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Developing preservice elementary teachers' self-efficacy toward teaching science

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ABSTRACT
Having a negative attitude toward science plays a major factor in elementary teachers avoiding teaching science in elementary school. This mixed methods study examined changes in pre-service elementary teachers' (PSETs) attitudes toward teaching science. PSETs (n=59) engaged in a semester-long university course in the Southeastern United States. The course focused on demonstrating and applying knowledge of scientific concepts and inquiry-based teaching. PSETs took a Dimension of Attitudes toward Science (DAS) questionnaire before and after the course. Six of the PSETs were interviewed in a focus group and asked how the course impacted their attitudes toward science. Data were analysed quantitatively through frequency of responses and mean values. Qualitative analysis was done through concurrent triangulation design analysis of focus group interviews and survey responses. Results show that PSETs had more positive attitudes toward science in feelings attached to teaching science and their confidence in teaching science. Follow-up focus group interviews indicated that some of the PSETs highlighted verbal persuasion, the Cognitive Pedagogical Mastery (CPM) experience of engaging in hands-on activities, and the Cognitive Content Mastery (CCM) experience of using learning technologies as factors in positive changes in self-efficacy and feelings toward teaching science. Implications for PSETs methods courses are discussed

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KEYWORDS
Attitudes towards teaching science; pre-service elementary teachers; self-efficacy in teaching science

Introduction

Pre-service elementary teachers (PSETs) report having challenging experiences with science (Carnes, 2003; Tosun, 2000), finding it more difficult when compared to other subjects such as reading and which may lead to them focusing less on teaching science once they are in their own classrooms (Brickhouse et al., 2000; Gagnier et al., 2022). Underlying these experiences is a reported lack of confidence – or self-efficacy – as it pertains to their ability to teach science, stemming from weak science content backgrounds and poor experiences when they were science students (Hulings, 2022; Knaggs & Sondergeld, 2015; Lee & Houseal, 2003). Research has also shown that

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teachers who have a low level of scientific literacy tend to generally have negative emotions (e.g. anxiety) and negative attitudes towards science and hence lower confidence and self-efficacy beliefs about teaching it (Bursal & Paznokas, 2006; Gagnier et al., 2022; Palmer, 2001; Tosun, 2000), which may lead them to feel uncomfortable and unprepared to teach the subject. This study addresses the need to examine PSETs' attitudes towards science and science teaching, as it may in turn influence their own students' achievement in science, attitudes towards science, interest in pursuing advanced science education and careers, and students' levels of scientific literacy (Hulings, 2022; Kazempour, 2014).

Literature review

Studies have shown that PSETs who have more positive experiences with science tend to have a higher level of science-teaching self-efficacy (Hulings, 2022; Yürük, 2011). For instance, Hulings (2022) examined past science learning experiences of PSETs and how they affected their attitudes towards science teaching. The study found that those with positive past experiences or who named positive influences (e.g. parents, teachers, or fictional people from science shows) had a higher self-efficacy towards teaching science and that a lack of positive personal experiences with science could explain the low science teaching self-efficacy found in prior studies.

Yet while teachers' low self-efficacy to teach science can have a negative impact on students' access to knowledge and skills (Bandura, 1997), the converse holds as well: studies have shown that increased self-efficacy towards teaching science can positively affect students' science achievement and motivation (Caprara et al., 2006; Kazempour & Sadler, 2015). Furthermore, teachers with high self-efficacy with regard to teaching science were found to be more effective and more likely to spend the time needed to develop science concepts and to devote more time to inquiry-based science (Cantrell et al., 2003; Marshall et al., 2009).

One potential means of fostering PSETs' positive attitudes and self-efficacy towards teaching science is to have them participate in an inquiry-based methods course, or a course that follows a constructivist approach to teaching and learning – one where they 'build conceptual understandings, investigation skills, and understandings of the nature of science through inquiry procedures that mirror methods used by scientists' (Contant et al., 2018, p. 85) as well as content-methods courses. Numerous studies have documented how experiences like engaging in inquiry-based investigations in teacher education courses and creating and implementing inquiry-based lessons in the field can have a positive impact on PSETs' science teaching self-efficacy (Gunning & Mensah, 2011; Menon & Sadler, 2016; Soprano & Yang, 2013; Velthuis et al., 2014). Other studies have found that PSETs' science content courses, with a focus on physical science (Bergman & Morphew, 2015), can improve their science teaching self-efficacy.

Elementary in-service and pre-service teachers often have negative emotions towards science and tend to avoid teaching science (Avery & Meyer, 2012; Kazempour & Sadler, 2015). Avery and Meyer (2012), for instance, examined the influence of an inquiry-based science course on self-efficacy for science and science teaching for PSETs. The findings of the study showed there were gains in PSETs' conceptual understanding of science content and improved confidence in their science teaching. However, when examining the participants in the study, there were two distinct groups – one that improved their outlook on science teaching and one that regressed. The group that improved their outlook towards teaching science was able to identify what they were learning early in the process and gained a deep conceptual understanding of science. The second group was not 'able to get beyond the discomfort with a new learning style, their expectations about a science course, or their years of "training" with the traditional methods of teaching science' (p. 405). The result of the study offered intriguing insights into how to optimally prepare PSETs for science teaching. Kazempour and Sadler (2015) found that the PSETs who self-reported using reform-based instructional strategies (e.g. inquiry and hands-on experiences) tended to have higher levels of self-efficacy and more confidence in teaching science.

