinary core ideas: PS1: Motion and Stability: Force and Interactions, PS3: Energy, LS1: From Molecules to Organisms: Structures and Processes. Science and Engineering practices (e.g., asking questions, using models to conduct investigations, analyzing and

interpreting data, using mathematical thinking to identify patterns and suggest relationships in the data, and construct evidence-based explanations) were integrated throughout the 5E modeled science lessons (Menon et al., 2016).

Preservice teachers co-planned and designed their science lessons, based on the investigations and pedagogies they experienced in the course, to teach in elementary classrooms. The field experience involved co-teaching and individual teaching components in 45 minutes of teaching sessions three times a semester. Another critical component of the course was to engage preservice teachers in reflective practices to help them emerge as "reflective practitioners" (Yuan & Mak, 2018). The reflective practice included preservice teachers writing science autobiographies, where they shared past life experiences that shaped their current beliefs about science and science teaching, and written reflections on their field teaching.

Research design: a case study

The study employs a case study design to explore two preservice teachers', one from the USA and the other from Canada, development of science teacher identities as they continue to learn to teach science (Creswell, 2007; Yin, 2009). The case study method was a strong fit for the study considering an in-depth exploration of the complex phenomena (development of science teacher identity). It was necessary to follow the preservice teachers for a longer duration than a semester to gain a comprehensive understanding of the formation of science teacher identity. The two cases, described below, were purposefully selected from the larger group of participants (as part of the large project). Both cases offer insights about their prior experiences and relationship with science that resonate with the larger populations of preservice teachers, those who are less comfortable with science and science teaching and others who hold a strong affinity toward science and science teaching. Both participants showed genuine interest in participating in the study.

Case 1. Jamie

Jamie was a Caucasian, 21-year-old female and in her junior year at the time of the study. She was pursuing a dual-major degree in elementary and special education (in the United States). She had taken four science courses in high school (biology, chemistry, physics, and forensics). Her college science content courses included biology, anatomy, physical science, and earth-space science. She reported having some informal teaching experiences during high school, such as a volunteer in before and after school care programs and tutoring, where she helped 2nd graders with their homework (any topic) on a need basis. She expressed her passion for becoming an elementary teacher but did not feel comfortable teaching science.

Case 2. Rudy

Rudy was a Caucasian female in her late twenties, enrolled in a Bachelor of Education (Primary/Elementary) program (in a Canadian university). She had completed a Bachelor of Arts (BA) degree and majored in English and French. In high school, she took three science courses (a general science course and two courses in biology). Her college science courses included two science courses in biological and physical science, specially designed for K-6 teachers. She did not have any formal classroom teaching experiences before entering the Bachelor of Education program. However, she had some experience teaching at a summer daycare where she taught the life cycle of a frog to young children. Overall, she held positive impressions of teaching science to elementary students and was excited to become a science teacher.

Data collection

Data were collected over one year, beginning from the time participants entered the science methods course and concluded at the end of the academic year at three-time points (see **Table 2**). Two sources of data collected at the beginning of the science methods course included a written science autobiography and a demographic and open-ended questionnaire, which revealed experiences with science before entering the program. Data sources collected during the semester included

Table 2. Description of data sources.

Time points	*Data Source*	*Description*
T1	Demographic and open-ended questionnaire	Implemented on the first day of the class in a paper format to collect demographic information. Open-ended responses gathered information about preservice elementary teachers' motivation to become science teachers, for example, questions included: Do you feel motivated to teach science? Why? Why not?
	Science Autobiography	Collected in an electronic format in a week after the course began and targeted to reveal preservice teachers' prior science experiences and their beliefs about science and science teaching.
T2	Field observations and fieldnotes, artifacts	Field notes were taken by the two researchers (research journal) at the teaching site when participants taught their lessons in an elementary classroom for (spread out over 3 times in a semester for 45 minutes each). Artifacts such as lesson plans were also collected. These were used as secondary data sources to corroborate our findings on preservice elementary teachers' science teaching identity.
	Reflection papers	Reflection papers were collected in an electronic format a week after the teaching session concluded. The prompts provided opportunities to summarize their experiences of planning, designing, and enacting science lessons.
T3	Semi-structured interview	All interviews were conducted in person with the participants. The interview questions were specifically designed to reveal participants' beliefs about science teaching to gain insights into participants' developing professional science teacher identity.

