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I can't teach science! A case study of an elementary pre-service teacher's intersection of science experiences, beliefs, attitude, and self-efficacy

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The case study reported in this paper is part of a larger multiple cross case analysis focusing on pre-service teachers with various initial confidence and attitudes toward science and science teaching. In this paper, the focus will be on one elementary teacher candidate, Lisa, who began the science methods course with a negative attitude and low self-efficacy. An in-depth description of her beliefs, attitude, and self-efficacy, before and after the course, the impact of her prior science experience and the science methods course on shaping these domains, and the possible interrelationship between the three variables are discussed. The findings revealed the impact of Lisa's prior science experiences on all three domains and shed light on the interrelationship between her beliefs, attitude, and self-efficacy. Her course experiences allowed for changes in her beliefs about science and science teaching, and an improved attitude toward and a stronger sense of confidence toward learning and teaching science.

KeyWords: elementary preservice teachers, teacher education, beliefs, self-efficacy, attitude, science teaching

Introduction

> I hated science. I was never good at it so I didn't like it. I never felt as though I could grasp the concepts my teachers were explaining. I would understand bits and pieces but could never put the pieces together. I would struggle with memorizing definitions and facts. With science, it was just, you do this and you do that and it was pretty set in stone and rigid. So I continuously struggled with it. (Lisa, pre-interview excerpt)

The primary grades have been identified as an important stage for establishing a strong K-12 science foundation (NRC, 2012; NSTA, 2002). Early science experiences are essential for developing students' science knowledge, skills, positive attitude, and confidence toward science.

A strong early science foundation is necessary for a positive and successful secondary and post-secondary science experience. It is especially critical for equipping students with the essential scientific understanding and skills, as well as the affective features, necessary to becoming scientifically literate and socially responsible citizens (King, Shumow, & Lietz, 2001).

In spite of the reform efforts and calls by science education organizations to establish science as an important component of elementary school curriculum, science continues to be ignored or approached through traditional teacher-centered instructional methods in many elementary schools today (Appleton & Kindt, 2002; Blank, 2012). The *2012 National Survey of Science and Mathematics Education* (Banilower, Smith, Weiss, Malzahn, Campbell, & Weiss, 2012), revealed that the majority of K-5 classroom instruction occurs through lectures, worksheet or textbook-based assignments, reading texts about science, and whole class discussions. Furthermore, as students progress through elementary grades, they engage in an increasingly greater number of traditional activities and fewer hands-on or laboratory activities (Banilower et al., 2012). These trends may explain the decline in elementary students' interest in science beginning in fourth grade (Mullis & Jenkins, 1988) and the continuous decline in fourth grade students' science performance on TIMSS *(Trends in International Mathematics and Science Study)* and NAEP *(National Assessment of Educational Progress (NAEP)* since 1995 (Kerachsky, 2008).

The interview excerpt, at the beginning of this article, may serve as an evidence for one explanation for this undesired trend. Elementary teachers may avoid teaching science, in particular, reform-based science instruction, as a result of their negative attitudes toward science, low levels of confidence in science and their ability to teach it, as well as their beliefs about science and science teaching that are often not aligned with reform philosophy (King et al., 2001). Teacher education reform initiatives have focused on improving pre-service teacher (PST) education in an effort to instigate changes in elementary teachers' cognitive and affective domains and consequently their instructional practices (NRC, 1996; NSF, 1993). Research examining elementary PSTs' beliefs, attitude, and self-efficacy with respect to science and science teaching, and influential factors that may shape these features, is deemed necessary in enhancing PSTs' experiences during teacher education programs.

A review of prior research indicates that teacher education programs, mainly the science methods courses, have the potential to lead to appropriate beliefs, increased confidence levels, and positive attitude with regard to science and science teaching, which in turn, have been shown to lead to more effective and reform-based instructional practices (Morrell & Carroll, 2003; Tosun, 2000). However, a number of gaps exist in our understanding of PSTs' affective and cognitive features. Studies on teacher belief have focused predominantly on beginning and veteran teachers (e.g. Beck, Czerniak, & Lumpe, 2000; King et al., 2001) and teachers at the secondary level (e.g. Hashweh, 1996; Luft, 2001; Simmons et al., 1999). The studies on elementary PSTs are far fewer and tend to be descriptive accounts of the current nature of their beliefs rather than changes they may experience. The studies dealing with PSTs' attitude and self-efficacy share similar limitations. A majority of these studies utilize quantitative methods and instruments to measure current trends or pre-post changes within entire groups of students, without focusing on individuals, especially those with initial low self-efficacy and negative attitudes. Finally, prior studies do not focus concurrently on all three domains nor explore possible interrelationships between them.

There is a need for qualitative approach that will allow for rich description of changes in PSTs' beliefs, attitude, and self-efficacy and possible instigating factors (e.g. instructional methods and strategies). It is especially necessary to identify PSTs with negative attitudes and low self-efficacy early in the program and focus on them to ascertain whether a reform-based methods course leads to any changes in these domains and explore possible factors that may have influenced such changes or the lack thereof. Possible interrelationship between these three variables should also be explored.

The current case study is part of a larger multiple cross case analysis (focus of a separate manuscript under review), which aimed to address some of the aforementioned gaps in the literature by focusing on PSTs with various initial confidence and attitudes toward science and science teaching. In this paper, the focus will specifically be on one elementary PST who began the course with negative attitude and low self-efficacy. I will provide an in-depth description of her cognitive and affective features, before and after the course, the impact of her prior K-12 science education and the science methods course on shaping these domains, and the possible interrelationship between the three variables.

Theoretical Framework

The NSTA's position statement on elementary school science (2002) identifies the following as key components of effective science instruction: developing inquiry/process skills through first-hand exploration and investigation, building instruction around students' conceptual framework, organizing content around broad conceptual themes, and integrating math and communication skills into science instruction. Teachers should also use various modes of presentation to accommodate different learning styles, allow students to work in groups and share ideas, and model inquiry skills and positive attitudes in an effort to aid students in developing positive attitudes towards science. Elementary teachers play an instrumental role in nurturing young students' knowledge and attitude toward science (Rennie, Goodrum, & Hacking, 2001) and, for that reason, teachers, who possess strong pedagogical content knowledge (PCK), positive attitude and high self-efficacy with regard to science and teaching science, have been identified as the key to the success of science education reforms (Shulman, 1986; Supovitz & Turner, 2000). In order to instigate changes in elementary teacher's instructional practices requires a major shift in their attitudes, beliefs, and confidence levels. Creating opportunities for the shift to occur has been identified as one of the core goals of teacher education programs. The following sections summarize our current understanding of these three domains, in particular, with regard to elementary PSTs.