Research efforts in teacher education emphasise the need to better prepare elementary teachers to teach science by providing opportunities to learn science content and to help them re-evaluate their own science learning experiences within the context of meaningful 'learning to teach' experiences that also help them feel less anxious about science teaching (Avraamidou, 2013; Bransford et al., 2000; Hulings, 2022; Novak et al., 2022). For this study, we designed a PSET education science content and methods course that teaches about the nature of science and scientific inquiry in the context of inquiry activities as well as engaging in technologically-enhanced online units centred on chemistry and physical science concepts. PSETs develop an understanding of the components, process and inquiry skills, and nature of science appropriate for the elementary classroom. They also take weekly quizzes around chemistry and physical science and engage in hands-on laboratory experiences and projects that align with 'big ideas' in physical science, chemistry, and the nature of science.

This study seeks to examine what aspects of a science content and methods course contribute to positive changes in PSETs' attitudes towards teaching science. The following research questions guided this study: (1) In what ways do PSETs' attitudes towards science change after engaging in an inquiry-based science content and methods course? (2) In what ways do PSETs' self-efficacy in teaching science change after engaging with an inquiry-based science content and methods course? The significance of this research is that it adds more insight into how an elementary science content and methods course can be developed to better prepare future elementary teachers to have more positive attitudes towards teaching science.

Theoretical frameworks

Self-efficacy and cognitive content and pedagogical mastery

Self-efficacy as a construct is defined as belief 'in one's capabilities to organise and execute the courses of action required to produce given attainments' (Bandura, 1997, p. 3) where individuals have confidence that they can perform an action successfully.

Bandura (1997) proposed four sources to promote self-efficacy beliefs in an individual. *Enactive mastery experiences* refer to a person's experiences of being successful in the past that add to his/her/their self-confidence to succeed in similar situations and increase coping efforts in challenging situations. *Vicarious learning experiences* allow individuals to observe, interact and compare themselves to a model of the action they want to be successful in performing. *Verbal persuasion* is based on the encouragement or discouragement an individual receives regarding an action they want to be successful in performing. *Physiological and emotional reactions* are responses to the sources of self-efficacy experiences, which can be either positive (e.g. joy) or negative (e.g. anxiety).

As noted above, within the context of science teacher education, some studies have examined how classroom teaching opportunities can positively influence science teaching self-efficacy (Avery & Meyer, 2012; Bautista, 2011; Knaggs & Sondergeld, 2015; Palmer, 2006), specifically focusing on how PSETs' science self-efficacy changes after participating in a science methods course. Palmer (2006) defined three sources of mastery experiences (Bandura, 1997) that significantly increased the science self-efficacy of PSETs after participating in a science methods course, including Cognitive Content Mastery (CCM) experiences, Cognitive Pedagogical Mastery (CPM) experiences, and simulated modelling experiences. CCM experiences are activities that provide a successful science content learning experience (e.g. engaging in technology-enhanced units or inquiry hands-on experiences) whereas CPM experiences are activities that enhance PSETs' knowledge of effective science teaching (e.g. planning a science lesson or watching videos of science teaching). Simulated modelling includes experiences in which teaching is role-played. Palmer noted that CPM experiences are one of the main sources of self-efficacy that PSETs named as influential (followed by simulated modelling).

Emotions and science teaching self-efficacy

Emotions play an important role in educational settings (e.g. Laine et al., 2020; Martínez-Sierra et al., 2019). Teaching is an emotional profession in which relationships are established between teachers and students. It involves an intense effort to regulate emotions (Frenzel et al., 2016) and teachers' emotions influence their teaching practices (Zembylas, 2002). In educational research, emotions are conceptualised as a dimension of *affect*, such as beliefs or attitudes (e.g. Hannula, 2019). Emotions are also seen as consisting of cognitive, physiological, and motivational components (Pekrun et al., 2011). In addition, emotions can be experienced as *pleasant or positive* (e.g. enjoyment) or as *unpleasant or negative* (e.g. anxiety) (Feldman Barrett & & Russell, 1998).

Anxiety has been found to affect confidence in teaching. Studies have found a relationship between self-efficacy and science-teaching anxiety and that negative emotions towards science lead to low science-teaching self-efficacy and high anxiety towards science and teaching science (Bursal & Paznokas, 2006; Gunning & Mensah, 2011; Senler, 2016; Yürük, 2011). For example, Bursal and Paznokas (2006) found that PSETs with low math teaching anxiety were more confident in teaching math and science than their more anxious peers. In science education, science teaching anxiety refers to anxiety that negatively affects a teacher's ability to begin or finish a science teaching task (Bursal & Paznokas, 2006). Similarly, Senler (2016) found a negative relationship between science-teaching self-efficacy and science anxiety in PSETs, while Yürük (2011) found that PSETs with higher science-teaching self-efficacy had lower science-teaching anxiety.