T1 = Beginning of the methods course, T2 = during the methods course, T3 = One year after

three individual written reflections on classroom teaching, observations and researcher's field-notes, and artifacts such as lesson plans and handouts prepared by preservice teachers. A year after, each participant participated in an hour-long semi-structured interview.

Written science autobiographies are useful to understand the past science experiences that have a positive or a negative influence on one's beliefs about science and science teaching (Ellsworth & Buss, 2000). The prompts were carefully designed to reveal critical incidents related to their high school experiences: "Summarize your experiences from the high school science course you liked the most. What did you enjoy about science the most? Summarize your science experiences from a course that you would classify as "not so good" or "negative"? What made you dislike that course? What was the best science teacher like? Similarly, participants were also asked to summarize their college science experiences. The science autobiographies were collected within a week the course began to ensure that past experiences are captured before any exposure to new experiences in the methods course. Preservice teachers were given a demographic and open-ended questionnaire on the first day of the science methods course.

Reflection papers, written by preservice teachers after their field teaching, also served as a primary source of data in addition to science autobiographies. Reflective practice on one's teaching is commonly used in science teacher preparation programs as it allows preservice teachers to "revisit the sequence of one's teaching for the purpose of making a thoughtful judgment" (Amobi, 2005, p. 116; Davis, 2006; Lee, 2005). We designed specific prompts for preservice teachers to reflect on what they think went well and did not go well in their teaching. They are asked to provide reasoning for the episode they choose to describe and suggest things they would do differently in their future lessons. Also, preservice teachers are asked to think about areas of improvement to continue to grow professionally. Additional data sources collected were lesson plans and handouts designed by preservice teachers. Furthermore, the two researchers conducted classroom teaching observations, specifically for the two case participants and recorded detailed field notes.

A year-after the science methods course, the two case participants were interviewed for an hour and 15 minutes, and these interviews

also served as the primary source of data to understand their developing science teacher identity. The interview questions prompted participants to reflect on their professional science teacher self, such as "Do you see yourself as a science teacher?" How would you rate yourself on confidence to teach science on a scale of 1 (very low) to 5 (very high) and why?" The interviews were audio-recorded, and transcribed, and analyzed using a series on steps (described below).

Data analysis

A case study design was employed to understand the development of science teacher identity as participants learn to teach science (Yin, 2009). Considering that we collected multiple sources of data at three different time-points, data analysis was ongoing, and we used memoing throughout this year-long study (Groenewald, 2008). To assist this process, we kept notes, highlighted relevant facts, and underlined key issues that guided subsequent coding procedures. The first phase of analysis involved reading the raw data to identify common factors or events as described by the participants. After the data were read and re-read multiple times, initial codes were assigned. The two researchers (first and second author) independently coded one autobiography, which followed a discussion to compare the similarities and differences between the codes developed by the researchers. After the consensus was reached, each researcher independently coded the second participant's autobiography, followed by the second round of discussions where all codes were revisited.

During the second round of analysis, the researchers assembled the open codes, used axial coding to create categories and sub-categories, and developed a coding scheme (see **Table 3**). Then, we developed unique profiles for each participant to draw meaningful links between the categories that lead to emergent themes representing preservice teacher's views and beliefs about science and science teaching. The categories and sub-categories within each case profiles were read and re-read and interpreted using Feiman-Nemser's (2008) thematic framework of learning to teach. The framework allowed for tracing preservice teacher's prior experiences that shaped their feelings, knowledge, and beliefs about science and science teaching and how they learn to teach science in science methods courses. The framework also helped us interpret preservice teacher's thought processes

Table 3. An example of coding scheme.