PSTs' Epistemological Beliefs

Teacher beliefs include their understanding of the nature of knowledge as well as a field of study, such as science (Pajares, 1992). Nespor (1987) suggested that these beliefs are episodic, affective, and built on existential presumptions. Numerous studies have described how teachers' epistemological beliefs about science, students, teaching and learning, and, more specifically, the teaching and learning of science, which have been shaped by their own prior experiences, influence their teaching practices and may impede the implementation of reform based curricula (Bryan, 2003; Eick & Reed, 2002; Kelly, 2000).

It has been argued that, since PSTs' pre-existing beliefs substantially influence what and how they learn, these beliefs and the process of aligning and adapting their beliefs must be a focus for instruction during teacher preparation programs (Moore, 2008). It is imperative for teacher educators to consider PSTs' prior educational beliefs and experiences and adapt their teaching to facilitate prospective teachers' pedagogical knowledge. Similarly, research focusing on identifying and understanding the initial and evolving beliefs of PSTs, in particular, those with low affinity for and confidence toward science, will play a key role in assisting teacher educators in mapping out "how beliefs about teaching and learning can be explored and what experiences within a teacher education program will best facilitate prospective teachers' development of professional knowledge." (Bryan, 2003).

PSTs' Attitude Toward Science and Science Teaching

Fishbein & Ajzen (1975) described attitude as a person's favorable or unfavorable evaluation of the object. The literature suggests that attitudes influence actions (Alport, 1967), are relatively durable (Petty & Cacioppo, 1981), but can also be learned and modified (Koballa, 1988). In addition to teachers' instructional practices, their attitudes toward science and science teaching have been identified as factors that greatly impact students' science achievement, attitude, inclination to further pursue science education, and their overall scientific literacy (Bittner & Pajares, 2006; Pasley, Weiss, Shimkus, & Smith, 2004; Turkmen, 2008). Elementary teachers' performance and success in facilitating science instruction is affected not only by their "knowledge in science, but also by their feelings or attitudes toward those cognitions." (Watter, Ginns, Neumann, & Schweitzer, 1994) Prior studies have suggested that, elementary teachers' negative attitudes toward science and science teaching, which have been attributed to their negative K-12 science experiences (Appleton, 2006; Kelly, 2000), may be major obstacle in their teaching of science or doing so effectively. Therefore, in order to prevent the further perpetuation of the cycle of a student population that fears and dislikes science, in part, due to their teachers' negative attitudes and teaching practices (Siegel & Ranney, 2003), considerable effort must be invested in preparing a teaching workforce that possesses positive attitudes toward science that will be reflected in their teaching. Although there are studies that show a positive change in prospective teachers' attitudes (e.g. Wagler & Wagler, 2011), factors leading to the development of positive attitudes are not entirely clear (Koballa, 1988). Furthermore, the predominantly quantitative studies on PST's attitude, report whole group changes rather than focusing on changes experienced by individual PSTs, especially those who begin with negative attitudes toward science and science teaching.

PST's Self-Efficacy

Science teaching self-efficacy refers to (Ramey-Gassert, Shroyer, & Staver, 1996) the belief that one has the ability to teach science effectively (personal science teaching efficacy) and the belief that one's students can learn science (science teaching outcome expectancy). Teachers with low perceived science teaching self-efficacy doubt their ability to teach science and have a poor attitude toward science. Therefore, they avoid difficult tasks or science instruction altogether, whereas those with strong science teaching self-efficacy see difficult tasks as challenges to overcome instead of avoiding them. Several studies (e.g. Enochs & Riggs, 1990; Henson, 2001) have found that teachers tend to spend less instructional time on science and other subject areas in which they perceive their self-efficacy to be low. Students learn more from teachers with high self-efficacy than those whose self-efficacy is low. When it comes to teaching science, elementary PSTs report inadequate preparation to teach science as a result of their poor and negative K-12 science experiences (Avery & Meyer, 2012; Hechter, 2011; Tosun, 2000).

A number of studies (e.g. Avery & Meyer, 2012; Bleicher & Lindgren, 2005; Moseley & Utley, 2006; Palmer, 2006) have indicated that a purposeful selection of science experiences during teacher education programs, potentially result in lower levels of science anxiety, improved attitude toward science, and a greater willingness to teach science. A few studies (e.g. Wagler, 2011) have suggested no change in self-efficacy as a result of field-based science education experiences. As with teachers' science attitudes, PSTs' self-efficacy, in particular, the impact of science methods courses and other teacher education program components, deserve further attention. It is especially necessary to focus research on exploring self-efficacy changes and experiences of elementary PSTs who enter the program with low self-efficacy.

Methodology

This study employed a case study approach to explore the impact of prior K-12 science education, as well as recent science methods course experiences, on the beliefs, attitudes, and self-efficacy of an elementary PST who began the course with negative attitude and low self-efficacy, as well as the interconnections among the three domains. The participant was purposefully selected from the pool of students in the science methods course I was teaching at the time. I chose to select the case from my own course because, as the course instructor, I was able to develop and execute the course and conduct course assignments aligned with reform-based initiatives and had access to the participants. The selection of the case was based on the scores on two quantitative instruments, the Science Teaching Efficacy Beliefs Instrument for PSTs (STEBI-B) developed by Riggs and Enoch (1990) and the Revised Science Attitude Scale for PSTs (Bittner, 1994; Thompson & Shrigley, 1986), which were administered during the first week of class. Qualitative data were also checked to corroborate the quantitative findings. In an effort to enable participant anonymity and prevent instructor bias, a colleague administered the instruments and the data were analyzed after the completion of the course.