In contrast with science anxiety, science interest plays an important role in elementary science teaching as teacher motivation to do science with their students is positively correlated with their interest in science and general attitudes towards science (Senler, 2016). For example, Novak et al. (2022) found that the science teaching anxiety of PSETs was significantly and negatively related to science teaching self-efficacy and science interest. In other words, teachers with high self-efficacy in teaching science and high interest in science had low science-teaching anxiety. Therefore, science interest can be seen as a variable that motivates teachers to spend more time doing science with their students (Novak et al., 2022).

Studies have shown how PSETs' emotions towards science play a role in how they may teach their own elementary students (Jesky-Smith, 2002; Wilkins, 2009) To this end, Wilder et al. (2019) proposed a framework – the Pre-service Elementary Teacher Affect Scale for Science (PETAS–S) – to validate an instrument designed to measure PSETs' level of positive affect towards science. The instrument highlights the important role of emotions in pre-service teachers' attitudes towards the subject of science and how it might influence the way they teach their future students. The results of this study support the idea that when designing science methods courses it is important to factor in enjoyment, as it can lead to a better attitude towards science.

Novak et al. (2022) examined PSETs emotional responses to planning and teaching situations related to science instruction. The authors developed and validated the Science Teaching Anxiety Scale (STAS) for measuring science teaching anxiety with 191 PSETs, and investigated the relationships among science teaching anxiety, interest in science, science teaching self-efficacy, and science teaching outcome expectancy.

They found that science interest was positively correlated with science teaching self-efficacy. They also found that PSETs were most anxious about teaching certain content domains, particularly technological and engineering design topics, followed by physical science and earth and space topics. Their study suggests that science teaching anxiety can influence teachers' inclusion of science content in K-12 classrooms as well as affect PSETs' learning experiences during their teacher preparation.

Methods

We used a mixed-method approach for this study (Fetters & Molina-Azorin, 2017) to provide an in-depth understanding of factors that affect PSETs' attitudes towards science through comparative analysis of quantitative findings and qualitative findings.

This explanatory sequential mixed-method single group design study (Creswell & Plano-Clark, 2011) included 59 third-year PSETs enrolled in an undergraduate program at a southeastern university in the United States between two sections of a science methods course designed to teach pedagogical content knowledge along with science content. The science methods course was taught during the fall semester of 2019 with 29 students in section 1 and 30 students in section 2. All the PSETs (study participants) in the course were female with an age range between 19 and 21.

The PSETs arrived with varied experiences in science and most of them had taken at least one science college course before this course, which was the first science course PSETs take to receive teacher certification in elementary education (grades K-6). In this course, PSETs learn how key aspects of the nature of science are integrated into state and national standards for grades K-6. They also demonstrate and apply knowledge of basic concepts in physical science relevant to elementary teaching such as the properties of sound and chemistry. The course was held over 15 weeks and met once a week in a 2.5 hour face-to-face combined lecture and lab.

Context

In this study, as part of an inquiry-based science content and methods course, we focus on the role that CCM and CPM experiences play in promoting PSETs' attitudes towards science, their self-efficacy towards teaching science, and their science content knowledge. PSETs were given a lesson planning assignment as a CPM experience where they identified standards based on the grade level. They were assigned to their field classroom experience and planned a lesson with at least three activities that considered their students' ideas. CCM activities included practising how to use the Claim-Evidence-Reasoning (CER) framework by McNeill and Krajcik (2011) to help their students construct scientific explanations. McNeill and Krajcik (2011) argued the importance of including reasoning along with evidence as part of the claim in a scientific explanation. They described a claim as a testable conclusion that typically answers a question. Evidence is scientific data, consisting of appropriate and sufficient evidence, which supports the claim. Data can come from an investigation that students complete or from another source, such as observations, reading material, archived data, data tables, models, or other sources of information. Lastly, reasoning is a justification that shows why the data counts as evidence to support the claim and includes appropriate scientific ideas. An example of a CCM activity was the 'oobleck' activity. PSETs made 'oobleck' (a non-Newtonian substance created by mixing water and corn starch with the characteristics of both solids and liquids) and then made a claim about whether it was a solid or a liquid and defended their position with evidence and reasoning using CER as a framework.

Another CCM experience included completing online science units that incorporate learning technologies and science and engineering practices. For example, PSETs complete over two class periods a physical science curricular unit called *Musical Instruments and the Physics of Sound Waves* that was developed online and is open-sourced in the Web-based Inquiry Science Environment (WISE) (Linn et al., (2004). PSETs learn about the properties of sound waves and apply this information to the design and construction of a water xylophone (Linn et al., (2004) that plays a specific tune (e.g. Mary Had a Little Lamb). Other studies have successfully used WISE as a CCM experience and a platform for teaching content areas to pre-service teachers. For example, Namdar (2018) investigated the effects of the WISE *Global Climate Change* unit inquiry on pre-service middle-school teachers' content knowledge about global climate change and their beliefs about teaching it. His study found that the WISE inquiry-based activities caused significant learning gains in the pre-service middle-school teachers' global climate change knowledge understanding and their perceptions of teaching about climate change. Similarly , Ibourk et al. (2023) investigated PSETs' understanding of the properties of sound waves, specifically frequency, wavelength, and amplitude after engaging with a WISE unit. They found that PSETs' understanding of sound waves became more normative and coherent, particularly around ideas of frequency and wavelength.