Categories	*Codes*	*Sample Data*
Prior science experiences: Positive impressions of science	Interesting topics, memorable	The topic of clouds was interesting and memorable to me because it was something that I could observe in my own life outside of school.
Negative dispositions toward science	Worksheets, memorization	The biology and chemistry classes included more worksheets and memorization than anything else.
Perceptions of science teaching: Hands-on science	Hands-on, effective lesson, learn by doing	The most effective science lessons were hands-on, where the students could learn by doing.
Positive classroom culture	Safe, respected, grow	Classroom where students feel safe and respected and their learning opportunities grows immensely.
Teaching science using 5E model and inquiry	5E model, student interest	I hope to continue to use this model [refers to 5E] to continue building on my ability to teach science in a way that interests and empowers my students.
Increase in confidence to teach science	Skills and confidence, efficient, effective	I do believe I have gained some of the skills and confidence necessary to be an efficient and effective science teacher.

that lead them to think and act in a classroom setting. A similar process was conducted for coding reflection papers and interview transcripts, leading to the triangulation of the findings.

Findings

We first present the two case studies that provide an array of individual's prior science experiences and background, the development of

teacher identity immediately after the science methods course, and several months after the methods course ended (near the end of the program). Then, we present the science teacher identity of each case representing the interplay of four themes (*think, feel, know, and act like a teacher)*.

The case of Jamie

Prior science experiences: a mixture of positive and negative events

Jamie's science autobiography provided rich descriptions of her existing views and beliefs related to science and science teaching originating from her K-12 learning experiences. She had mixed experiences with science in her high school science classes. For the science classes that she felt excited to learn, she acknowledged the use of contemporary ways such as problem-based learning in her high school courses and mentioned that "these courses helped me understand why certain things occurred, and the problems that we solved were relevant." The classes that involved traditional ways, such as lecturing, did not leave her with a positive impression of science as she shared, "biology and chemistry classes included more worksheets and memorization than anything else."

Another factor that impacted her interest in science was science teachers' attitude and enthusiasm toward the subject. She described her high school physics teacher as a role model "because of his passion for the matter and the excitement toward teaching it. He constantly supported students to learn by giving up his mornings, lunchtime, and after school to help students with what they didn't understand. This teacher cared about my learning and didn't give up on anyone". On the other hand, negative dispositions left her with a "feeling that I am not good at these areas of science." She described that "the biology teacher did not encourage me to do my best and did not seem to care that I was struggling." When asked to share her views of science teaching, which depicted how she *thinks* science should be taught, she made explicit references to hands-on approaches that "allow their students to make discoveries about concepts through hands-on experiences." However, she did not position herself as a future teacher of science as she wrote in her science autobiography about not *feeling* comfortable to teach science, but was motivated to become an elementary teacher.

Developing teacher identity: immediately after the science methods course

Throughout the participation in the methods course, Jamie's perception of science teaching changed, which influenced her developing science teacher identity. Her developing science teacher identity was evident from the details provided in the reflection paper, which provided an understanding of how she *thinks* and *feels* about science teaching. One of the influential factors was experiencing hands-on science through the reform-based models such as the 5E model and learning about the science and engineering practices, which added to her knowledge-base (*know*) about science teaching. Jamie mentioned, "Before this semester I knew that the most effective science lessons were hands on, where the students could learn by doing. However, as a student I never learned science this way and could never picture what this type of lesson would look like."

She also reflected on her position as a science teacher as she became more aware of her role (*act* like a teacher) after her field teaching in a real classroom. Jamie acknowledged the responsibilities as a teacher to create a positive classroom culture "in which students feel safe and respected, and their learning opportunities grow immensely." Jamie also began to recognize the importance of hands-on learning over traditional methods in engaging students in an effective way: "If you have a lesson plan that is all lecture, you will probably lose students because they become bored and cannot stay focused." Jamie often referred to her prior science experiences while discussing her change in views of science teaching after teaching science to young learners using the 5E model. Her responses to her teaching reflections suggest that she *felt* more confident to connect students to science topics because of the 5E model as she wrote:

> I remember when I was in fourth-grade we did a lesson on the oils in foods and which one had the most. However, the teacher told us which foods contained the most oils and then gave us the supplies for the experiment. The lesson where all the information is given and then the experiment is preformed is not great because students will question "What is the point? The teacher just told us what will happen?" Throughout this semester I learned a lot of things about

> effective 5E science lessons that I would not have known without this course. These views [refers to science teaching] have changed a lot, they are a lot clearer now that I know the best ways to teach science.