A case study approach was deemed most appropriate, because it allowed for rich, in-depth analysis of participant's experiences, changes in her affective and cognitive domains, and factors or key experiences that may be responsible for such changes, mainly through an exploration of her own personal words and artifacts. A case study involves identifying emerging patterns through triangulation of various data sources and is unique as a qualitative approach that lends itself to developing theories (Creswell, 2002; Denzin & Lincoln, 2000; Merriam, 1998).

Course Context

The science methods course from which the case was selected was part of the first cluster of professional education courses for elementary education majors at a large Midwestern university. Student clusters were simultaneously enrolled in this course, the mathematics methods course, and the joint field observation component. PSTs enrolled in the course were overwhelmingly female and typically consisted of sophomores and juniors. Pre-requisites for this course included a science content course designed to introduce elementary PSTs to scientific inquiry within the context of simple chemical concepts. To complete the program, students were expected to take three additional introductory science courses customized for elementary PSTs. The methods course was designed to help students develop the necessary knowledge, skills, and dispositions so that they may implement developmentally appropriate, inquiry-based science lessons in their future classrooms. It was based on the constructivist perspective (Yager, 1991) in which students learned science content and pedagogical strategies in an active, inquiry-based approach that allowed them to construct new knowledge based on their own prior experiences and in a social setting. Students were concurrently enrolled in a social studies and a math methods course as well as an accompanying field experience which required them to be in an assigned elementary classroom on a weekly basis. They had varying levels of interaction with students in their field experience, but all got to co-teach several science lessons in their field classroom as part of a course assignment. Students did a micro-teaching of the lessons in the methods course and received feedback from the instructor and their peers before teaching their lessons. During the course, they were involved in a number of collaborative hands-on, minds-on activities to simulate and experience science concepts, as students would be in an elementary classroom. Most of these in-class activities followed the 5E learning cycle (Bybee, et al., 2006).

Data Collection

The case study design calls for collection of data from multiple sources in order to develop an in-depth understanding of the case(s) and seek patterns and themes within the data. The two quantitative instruments were utilized to identify the case as well as gauge changes in this individual's attitude and self-efficacy. The qualitative data included student artifacts, pre and post semi-structured interviews, and videotaped course observations and daily logs. Artifacts included initial course information sheet filled out on the first day, bi-weekly reflections on her learning and growth in the course, the pre/post science autobiography/philosophy papers, and pre/post drawings and descriptions of scientists and science classrooms. The participant was interviewed in order to further probe her initial and post science and science teaching beliefs, attitudes, and self-efficacy as well as the impact of her previous science experiences and the science methods experiences in shaping these three domains. The interviews were audiotaped and transcribed.

Data Analysis

The multiple sources of qualitative data were analyzed to identify recurrent patterns and emergent themes (Bogden & Biklen, 1992), which resulted in a rich description of the case that chronicled her previous science experiences, pre and post beliefs, attitudes, and self-efficacy as well as possible changes in these domains. Interview data and artifacts were simultaneously analyzed using the constant comparative model (Glaser & Strauss, 1967; Denzin & Lincoln, 2000). The participant reviewed the in-depth case analysis to allow for member checking and ensure accurate portrayal of her experiences and changes within her affective and cognitive domains. An outside reviewer analyzed portions of the data and verified the emergent themes.

Findings and Discussions

Lisa (pseudonym) was a third year white female student in the elementary education program, with history as her declared area of concentration. Prior to the science methods course, she had completed the prerequisite science content course and the physics course. Lisa described her life-long desire to be an elementary teacher, especially at the K-3 grade levels and noted her excitement in working with young children and helping them succeed.

> I decided to become an elementary teacher because I genuinely enjoy children. Teaching will allow me to be a creative, fun, energetic, insightful role model. I find great pleasure in knowing I can help students succeed. I think that being a teacher is a wonderful way to be a part of a child's life. The thought of being allowed to decorate my own classroom, meet lots of new students, and teach everyday, excites me.

Her initial philosophy of teaching statement, self-rating of attitudes, and interview responses further clarified Lisa's lack of interest and aversion toward science as well as her lack of confidence in both learning and teaching the subject. Lisa rated her interest in science learning and teaching a 2 on a scale of 1-10 (10=highest), which was also the lowest rating in the class. She rated her confidence level in science learning a 1 on a scale of 1-10 (10=highest). While she expressed a high interest and comfort level in learning and teaching English, art, and social studies, Lisa identified science and math as the subjects she felt least comfortable with. She felt equally nervous and uncomfortable with life, earth, and physical science. She discussed experiencing fear of not being able to teach science "correctly" and "messing up the lesson". Lisa expressed a need to "be *given* a lesson to teach science which I can memorize and carry out in the class" and was even afraid and extremely nervous about her execution of the pre-planned lessons.

Lisa's Initial Science and Science Teaching Attitude and Self-Efficacy

Lisa's initial attitude and self-efficacy scores, as measured by the two instruments, were the lowest in the class (Table 1). Her major trepidations in teaching science were being unable to answer students' questions posed by students, in particular, "those curious students who want to know whys and hows behind the material presented", as well as not being able to deal with "experiments that could go wrong" and "lessons that do not go as planned."

The analysis of the various data sources revealed that Lisa's lack of interest and confidence with regard to both learning and teaching science was evidently rooted in her K-12 science experiences. She explained how her experiences with science throughout her education had left her feeling unsuccessful and uninterested in science.

> I was never really strong at it (science), so if I wasn't good at it I don't think I liked it as much. In English, you know, I could do a book report and make a poster board and make it look really pretty and in science, it was pretty much you do this and this and I just wasn't, (pause) it wasn't one of my strong subjects. I struggled.

Table 1.Lisa's Pre and Post Attitude and Self-Efficacy Instruments Scores

	Before the Course		After the Course	
	Lisa's Scores	Class Average	Lisa's Scores	Class Average
Revised Attitude Mean Score	2.9	3.7	3.95	4.1
STEBI-B Total Score	57	79	86	87.5
STEBI-B Mean Score	2.48	3.4	3.74	3.81
STOE (sub-category) Mean Score	2.9	3.4	3.9	3.5
PSTE (sub-category) Mean Score	2.15	3.6	3.62	4.1

Lisa associated science with reading textbooks and memorizing information and terminology, which she struggled tremendously with; hence she consequently began to loath science.