Table 1. Examples of experiences of self-efficacy in preservice teachers.

Types of experiences	Description of experiences	Examples of experiences
Cognitive Content Mastery (CCM)	Students participate in activities that help them demonstrate their content knowledge	Quizzes, lab activities, exams, presentations, using learning technologies (such as PhET simulations and WISE units); *PhET stands for Physics Education Technology site that has interactive math and science simulations
Cognitive Pedagogical Mastery (CPM)	Students participate in activities that help them learn ways of teaching science	Small-group hands-on activities, lesson planning assignment, using the CER lens for teaching, watching videos of teachers using CER framework

Table 1 summarises the mastery experiences used in our study and that Palmer (2006) described and that Knaggs and Sondergeld (2015) referred to in their study.

Data sources and analysis

We collected data from three sources for our study. In chronological order, the first data source collected was a survey during the first week of the course asking PSETs to describe their personal experiences in learning and teaching science. The survey was given in hard copy form and took about ten minutes to complete. The second data source was the Dimensions of Attitudes towards Science (DAS) questionnaire given to students to measure attitudes towards teaching science. The questionnaire was given online, and it took PSETs less than ten minutes to complete. The questionnaire was administered twice during the first and last week of the course. After the second time the DAS survey was conducted online, we conducted two focus group interviews with six PSETs who volunteered to be part of a follow-up interview after the course ended.

The DAS questionnaire was developed by the Dutch researchers van Aalderen-Smeets and Walma van der Molen (2013) and validated in an English version of the study of 300 U.S. in-service and pre-service teachers by Wendt and Rockinson-Szapkiw (2018). The English version of the DAS tested was found to have a good face, content, and construct validity with a Cronbach's coefficient alpha for the entire DAS at an acceptable 0.89. The DAS questionnaire had the following subscales: (1) perceived relevance of teaching science, (2) beliefs about gender stereotypes in science, (3) perceived difficulty of teaching science, (4) affective dimension of feeling of enjoyment when teaching science, (5) affective dimension of feeling anxiety when teaching science, (6) self-efficacy towards teaching science, and (7) context related to teaching science. We adapted the DAS questionnaire and only used 18 questions out of the original 25 and administered it as a pre/post-questionnaire during the first (pre; $n = 57$) and last (post; $n = 55$) week of the course. The shorter version of the DAS was used to account for only the subscales that were pertinent to the scope of our study (i.e. we did not ask the PSETs about their beliefs about gender stereotypes in science). PSETs' responses to 18 questions were coded and converted to a Likert scale ranging from 0 to 1. 4. Students were given five choices of responses: *Strongly Disagree – 0, Disagree – 1, Neutral – 2, Agree – 3, and Strongly Agree – 4.* Table 2 below provides the breakdown of the DAS subscales.

McDonald et al. (2019) used the DAS instrument with 96 Australian PSETs to investigate their attitudinal constructs towards teaching science after taking a semester-long

Table 2. List of DAS subscales along with corresponding description and questions.

Subscale	Description	Questions
Importance of teaching science in elementary School	The belief that science education is essential in elementary education	1–5
Perceived difficulty of teaching science	The belief that teaching science education is difficult	6–8
Feelings attached to teaching science	The emotional attachment one feels when teaching science	9–12
Self-efficacy in teaching science	The confidence a person has in teaching science (relative to their knowledge around science content and engaging in inquiry activities)	13–16
Context-dependent	The contextual factors that impact one's ability to teach science	17–18

science education course. They found that PSETs made gains in their attitudes towards science with regard to confidence, perception of relevance, and enjoyment. After the science methods course, the authors found that the PSETs were less nervous about science teaching and expressed more intention to incorporate science activities in their classrooms. Our study differs from McDonald et al. (2019) in that the course included CPM and CCM experiences (listed in Table 1) as interventions that were designed to explore whether PSETs could improve their attitude towards science and content knowledge.

To further unpack PSETs' attitudes towards science, one week after the conclusion of the course, we conducted a follow-up semi-structured interview with six PSETs. Two groups of three PSETs from the course participated in focus group interviews. We informed the participants that taking part in the interviews was voluntary. Each co-author (one being the instructor of the course) conducted one of the focus group interviews. The list of questions asked were: (1) What activities based on the course do you believe were influential in developing your self-efficacy towards science? Can you explain why you referred to these activities? (2) Based on this course, do you feel you have a better ability to teach science? Explain; and (3) What were your attitudes towards science before and after the course? Can you explain why?