Teacher identity toward the end of the program: at the threshold

As Jamie entered the final year of her program, her beliefs in the hands-on approach to science teaching solidified, and her expressions of *think, feel, know*, and *act* like a science teacher were more clearly visible. During her interview, she expressed, "I just *think* science has more opportunities to be hands-on and experimenting with things that students can really learn from and benefit from." Interestingly, Jamie's *affinity* toward science teaching increased after completing her internships in language arts and literature the semester after the science methods course. Unlike a year before, where she did not position herself as a teacher of science, she expressed that she is now more driven toward teaching science than other subjects as she said, "I do know that I am more interested in teaching science rather than language arts and literature."

There was a progression in how Jamie talked about her preparedness in teaching (*knowledge* about teaching) as she acknowledged: "I gained a lot of experience in my methods course [referring to science methods course, but I think every single semester I go through I am gaining more and more experience." Jamie became more aware that there are more things she aspires to learn as she speaks about herself as a lifelong learner: "I just need to learn what is out there. I think continuing to gain those resources will help me teach when I have my own classroom." At times, during her interview, she expressed feeling unprepared and nervous about handling the whole class single-handedly, as she mentioned, "I get really nervous when I'm up in front of a whole class, and that comes from a lack of confidence, so I think continuing to gain confidence in myself as a teacher is one thing." It appears that even though Jamie began to identify herself as a science teacher more than before, she is hesitant about handling the class on her own, which indicates an expression of feeling doubtful to *act* like an independent science teacher. When asked to share about whether she identifies herself as a science teacher, she said: I wouldn't say I

identify myself as a science teacher right now like I don't think that's one of the tags I wear on my sleeve, but I think one day I could so it's just gaining the confidence to be able to walk into a room and be like, yeah I'm a science teacher. Because of mixed views on her confidence in science teaching, she is at the threshold of her developing science teacher identity.

The case of Rudy

Prior science experiences: generally positive

Rudy's prior K-12 science experiences, as described in her science autobiography, were mostly positive. Rudy attributed hands-on learning, informal science experiences, and effective science teachers to help grow her interest in science. While describing her elementary school experiences, she recalled making a model Tornado using two soda bottles filled with water and glitter to present in a science fair. She felt connected with science during her K-12 school years because the science topics were relevant to her life, below is the excerpt from her science autobiography:

> In my third grade, my class studied the different types of clouds. I remember looking at the colored pictures of my textbook and being intrigued by the analogy of cirrus clouds looking like "mare's tails". The topic of clouds was interesting and memorable to me because it was something that I could observe in my own life outside of school and to this day many of the terms that we learned come to my mind (science autobiography).

Rudy also described a variety of informal science learning experiences that she experienced as a child performing fun science experiments at home with her father including "building a small car with my father and decorating it with my mother or to find many types of bugs and keeping them in a plastic container with soil, leaves, and water." She further described her "favorite outings were visiting the Science Center." When prompted to discuss her views on science teaching, she mentioned *feeling* inspired by her K-12 science teachers who

"promoted student-oriented classrooms." She believes (*thinking* like a teacher) that she would "create a classroom where there is a high level of student involvement in-class activities."

Developing teacher identity: immediately after the science methods course

Rudy *felt* excited about planning a science lesson and practice teaching it in a real classroom, and she positioned herself as a teacher of science. Her reflections provided rich descriptions of the four dimensions of "learning to teach" as she mentioned about incorporating new knowledge learned in the methods course (*know*) into her planning and teaching (*act like a teacher*). Rudy planned a lesson in collaboration with her partner, where she "tried to implement the principles of inquiry," an idea discussed during the science methods course in the context of reading—*Many Levels of Inquiry* by Banchi and Bell (2008). She explained her lesson where "they planned an experiment which involved rolling a toy car and an apple down a ramp to allow students to make observations regarding its motion and change of position relative to other objects." During her lesson implementation, Rudy asked probing questions, such as "why they believed that the apple moved differently than the car?" and listened to students' responses to guide their thinking toward the scientifically correct ideas later (researcher's field notes). She mentioned in her reflection: "I was impressed to hear one child's belief that the apple rolled more quickly than the car because it was bigger and heavier."