> I hated science. I never felt as though I could grasp the concepts my teacher was explaining. I would understand bits and pieces of certain lessons, but could not put all of the pieces together. Also, science was a subject in which I had to memorize many definitions.I would struggle to learn all of the definitions before a major test, and then soon forget them thereafter.

Lisa had a difficult time recalling her elementary science experience. She noted there was little emphasis on science in the small rural school she attended. Science only occurred once or twice a week and was taught by one science teacher who rotated "science time" between various grade levels. Even the brief amount of time they spent on science, she explained, was mostly devoted to lectures, note taking, and completing worksheets.

Lisa was only able to recall a few elementary science experiences that were either "hands-on" or in some way different from the typical routine of lectures and worksheets. One such experience was her third grade solar system research and presentation for which she decided to focus on the planet Neptune because of her interest in this planet's "pretty shade of blue." She enjoyed doing the independent research and constructing the model and felt "very knowledgeable and was excited to share with my classmates what I had found out about Neptune". She noted having more interest in the subject of science if it involved any "hands-on" experience or "experiments which were always so much fun to do and easier for me to learn;" therefore, her

Neptune project was the only experience that had remained in her memory till this day. Her elementary school science experiences, which she described as intermittent, teacher-directed, monotonous, and dearth of hands-on experiences, left her confused and struggling with the concepts and gradually resulted in Lisa developing an indifferent and negative attitude toward science.

Lisa's middle school science experiences continued to be dominated by lectures and worksheets with some labs and experiments dispersed throughout the year. The only thing she was able to recall from this period was the science fair project, which she actually found quite frustrating and did not enjoy. Because she was not used to doing experiments, especially extended ones that centered on student-generated questions, she had difficulty initiating and doing the project and understanding how to make sense of her data.

> One year I decided to research bean plants and found my experiment to go very differently from my hypothesis. I couldn't scientifically explain how I came to my results. My science fair frustrated me entirely and I could not wait until I started high school and no longer had to deal with science fairs.

Lisa had eagerly anticipated going to high school where she believed science learning would involve more hands-on experiments and fun labs, but she soon found out otherwise. Even that "inkling of curiosity and interest in science throughout elementary grades" diminished during her high school life science, biology, and chemistry courses. She noted that although these courses involved relatively more hands-on experiments as compared to her elementary science experience, they continued to be teacher-centered and focused solely on the memorization of concepts and formulas: "My teachers would lecture or have us read a chapter from our science textbook and then conducted a demonstration that coincided with the reading or we did an experiment after watching the demo or listening to the lecture."

This was something Lisa struggled with throughout her high school experience. She soon began associating success in science with the ability to memorize content in order to earn a passing grade in these courses. In describing one example of her struggles, Lisa explained:

> I remember trying to memorize the periodic table and it was *so* hard. There wasn't any real rhyme or reason how to memorize it. You just had to know it and I was UGH, this is so hard and gave up on it.

Lisa's extremely negative attitude and low confidence level with regard to science, which was generated as a result of constant challenges, difficulties, and frustrations she experienced in her K-12 science courses carried over into her college science experience. She perceived her two college science courses to be challenging and uninteresting and found herself constantly struggling "to make it through these science courses in order to be able to be admitted into and remain in the program." She described a tremendous sense of "unpreparedness, fear, and panic" that even brought her to tears on a number of occasions. It was evident that her fears about and lack of comfort with science had intensified over the years culminating in a sense of sheer intimidation and trepidation toward learning and teaching science. She expressed grave concerns and dreaded taking the subsequent biology course, which she had learned from her peers, involved extensive memorization. She mentioned, "I'm hoping you know I'm smart enough to do okay in that course. Like I'm not stupid. But [*nervous laugh*] at the same time it's just that the word *science* is intimidating to me."

Initial Epistemological Beliefs

Beliefs about science. Lisa's initial drawing of a scientist was a male figure with stereotypical features including spiky hair, a lab coat, and glasses. She explained that science is about "doing experiments" and "searching for truth" or "proving ideas" using "the scientific method." Lisa added that science is a process of "trial and error". She viewed school science as a "more basic and cut and dry form" of real life science and explained that the purpose of science in schools is "to confirm real science experiments and findings."

Beliefs about Teaching and Learning. In describing her beliefs about teaching and learning, Lisa outlined several student learning goals that she envisioned to be central to her future teaching. The first goal was for her students to develop general characteristics and virtues, such as learning "respect, acceptance, and responsibility," which she described would be important in their future learning and the world beyond the classroom. Lisa emphasized developing students' sense of self-esteem, allowing them the opportunity to learn the importance of putting forth effort and hard work regardless of the consequences, and helping them realize that it is "okay to be wrong as long as you have done your best." Finally, concerning class content, Lisa felt it was necessary to teach students in a manner that would ensure their "knowledge base is in line with state standards and other classes of the same grade level." Lisa believed she possessed several key features that would allow her to be an effective teacher and help her students attain these learning goals. She felt she had a passion to teach that would enable her to reach all students, encourage her to continuously challenge herself and her students, and urge her to "seek support and collaborate with other teachers and the community" in order to augment student learning.

In her comments about teaching and learning, Lisa advocated making "the classroom environment fun and enjoyable" by taking a "fun and hands-on approach to learning" so that "children can have great memories of being in school." She reflected on her own experiences and wanted to offer her students pleasant memories of learning. However, when she was asked to reflect specifically on her ideas about teaching and learning science, she had no immediate response. She giggled as she explained: "I am honestly not sure how they (students) learn science. I am hoping this class is going to tell me how." Further probed to describe how she would teach science if she were to walk into the classroom the next day she paused momentarily and then responded: "it seems like now once we'll be getting to be teachers everything is pretty much laid out for us, a curriculum and what's expected, so I guess I would just follow what was already there for me." She explained how her own elementary teachers seemed to have pre-planned lectures and worksheets which led her to assume that all science lessons and curriculum material would be laid out for her to pick up and teach if necessary. She indicated that she would do more group work and make science more hands-on than her own experiences, but she did not seem to have a clear idea as to what that would entail.