Focus group interviews were audio-recorded with an average duration of 60 minutes and transcribed for analysis. We used concurrent triangulation design analysis (Doyle et al., 2009) and latent coding to analyse the interview data to identify aspects of the intervention that facilitated or hindered PSETs' attitudes towards science and their self-efficacy. We transcribed and categorised question responses and looked for CCM or CPM experiences the PSETs mentioned that helped develop their self-efficacy and then aligned them with their corresponding subscale. For example, if the PSETs mentioned the CCM experience of small-group hands-on activities as enjoyable, we coded it under feelings attached to the course.

Finally, a survey was given to PSETs that inquired about their experiences in teaching and learning science prior to the beginning of the course. The survey asked questions about courses taken in high school and college, experiences in teaching science, and memorable science experiences in their K-12 along with college years. We gathered students' responses with the intent to make comparisons to responses on the DAS and focus group interviews.

The study met the ethics/human subject requirement of the institution at the time the data was collected. Informed consent was obtained from participants at the beginning of the course. PSETs were told the data analysis would not begin until after completion of the course and final grades were submitted. Participation in the study was voluntary and PSETs could choose to not be part of the study.

Results

In what follows, we report the results in two sections. The first section details the quantitative pre- and post-results from the DAS questionnaire while the second section presents the qualitative data from the focus group interviews of the six participants.

Quantitative analysis

Dimension of attitudes towards science questionnaire (DAS) results

We primarily used descriptive statistics to show the differences in PSETs' attitudes towards science. Our sample size (57 PSETs responded in the pre-test; 55 responded in the post-test) was small and we used 18 out of the original 25 DAS items. The Cronbach's alpha for the 'pre' data-set was 0.546 with 95% CI [0.348, 0.671] while the Cronbach's alpha for the 'post' data-set was 0.712 with a 95% CI [0.597, 0.787]. Table 3 provides the mean and standard deviation (SD) of the pre- and post-DAS questionnaire-coded responses.

As the response categories in Likert scales have a rank order, the intervals between values cannot be presumed equal, so the mean and SD are provided for reference purposes when comparing pre- and post- questions. We also looked at medians and modes (which are whole number values) and they tell the same story. Our goal was to detect any consistent pattern of the PSETs' attitude change before and after taking the course. The focus of our analysis was to examine PSETs' attitudes towards science. Therefore, we report the results of paired *t*-tests for the DAS subscales. We broke down the subscale of feelings attached to teaching science to either positive (3a) or negative (3b). The subscales we reported on were: (1) importance of teaching science in elementary school (Q1–5), (2) perceived difficulty of teaching science (Q6–8), (3a) positive feelings attached to teaching science (Q9–10), (3b) negative feelings attached to teaching science (Q11–12), (4) self-efficacy in teaching science (Q13–16), and (5) context-dependent (Q17–18). The higher scores indicated a more positive attitude for the subscale of (3a) positive feelings attached to teaching science (mean scores increasing from 5.36 to 6.28) and the subscale of (4) self-efficacy in teaching science (mean scores increasing from 8.36 to 10.77). The shift also in the subscale of (3b) went from 3.58 to 2.96 indicating that PSETs had fewer negative feelings attached to teaching science (Table 4).

Importance of teaching science in elementary school

Questions 1–5 assessed the importance of teaching science in elementary school. The mean values on both the pre- and post-questionnaires increased for Q1 (3.47–3.50) and Q5 (3.27–3.37). The mean values decreased for Q2 (3.49–3.39), Q3 (3.59–3.53),

Table 3. Mean and standard deviation for questions on the DAS questionnaire.

Question	Mean (SD) Pre	Mean (SD) Post
1. I think that science education is essential for helping elementary school students become more involved with society's problems.	3.47 (0.77)	3.5 (0.08)
2. I believe that science education is essential for elementary school children's general development as a citizen.	3.49 (0.59)	3.39 (0.82)
3. I think that science must be included in elementary education as early as possible.	3.59 (0.61)	3.53 (0.59)
4. I believe that science education in the elementary school is essential for students to be able to make good educational and career choices.	3.52 (0.59)	3.50 (0.71)
5. Because science education is so important in elementary school, I think that inexperienced teachers should receive additional training in this area.	3.27 (0.71)	3.37 (0.70)
6. I think that most elementary school teachers find science content to be a difficult subject to teach.	2.28 (0.83)	2.67 (0.97)
7. I think that most elementary school teachers find it difficult to teach subjects concerning science.	2.22 (0.87)	2.55 (1.02)
8. I think that most elementary school teachers find the topics that come up in science class complicated.	2.27 (0.86)	2.46 (0.93)
9. I feel happy while teaching science.	2.59 (0.83)	3.05 (0.69)
10. I feel enthusiastic when teaching science.	2.72 (0.76)	3.16 (0.62)
11. I feel tense while teaching science.	1.69 (0.89)	1.44 (0.60)
12. I feel nervous while teaching science.	1.86 (0.86)	1.50 (0.68)
13. I have enough science content knowledge to teach this subject well in elementary school.	1.57 (0.81)	2.41 (0.84)
14. I am able to deal effectively with questions from students about science.	2.11 (0.78)	2.58 (0.59)
15. I have a sufficient command of science content to support elementary students effectively with research/inquiry activities in the classroom.	1.94 (0.77)	2.66 (0.64)
16. I think I can succeed in helping elementary students reach a solution during assignments about science.	2.83 (0.62)	3.10 (0.52)
17. For me, having sufficient knowledge of specific science teaching methods (e.g., inquiry-based learning, problem-based learning, etc.) is decisive for whether or not I will teach science in class.	2.37 (0.84)	2.14 (0.96)
18. For me, the availability of a ready-to-use existing package of materials (e.g., science kits) is an essential prerequisite for being able to teach science in class.	2.13 (0.97)	1.80 (0.98)