During one of the debrief sessions after the lesson implementation, the class discussed the importance of strategies to engage *all* learners. Rudy mentioned that she gained the knowledge of inclusive education (*know*) and acted upon it in real-time (*act*). In her words:

> In class, we have been learning the importance of the engagement of all children, including those who are not confident in participating. I noticed that two of our female students were less eager to participate and volunteer answers. After I took the time to ask them about their ideas, they began to participate willingly in the discussion. This was a great learning experience for me.

The knowledge of the 5E model itself proved beneficial toward her developing science teacher identity as she specified in her reflection that "before learning about the 5E approach science teaching, I felt apprehensive about my ability to successfully lead a science class. However, once I learned the five elements necessary to create an engaging lesson, planning for our short teaching experience was less intimidating." She felt "glad to have the opportunity to discuss 5E lessons in class." While Rudy felt more prepared to teach science, she still felt the need to learn more, which indicated her passion for growing professionally (*think* and *feel* like a teacher-learner to grow). This was evident from the excerpt she wrote in her reflection:

> I am a pre-service science teacher, and my short experience teaching a lesson at the elementary school was imperfect; however, overall, I do believe I have gained some of the skills and confidence necessary to be an efficient and effective science teacher. I know that I still have a lot to learn about teaching science. In the future, I hope to continue to use this model [refers to 5E] to continue building on my ability to teach science in a way that interests and empowers my students (Reflection paper).

Teacher identity toward the end of the program: growing/grounded into the profession

During the interview, conducted toward the end of her teacher education program, Rudy described her as a teacher of science in addition to a teacher of literacy and social studies (as per her background). Her descriptions about science teaching suggested stronger connections between the four dimensions of "learning to teach" (*think, feel, know*, and *act* like a teacher). She said, "I think that I am a science teacher and a science learner now." Rudy considered the science methods course as a source of her developing science teacher identity. In her words: The course that I have taken, I think I have a good understanding of how I can convey these topics to children in a way that allows them to experience science hands-on." Drawing upon her experience from the science education course, she further mentioned, "Inquiry was something that I learned about through the education

program" and "we did a lot of hands-on experiments" which "captured my interest and attention and made me see that I am capable of attracting my own student's attention and interests through hands-on science." Rudy also feels that her confidence in teaching science has dramatically increased during the past year, she said: "I feel confident as I understand how to use the curriculum guides and integrate it into the classroom."

Besides her reference to inquiry and hands-on science, suggesting that positioning as an inquiry-oriented practitioner, Rudy spoke highly about scientific literacy and citizen science and its place in the education system. In her words: "the concept of scientific literacy has changed the way that I view science in the educational system. In the past, I thought that science class served to inspire future scientists and that for all other students, it was less relevant." It is important to note that earlier, Rudy viewed science as a discipline for those who want to become scientists. However, toward the end of the program, she "realize that science class is an area of high relevance for all students as, while it does serve to prepare future scientists and engineers, it teaches *all* students to be curious about the world around them, enabling them to find solutions to practical problems and participate in social discourse in a meaningful way". Toward the end of the program, Rudy felt *grounded in the profession* of science teaching and viewed the benefits of science teaching beyond just a career to choose. "In today's society, it is imperative that citizens understand basic science in order to develop informed opinions and make wise decisions."

Discussion and implications

In this study, we drew upon the process of "Learning to Teach" as a construct to understand the formation of preservice elementary teachers' science teacher identities. Our findings indicate that while K-12 and life experiences are essential sources toward the development of teacher identity, new and fresh experiences gained during teacher preparation courses can bring lasting effects on the development of identity. What makes our study unique is that by positioning our research over a year, we were able to capture our cases' identity changes at multiple time points, which provided information about

how identities are shaped as they acquire knowledge and skills gained during the science methods course and in practice teaching. In this discussion, we focus on cross-case analysis and discuss the similarities and differences between the two cases under two themes: initial identity shaped by prior experiences, and development of science teacher identity embedded in the process of learning to teach.