The idea of having students working collaboratively was projected in her initial drawing of a science classroom where she had students in four teams of four students and explained that students would "work in teams so that they can learn from one another and use each other's opinions/ideas." Her drawing and its description included the teacher as the "big person" walking around to "help students with questions and to check on how they are coming along." She explained that the role of the teacher in a science classroom is to be the person directing the learning and guiding the students by "giving directions, answering questions, or offering help." The students would, individually or collaboratively, "follow directions and perform the given tasks." Lisa stated that, although she had a negative attitude toward science, she thought science was "equally valuable as a school subject as English and mathematics and should be devoted the same amount of instructional time". Reflecting again on her own prior experiences with school science, she explained that she wanted students to leave school and her classroom "thinking positively about science" and was conscientious about the importance of not projecting her negative attitude in the classroom.

The findings in this study revealed the impact of Lisa’s prior science experiences on all three domains and also shed light on the interrelationship between her beliefs, attitude, and self-efficacy (Figure 1).

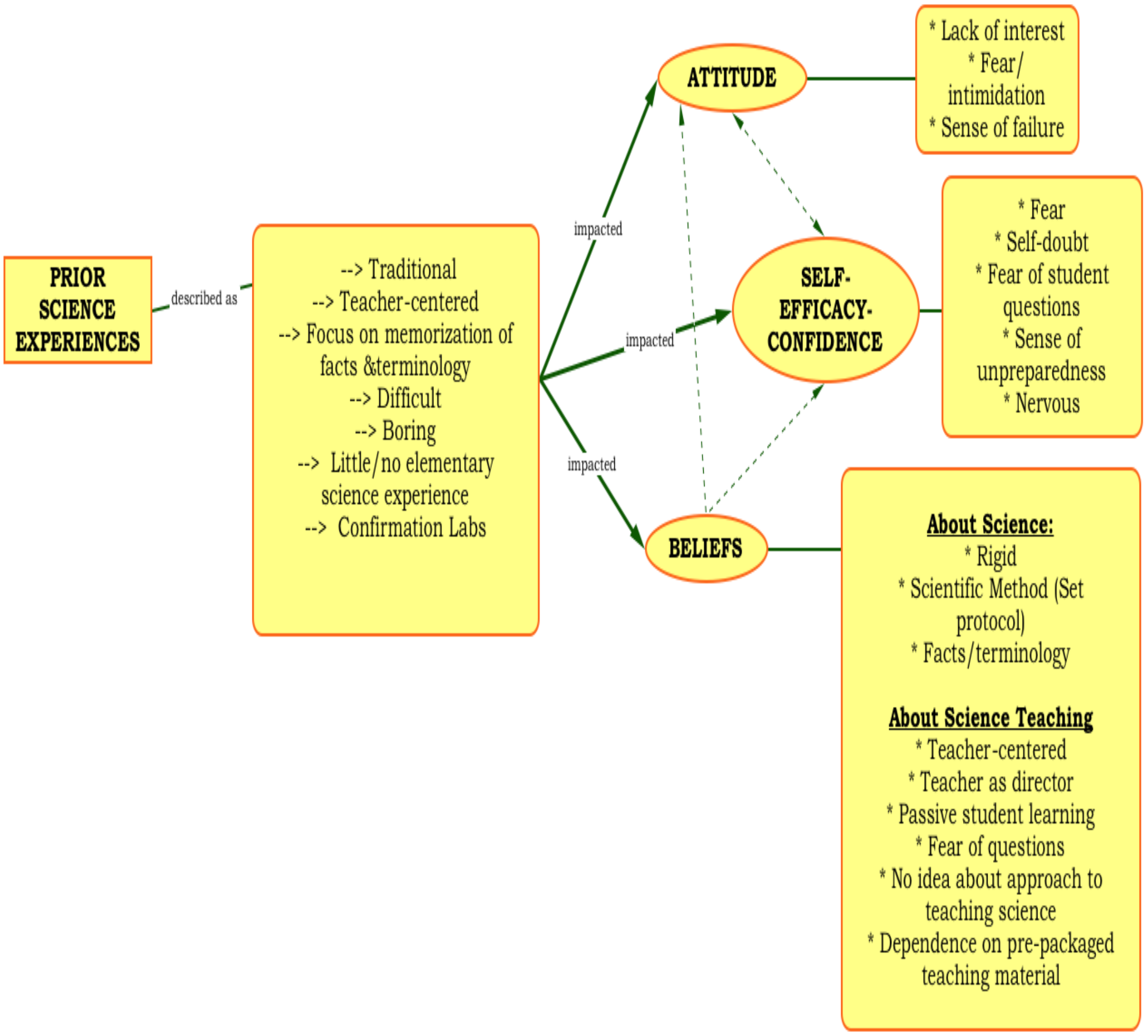

Figure 1. The impact of Lisa’s prior science experiences on her beliefs, attitude, and self-efficacy.

Lisa’s prior science experiences had been mainly traditional, teacher-centered, and focused on memorizing and regurgitating facts and terminology and performing sporadic confirmation type laboratory activities. This type of experience had left Lisa (a) struggling to learn science concepts, (b) perceiving science as boring, irrelevant, difficult, and uninteresting, (c) viewing the scientific process as rigid, linear, and fact-driven, (d) believing that science teaching should be teacher-directed, and (e) developing a lack of confidence and a sense of fear, intimidation, anxiety, and unpreparedness about doing and teaching science. There were clear interactions between her beliefs, attitude, and sense of confidence. Her beliefs about science and science teaching, which were influenced by her prior experiences, had shaped her beliefs about science and science teaching, and consequently influenced her science and science teaching attitude and self-efficacy. Her attitude and sense of confidence had reciprocally influenced one another. Not feeling confident and comfortable with science and teaching the subject, Lisa also lacked any interest in doing so and vice versa. Finally, her attitude and self-efficacy with regard to science had impacted her science teaching attitude and sense of confidence. Because she had struggled with learning science and viewed herself as an unsuccessful science learner, Lisa also lacked the necessary interest and confidence in teaching science in the classroom.

Post Epistemological Beliefs

Beliefs about science. By the end of the semester, Lisa began to realize that science is a process of inquiry and discovery that is not confined to one specific group of people and does not require a lab or set protocol (as she had previously suggested). She described it as applicable to every dimension of our daily lives. Explaining her post drawing, which depicted a female scientist with long ponytail and wearing a lab coat, she remarked: "When I envision a scientist now, I do not imagine an Albert Einstein look-alike, but just a person, even me!" She acknowledged that the traditional approach of teaching science through lecture, worksheets, and simple experiments, significantly deviates from the way real and authentic science is conducted. She felt that the basic processes carried out by scientists and students involved in inquiry-based learning are identical.