Table 4. Results of the subscales.

Subscale	Pre		Post		*t* (52)	*p*	Cohen's *d*
	M	*SD*	*M*	*SD*			
Subscale 1	17.25	2.235	17.30	2.893	0.148	0.883	0.02
Subscale 2	6.75	2.369	7.74	2.466	2.592	0.012	0.36
Subscale 3a	5.36	1.495	6.28	1.215	4.634	0.000	0.64
Subscale 3b	3.58	1.622	2.96	1.160	−2.862	0.006	−0.39
Subscale 4	8.36	2.434	10.77	2.100	8.203	0.000	1.13
Subscale 5	4.51	1.325	3.98	1.550	−2.241	0.029	−0.31

and Q4 (3.52–3.50). The mean values on both the pre- and post-questionnaires fell between *Agree (3)* and *Strongly Agree (4)* showing that PSETs believed in the importance of teaching science in elementary school prior to the course and this belief did not change much after taking the course.

Difficulty in teaching science

Questions 6–8 measured the beliefs related to the difficulty of teaching science. Results show that PSETs' responses mostly ranged from *neutral (2)* to *Agree (3)* for this subset of questions. The trend of increasing values from pre to post was observed among all three questions. The mean response for Q6 rose from 2.28 to 2.67. For Q7 and Q8, the mean rose from 2.22 to 2.55, and from 2.27 to 2.46 respectively. This indicates that their attitudes towards science being difficult to teach may have slightly shifted from neutral to Agree.

Feelings attached to teaching science (enjoyment and anxiety)

Questions 9–12 measured feelings attached to teaching science. For Q9 and 10, there was a positive change in the mean from 2.59 to 3.05 (Q9) and 2.72 to 3.16 (Q10). The increase in mean values indicates teachers were happier and more enthusiastic about teaching science. When asked if PSETs felt tense and nervous (Q11 and Q12), their attitude change went the other direction, with their mean values decreasing from 1.69 to 1.44 (Q11) and 1.86 to 1.50 (Q12), indicating PSETs felt less tense and anxious about teaching science after the course. Overall, the feelings towards teaching science after the course became more 'positive'.

Concept of self-efficacy in teaching science

Questions 13–16 measured the self-efficacy of teaching science. For this subset, we see the most noticeable change from pre- to post-questionnaire. For Questions 13 and 15, when asked about sufficient science content knowledge, PSETs' mean responses went from 1.57 to 2.41 (Q13) and 1.94 to 2.66 (Q15) after taking the course. This shift means that PSETs believed they were more confident in applying the science content knowledge they received from the classroom teaching.

Questions 14 and 16 are statements about the PSETs' confidence in successfully addressing students' science questions. For Q14 PSETs' mean values shifted from 2.11 to 2.58, which showed an increase in PSETs feeling that they can address effectively with student questions. Q16 showed a mean increase from 2.83 to 3.10, indicating PSETs' increase in the belief that they can succeed in helping elementary students reach solutions during class about science.

Context-dependent

Questions 17 and 18 asked about their agreement regarding the availability of a ready-to-use existing package of materials (e.g. science kits) as an essential prerequisite for being able to teach science in class. For Q17 PSETs' mean values shifted from 2.37 to 2.14 while for Q18 they shifted from 2.13 to 1.80. The decrease in agreement with the statement on the post-test indicates that PSETs felt less dependent on the external materials that assist teaching.

Qualitative analysis

To further unpack PSETs' attitudes towards science, after the conclusion of the course we conducted focus group semi-structured interviews with a subset of participants.

Doing a focus group with two groups of three PSETs as opposed to just conducting six separate semi-structured interviews with each PSET was intentional, as research suggests the social interaction will generate deeper and richer data than obtained from one-on-one interviews (Rabiee, 2004). For each of the subsections below, we present individual case reports of each of the six PSETs that incorporate quantitative findings from analysis of DAS results and qualitative findings from interview analysis.

The PSETs' names (pseudonyms) were Erin, Nancy, Marie, Amanda, Carrie, and Megan. Table 5 presents the personal science experiences of the six focus group participants based on the survey they filled out during the first week of the course. This data was used to further triangulate with the focus group response of each participant as well as to see if it could be connected to their results in the DAS post-questionnaire.