Initial identity shaped by prior science experiences

In the case of our participants, initial identity was related to their past science experiences, which dominated their vision of science and science teaching. As in Rudy' case, both formal and informal positive science experiences contributed to her desire to be a science teacher. In contrast, we found that despite a few positive experiences, Jamie's relationship with science was relatively weak due to her negative dispositions with science in her K-12 science classes. These findings suggest that a few positive experiences may not be sufficient to mitigate the influence of negative experiences on one's initial beliefs about science and science teaching. As discussed in previous studies, it is not uncommon for preservice teachers to "hold on" to their initial beliefs at the time of their entry in their methods courses (Menon, 2020). In both cases, K-12 experiences seemed to shape their initial views about the kind of teacher they want to be and how they feel like approaching science teaching in the future. Preservice teachers enter methods courses with a unique set of experiences and beliefs that may influence how they interact and interpret the new information presented in the methods courses (Zeldin et al., 2008). Allowing preservice teachers to reflect on their experiences and write science autobiographies early in the methods course will help course instructors to become aware of their initial values and beliefs, which will help design instruction to support individual preservice teachers strategically.

Development of science teacher identity in the process of learning to teach

We found that the four themes of Learning to Teach, namely—*think, feel, know*, and *act* like a teacher together shape preservice teacher's identity; field experiences provide the platform to articulate all the

four themes. For our case participants, while most of the themes of Learning to Teach were grounded within their science methods course experiences, the importance of the knowledge and learning about science teaching and the broader purposes of school science education were well understood only a year after their exposure to the methods course in a real sense. During the course, preservice teachers were exposed to new knowledge, including reform-based methods of science teaching such as the 5E model, science and engineering practices, and inquiry-based instruction as well as ways to engage *all* learners.

Both Jamie and Rudy recognized the importance of reform-based approaches during their practice teaching because it allowed them to witness the benefits of these approaches in a real classroom. Given that a majority of preservice teachers do not necessarily experience inquiry-based science in their science content courses, multiple opportunities of engagement and practice teaching using the reform-based strategies are needed as they negotiate their prior identities while trying to make sense of the new pedagogies learned in the course. As preservice teachers reflected on their teaching, which in the case of our study was in the form of written reflections and debriefing sessions after their practice teaching, they began to position themselves as who they are and what they value in the context of school science teaching. Jamie, who learned science in mostly traditional ways, now positioned herself as a teacher who values classroom culture as critical to students' interest in the topic. Rudy, who had positive past formal and informal science experiences, positioned herself more strongly as an inquiry-based practitioner.

We found that positive images and impressions from the successful implementation of the science lessons in the field are promising toward identity development. That being said, whether or not identity continues to build and strengthen depends on how individuals embrace their science teacher identity. Based on our findings, we argue that a comprehensive understanding of learning to *think, feel, know, and act like a teacher* develops more strongly toward the end of the teacher preparation program, in our case a year after the methods course concluded. In Jamie's case, she felt more inclined toward science teaching, and this realization only came after she taught other subjects in subsequent semesters after her science methods course. However, Jamie became more aware of her challenges and dilemmas

soon after the science methods course concluded, which conflicted with her teacher identity, involving confidence in handling class singlehandedly and her confidence in the content preparedness. As other studies suggest, it is not uncommon for preservice teachers to experience such conflicts or become more "conscious" of their identities before beginning as full-time teachers (Carrier et al., 2017). On the other hand, Rudy felt grounded in her role as a teacher of science, recognized the importance of scientific literacy for society, and saw herself as a "teacher already". An important implication for this study is that teacher educators should be aware of how the past experiences, modeling of effective pedagogies, and practical teaching are relevant sources of "learning to teach" that shape positive teacher identity. We acknowledge that there are limitations of the study with two cases presented and that our findings may not be generalizable to other contexts. However, the findings of our study provide an understanding of how the science methods course that provides an integrated experience of "Learning to Teach" elements helps in re-formation of science teacher identities. Given that teacher identity is multi-dimensional and dynamic in nature, further research is needed to understand multiple factors that shape preservice teachers' identity over time and during their first years of teaching.

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