> It is obvious that scientists do much more than students in a classroom. Scientists have many resources that students do not and they have the many years of education, training and experience that students lack. However, the processes involved such as making observations, estimations, predictions, calculations, and analysis are similar.

By the end of the course, Lisa began to discern commonalities and differences between science and other subject areas. She viewed science learning as an opportunity for students to inquire about their questions, a process which could proceed in various directions and deviate from original plans, whereas other content areas are more rigid and less exploratory.

Beliefs about teaching and learning (general). Lisa continued to view cultivating good student characteristics and behaviors as an important component of teaching and learning. At the end of the semester, she mentioned several new components that are essential in classroom teaching and learning and would be part of her own teaching in the future. The first was the establishment of good rapport with the students and "getting to know them on an individual basis" for more effective teaching at the individual level. Secondly, she emphasized preparing students to "learn how to be responsible and love learning" and "develop confidence and sense of preparation and achievement that will allow them to advance to the next grade level" and transition into the real world. Finally, Lisa stressed the value of creating a "free and open environment" in which "students feel comfortable enough to approach the teacher and continue to come back to in the future with anything on their minds."

Lisa's personification of an effective teacher remained similar to her beliefs at the beginning of the semester, but she identified additional features and provided a more in-depth discussion of each. She continued to emphasize the importance of possessing a passion for teaching and a positive attitude about the subject matter. She expressed how the attitudes of her previous teachers during K-12 were apparent to the students and influenced their learning in either a positive or a negative manner. Hence, she planned on displaying her interest in teaching and various subject matters such as science through engaging lessons and reaching out to all students. Lisa noted that she had gained useful skills that would be essential in effective teaching. The focus of her teaching had shifted from "making learning fun" to "making it worthwhile and productive using effective teaching methods such as inquiry." From the course she had also gained the idea that in a classroom, students and the teacher make up a community of learners, with everyone contributing to the understanding and growth of one another. In such a collaborative environment, student success and genuine learning are further guaranteed.

Beliefs about teaching and learning science. As evident from the multiple sources of data, Lisa had gained numerous ideas from the course that shaped her beliefs about science teaching and learning. Her new understanding of science as a field that is constantly evolving and based on observations and empirical evidence had convinced her that the process of learning science should mimic that as well.

> Students can come up with their own discoveries instead of me (their teacher) just telling them my discovery or what's in the books. Science is all about inquiry and exploring and drawing conclusions based on experiences which students need to be part of in order to understand the process of science and the content they are learning.

She continued that science teaching "should not be telling students the result of an experiment but rather facilitating them in the process of learning and inquiring." She supported the idea of teaching science in an inquiry-based fashion whereby students, rather than being passive learners, pose questions, actively explore those questions, critically think through and evaluate the process, and form conclusions based on evidence and communication of findings with their peers. She reflected on her own active learning in the science methods course.

> Our methods instructor would engage us in the learning and then we were allowed to try things out on our own. When doing the light bulb activity, she did not lead any of us towards the correct way to light the bulb, but she listened to us, asked questions, and allowed us enough time to think through the problem. This was a fun activity, and we explored the ideas before the concepts were introduced. By doing it this way, we got more out of the activity and will never forget it.

Lisa had become interested in the learning cycle model of inquiry. She discussed the value of engaging students, allowing them time and resources to explore ideas, having team and class discussions, allowing opportunities for students to apply the new learning to other situations, and assessing their learning on a constant basis. By learning about and implementing inquiry-based teaching, she realized that teachers are the facilitators and not the directors in the process of learning. This would mean that the "teacher needs to engage the students in independent and team-based explorations and discussions and prompt them to think critically and reflect on their learning rather than giving them all the information or tell them exactly what to do." Lisa reflected on how she utilized the learning cycle approach in her own teaching during the field experience and how such experiences confirmed her newly formed beliefs about inquiry-based science teaching.

> Not only did students learn, they had fun and felt as though they were in control. The students were engaged throughout the entire lesson. I gave them the tools and facilitated their learning when necessary, but they explored and came up with solutions and conclusions all on their own. I did not give them any answers. I saw how they learned more from this active inquiry learning process than they would have had I just told them what would happen. Teaching science to elementary students is a very tough task, but now I feel very prepared to take on this challenge.

She discussed the role assessment plays "in teaching for understanding, because it is the one tool that we have to know whether the concepts and ideas are being understood by the students." She planned to incorporate various forms of assessment in her teaching but asserted that she would incorporate more formative assessments. In particular, she recognized the critical role of questioning in an inquiry-based learning environment and the significance of teacher's ability to be able to ask effective questions in order to facilitate student learning.

In the beginning of the semester, Lisa stated that her goal was for her students to leave her class with a positive attitude toward science. Upon completing the course, she also stressed the importance of allowing students to develop critical thinking and independent learning skills. By allowing students the opportunity to be involved in inquiry learning, she argued, they would be able to develop scientific process skills such as questioning, observing, and communicating data and learn to be lifelong learners and inquirers. She wanted to provide her students with opportunities she never had herself so that they could "leave my classroom confident that they are remarkable scientists who love the subject of science, are good at it, and will be able to carry their positive attitude and their newly gained skills into the real world."

Post Science and Science Teaching Attitude and Self-Efficacy

Lisa's attitude toward science and science teaching underwent major change by the end of the semester. Her post-Revised Science Attitude Scale scores approximated class average (Table 1). Lisa, who had grown to view science as boring and uninteresting, now viewed it as an interesting subject and one she could actually enjoy. On the final teaching portfolio she rated her interest in science as a 6-7, which was a considerable change from her original rating. Similarly, she experienced substantial improvements in her attitude toward teaching science. She rated her interest in teaching science an 8 and attributed this increase mainly to her learning experiences in the course and the development and teaching of inquiry-based science lessons in the field.