Feelings attached to teaching science

During the focus group interviews, several PSETs stated how the class impacted their feelings towards teaching science. Overall, the focus group PSETs expressed the most positive emotions about science after participating in the course. In explaining how their emotions became more positive, PSETs recalled specific activities performed during the class that helped develop a more positive attitude towards science. Some small-group hands-on inquiry activities mentioned included (1) powering a flashlight bulb with aluminium foil, a battery, and tape, (2) making an LED light turn on with a

Table 5. Personal science experiences of focus group participants.

Pseudonym	High School and College Science Courses	Science Teaching Background
Erin	High School: Chemistry, Biology, Physics 1, 2. College: Environmental Science	No experienceNancy
Nancy	High School: Honors Biology, Honors Chemistry, Honors Physics, Environmental Science (AP). College: General Biology Non-Majors, Intro Environmental Science	Volunteered in a first-grade classroom at an elementary school and helped teach a science lesson on the chicken life cycle. Students were able to experience having an incubator in the classroom and were able to see the chicks once they hatched.
Marie	High School: Biology, Chemistry, and Physics. College: Intro to Environmental Science, General Biology Non-Majors; Intro to Environmental Science Lab	Only occasional science experiments with children
Amanda	High School: Chemistry, Biology, Foundations of Agriculture. College: Biological science, Survey of Chemistry, Microbiology 1, Anatomy and Physiology of the Speech Mechanics	Taught through demonstrations a few lab activities. Also taught a science lesson to 5th graders. Mentored small groups to help teach science concepts.
Carrie	High School: Biology, Chemistry, Physics, Earth Science, and Environmental Science. College: Earth Science; Intro to Environmental Science with Lab	Helped with teachers in class to set up experiments and work in small groups (2nd grade level)
Megan	High School: Biology, Chemistry, and Environmental Science; Anatomy and Physiology w/lab (Senior year of HS; dual enrolment). College: Biology Non-Majors (Freshman year)	Teaching a biology class, tutoring elementary students in science

makeshift battery from pennies and a vinegar and water solution, and (3) building circuits with wires, bulbs, and batteries.

In the demographic survey about her personal science experiences, Erin described that her most memorable experience was watching documentaries about how the universe works with her dad. During the interview, she recalled how before the class she had connected science to 'white lab coats', the 'Hubble telescope', or science documentary TV shows. She talked about how she enjoyed her experience in the course and engaging in activities like lighting a bulb that she felt she could also do with her own students:

> Science was never something so simple as setting up a battery and wires and lighting up a light bulb. I didn't realize it could be so simple. All of my science teachers growing up were very into the plant part of it, the biology part of it. And that bores me to death. So, I never got any influence from school that way … But I think doing activities with them and showing them, you know, you can light up a light bulb like we did … is cool and it will get them interested without having to make them sit and just watch a clip from a TV show.

Similar to the general sample, Erin's DAS scores displayed a positive shift in emotions, indicating that after completing the course she felt happier when teaching (Q9: I feel happy while teaching science; *Neutral (2)* to *Agree (3)*; mean = 2.5). For Q12, Erin showed an important change in that she disagreed with the statement about 'feeling nervous about teaching science' (shift from *Agree (3)* to *Disagree (1)*; mean = 2); the general sample stayed in the mean of 2 where they did not show a major change in feeling nervous about teaching science.

Nancy came into the course having taken several science courses in high school and one in college. Her survey about her personal science experiences indicates that she had taken Chemistry, Biology, and two Physics classes in high school and one science class in college before this course. Her most memorable science experiences were those around field trips. She talked about how the course made her more 'passionate' about science and 'excited about teaching science.' Although she did not reference any particular activities, she mentioned how the way the instructor engaged the students made her more passionate about teaching science in her own class.

> I was passionate about science, but throughout the semester I struggled. I was like, wow, I'm interested in this class because I think it's because [the instructor] had a way of just engaging students … slowly like my passionate interest in science grew.

Furthermore, her DAS scores on Q9: I feel happy while teaching science showed a change from; *Disagree (1) to Agree (3)* (mean = 2), which showed an increase in happiness in doing science as a result of the course. Q10 (I feel enthusiastic when teaching science; *Agree (3)* to *Strongly Agree (4); mean = 3.5*) indicated that Nancy was more enthusiastic about teaching science because of the course.

Marie talked about how the course made her reflect on past moments when she enjoyed doing science in school. In her survey, she mentioned that her most memorable science experiences were those that were 'fun' and 'enjoyable' and left an impression on her, like those in fifth grade where her teacher had the 'coolest experiments' and in seventh grade where her teacher jumped on tables to show the laws of physics:

> [The course] brought me back to the fun stuff that we would do when I was younger. So, I would … I definitely say … I feel … my viewpoint of science likely decreased when I went

> into high school, whether I realize it or not, I feel … I definitely had a less positive attitude toward it in high school. But then coming back and being … a child was good for me.