By the end of the course, Lisa's confidence in *learning* science had also improved as she developed a more positive attitude toward science. She did not fear science as much as she did in the beginning of the semester. She rated her confidence in science learning a 6-7 out of 10 and explained that she feels comfortable with learning science that is more inquiry-based and hands-on: "It is very different now. I feel very confident that I can learn science processes and concepts through inquiry." The boost in Lisa's level of confidence in learning science was accompanied by a great increase in her confidence in teaching science as evident in her STEBI-B scores and comments on the final portfolio and the post interview. Her rating of her confidence in teaching science rose to 6-7 and her STEBI-B scores improved substantially from earlier in the year and approximated class averages or exceeded them with respect to some subcategories (e.g. STOE total and mean scores)

Her explanations alluded in some way to the immersive, experiential nature of the course which had influenced her beliefs about science and science teaching. Due to her limited or negative science experiences during her formal education, she had been unable to experience inquiry-based science learning or witness effective inquiry-based science pedagogical approaches. She explained that the course had enabled her to realize the true nature of science as a field that is based on inquiry and investigation rather than on the memorization of facts and formulas.

> In the course of this class, I have not had to "memorize" one definition, yet I have completed a variety of science activities and experiments. This class has shown me science is far from definitions. Science is inquiry and exploration. Science is testing your ideas and challenging your views. My interest in science has changed dramatically.

As her beliefs about and attitude toward science learning changed, so did her confidence level in learning science, which subsequently led to a greater confidence level and positive attitude toward teaching science. Her experiences in the course had removed some of her "fears about science and teaching it" and allowed her to recognize that a student-centered inquiry approach to teaching science could be quite an enjoyable and genuine experience. Consequently, she felt more confident in teaching science. She was excited to allow her students the opportunity to ask questions, explore ideas, and learn science through doing science in a collaborative learning environment that emphasizes scientific practices, critical thinking, and problem solving.

Furthermore, she found it appealing and reassuring that teaching in such a fashion would not require her as the teacher to possess all the answers and be knowledgeable about and able to dispense all information to students as she had initially assumed and feared. She originally feared lessons or labs going "wrong," because she had come to believe that science was all about "facts and confirmation labs with pre-determined results." As she gained a better understanding of science and effective science teaching approaches, she felt a greater level of comfort teaching it, having "observed and realized that meaningful learning can take place with every science encounter." She now viewed herself as one of the learners in the classroom who was facilitating and guiding students' learning while simultaneously exploring ideas.

> I have realized that you do not have to be 100% knowledgeable in science to be able to teach it. It is okay and even great to be learning right alongside of your students. Not knowing everything about science should make creating science lesson plans exciting.

Lisa especially appreciated how, as a learner, she was immersed in the learning process and how effective science teaching methods were modeled in the course. She enjoyed and learned from exploring the concepts through activities and discussions and *then* being formally introduced to the concepts through teacher-facilitated discussions, readings, and videos. The readings and video clips allowed her to obtain a deeper understanding of the concepts explored in class and witness some of the ideas implemented in the actual classrooms. These shaped her beliefs as well as her attitude and sense of confidence about science pedagogy. Working collaboratively with her peers during in-class science explorations, discussions, and lesson development and microteaching activities allowed Lisa to communicate ideas and collaborate with her peers in order to enhance her teaching.

She had gained experience in developing and teaching science lessons, which involved developing and modifying lessons as well as observing classroom students doing and enjoying science when taught in an inquiry-based fashion. Creation of the lesson plans involved several iterations of instructor feedback as well as microteaching and getting peer feedbacks, which proved to be extremely useful for Lisa.

> I feel prepared to teach science because I have! I loved learning and teaching science this semester. A lot of my confidence has come from being able to develop, revise, and actually teach four science lessons. I also think that my partner had a role in strengthening my teaching, because we were able to bounce off of one another's ideas, which was extremely helpful and helped boost my confidence. Observing the children as they were learning our lessons and participating in the activities also helped my confidence because I was able to see that they enjoyed it and that they were understanding or not. If you told me at the beginning of the semester that I would love teaching science I would not have believed you!

Being able to implement the concepts she had experienced and learned in the course during her field experience teaching allowed her to apply her newly gained knowledge and skills and more fully understand what is involved in the process of teaching. Furthermore, it allowed her to become acquainted with and reflect upon students' misconceptions or learning obstacles, effectives strategies for interacting with students, and areas which she may need further practice with. Reflecting on her field experience, Lisa noted that she felt she needed more time and practice to enhance her "questioning skills to strengthen students' experiences" and "develop more creative lessons."

Figure 2 summarizes the interaction between Lisa's science methods experiences and her science and science teaching beliefs, attitude, and self-efficacy. Lisa identified a number of course experiences and factors that she believed were influential in shaping her cognitive and affective features. These experiences were related to an improvement in her attitude and self-efficacy and the further alignment of her beliefs about science and science teaching with those promoted by reform initiatives and modern understanding of learning. These domains also influenced one another in ways that have not been suggested in prior studies. Changes in her beliefs about science positively impacted her attitude and self-efficacy toward science as well as science teaching. Alterations in her beliefs about teaching and learning subsequently influenced her science teaching attitude and self-efficacy. Because she had a more accurate idea of what science entails and what teaching science should be like, she felt more comfortable and interested in teaching science. There were also reciprocal interrelationships between (a) her attitude toward science and her sense of comfort with learning and performing science, and (b) her attitude toward teaching science and her sense of comfort and confidence in doing so.

The following excerpt highlights Lisa's overall reactions to the various components of the course and the changes she had sensed in herself.

> I went into this class scared to teach science, uninterested about science, and with a negative attitude. All of those have changed because I have seen, both in learning and teaching that understanding how kids learn and how to create the best learning environment possible is key. Learning these things are very interesting to me and once I put what I learned to use I saw that I could teach science and that my students did come out learning something which was a huge confidence booster and made my attitude more positive. I saw that science is a subject that can't be overlooked because it creates so much inquiry in a child's mind and they will carry that with them to the other subjects and outside of school. I would not be able to be a science teacher had I not taken this course.

Overall, her experiences in the course had allowed her to (a) view science and science teaching in a different light, (b) find science interesting and fun to learn and teach, and (3) gain confidence in her abilities to learn and teach science.

Implications

The findings of this study underscore the importance of focusing, as teacher educators, on individual PST's prior science learning experiences, the types of changes s/he may experience with respect to his/her affective and cognitive features, and the factors and experiences that may instigate such changes. This focus is necessary in order to effectively address PSTs' needs and prepare and equip them with the appropriate beliefs, attitude, and self-efficacy required to teach science effectively. For instance, understanding individual PST's prior negative science experiences and difficulties with science will better enable us to understand and address their initial low self-efficacy and negative attitude toward science and science teaching. Furthermore, such findings, in particular, the interrelationship between beliefs, self-efficacy, and attitude, (Figure 2) highlight the value of concomitantly focusing our attention on all three domains if we wish to produce enduring changes in science teaching practices. It is imperative to understand that these three domains are not isolated; rather, they influence one another and, consequently also impact PSTs' actions. As teacher educators, it is vital to be attentive to such interactions and not ignore or make assumptions about one or more of these domains by just focusing on individual domains. Finally, influential course experiences and factors (Figure 2) that were discussed in this study should be collectively incorporated in science methods courses in order to allow PSTs, in particular, those with initial negative attitudes and low self-efficacy, to develop reform-based beliefs, positive attitude, and high self-efficacy with regard to science and science teaching.

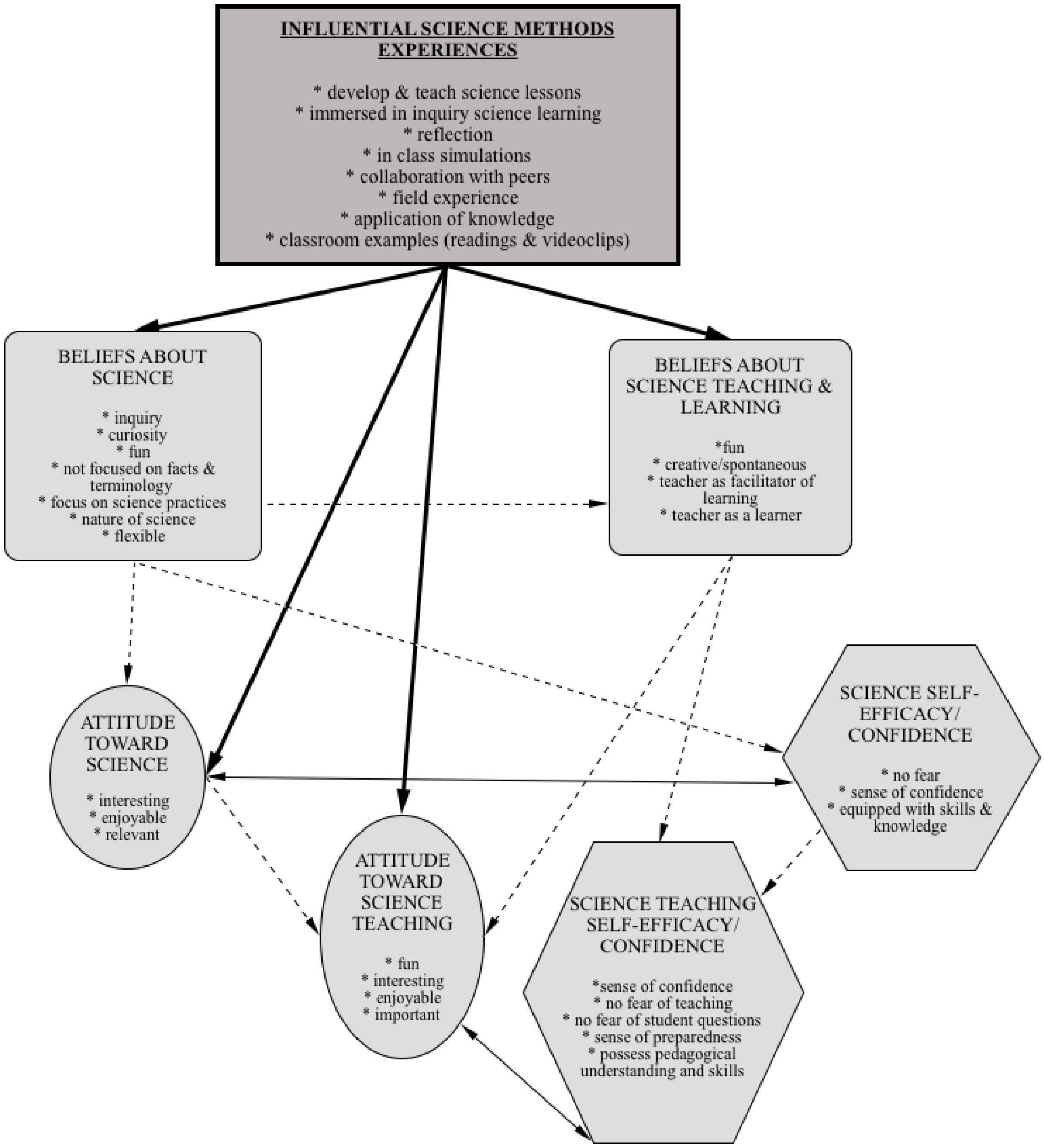

Figure 2. Interactions between Lisa's science methods experiences and her science and science teaching beliefs, attitudes, and self-efficacy. Wide, solid arrows indicate impact of course experiences on the domains. Dashed arrows indicate one-way interaction between the domains. Narrow, solid, double-sided arrows indicate two-way interactions between domains.

This study did not necessarily focus on the development of changes in the three domains as experienced by Lisa throughout the course, but it would be beneficial to explore how such changes unfold throughout the semester. The current study did not include observation and evaluation of Lisa's field experiences, but she had clearly indicated the importance of the field experience on shaping her beliefs and improving her interest and confidence in science. A closer examination of the PSTs' field teaching experiences and interactions with students in such settings would add to our understanding of the impact of such experiences on the three domains. Finally, further research is warranted to monitor and further probe into PSTs' initial beliefs, attitude, and self-efficacy, in order to examine the extent of the influence of the science methods course experiences and the changes in the three domains on their teaching practices and classroom interactions. It is also necessary to explore whether and to what extent such changes endure when they begin their teaching career and the factors that may impede or enhance their beliefs, attitudes, self-efficacy, and teaching practices.

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