Marie's statements reveal that her attitude towards science prior to the course was based on in-class experiences and her experience in the course helped her relive the positive science experiences she had at a younger age. The experience Marie had during the class was confirmed by her DAS scores on feelings about science, which show that she feels happy about teaching science (Q9: I feel happy while teaching science; *Agree* 1. *(3)* to *Strongly Agree (4); mean* = *3.5*) and enthusiastic (Q10: I feel enthusiastic when teaching science; *Agree (3)* to *Strongly Agree (4); mean* = *3.5*).

Amanda had contemplated going into the medical field and had taken several science courses before she decided to become a teacher. She described how during her time at a community college she enjoyed her microbiology class. Amanda did very well in the course, and the professor asked her to be a lab assistant the following year.

During the focus group interview, Amanda said that she came in with a positive attitude and described herself as a 'science nerd'. Amanda's scores in the DAS were the highest of all six participants in the focus group and many remained the same pre and post-test (e.g. Q9: I feel happy while teaching science; Q10: I feel enthusiastic about teaching science; *Strongly Agree (4)* and Q11: I feel tense while teaching science; Q12: I feel less nervous about teaching science*; Disagree (1)*).

Carrie's scores for Questions 9–12 remained neutral (i.e. a score of 2 on both pre- and post-questionnaire). This can be attributed to Carrie's prior experiences with science before taking the course. In the personal experiences survey, she described her memorable science middle and high school classes as negative due to the teacher not caring, finding chemistry hard to understand, and almost failing the class. However, she noted positive experiences during high school where she enjoyed her Physics class because it was math-based and did dissections in biology class. The latter aligns with Van Zee and Roberts (2001), who found that PSETs reported hands-on activities, experiments, or dissections as good experiences in learning science.

In her survey, Megan indicated that she had numerous hands-on experiences throughout elementary and middle school. She also expressed that it was the 'light-heartedness and fluency' of her Anatomy and Physiology professor who taught in 'real-life terms' that made learning science enjoyable, but which also inspired her to push beyond what she thought she could do. Megan's scores for Questions 9–12 indicate a negative shift about teaching science (e.g. Q10: I feel enthusiastic when teaching science; *Neutral (2)* to *Agree (3); mean* = *2.5,* and Q12: I feel less nervous while teaching science; Neutral *(2)* to *Disagree (1); mean* = *1.5*).

Overall, focus group participants offered feedback that suggested their feelings towards teaching science had mostly improved after taking the course. In each case, their comments aligned with their respective DAS scores, which indicates positive changes in disposition towards teaching science, but also underscored the importance of enjoyment in teaching science.

Self-efficacy in teaching science

Self-efficacy focused on how the course impacted the PSETs' confidence in teaching science. Erin expressed that she felt more confident in teaching science content. She said, I like the activity with the puzzle. So, it's … washers that have cardboard piece and you had to make a circuit and figure out the design of the wire that was sandwiched between the cardboard, but you couldn't see it … I learned a lot more and especially for the content that I'm going to be teaching. So, this was really beneficial to me.

Erin's DAS scores indicate she made strong improvements in her self-efficacy. Her scores showed increases in her belief that she has enough science content knowledge to teach well (Q13; *Neutral (2)* to *Strongly Agree (4); mean* = *3*), being able to effectively deal with questions from students (Q14; *Neutral (2)* to *Agree (3); mean* = *2.5*), having a sufficient command of science knowledge to support research/inquiry-based activities in the classroom (Q15; *Disagree (1)* to *Agree (3); mean* = *2*), and having the confidence to help students find solutions in assignments (Q16; *Neutral (2)* to *Agree (3); mean* = *2.5*).

Nancy believed the class gave her the confidence to want to teach science.

During the interview, she alluded to previously believing that teaching science was too difficult and complex for her. She mentioned that the instructor played a positive role in engaging her interest in the class:

> … And even when we were quiet, [the instructor] still chose to keep pushing and trying to ask, but it's only because [she] wanted to engage in the lesson, she wanted us to be interested in actually having thoughts about this, [and] make this memorable. So, slowly my passionate interest in science grew to the point where I'm just … wow, I'm excited to actually teach this in the classroom more than … other subjects.

As a result of the course, Nancy was more confident in her content knowledge to teach science (Q13; *Disagree (1)* to *Neutral (2); mean* = *1.5*) and the ability to teach it well (Q15; *Neutral (2)* to *Agree (3); mean* = *2.5*).

Marie also talked about how this course has shifted her viewpoint of science from negative to positive and that science learning can be 'enjoyable':

> I'm not … a big science gal. I haven't hated it, but I'm not … really into science. So, coming in here it was, okay wait, well hold on … .this can actually be cool, and I can actually as a teacher make it enjoyable so that my students … have a good experience similar to how I did in elementary school.

Her remarks make it clear that the course made an impact on Marie's self-efficacy in teaching science. DAS scores showed that Marie was more confident in her science content knowledge (Q13; *Neutral (2)* to *Agree (3); mean* = *2.5*) and believed she was able to deal with questions from students about science more effectively (Q14; *Neutral* 1. *(2)* to *Agree (3); mean* = *2.5*).

Out of all the participants, Amanda was the one who came in with a very positive attitude towards science, but even she felt more prepared to teach after the course:

> So, for myself, I love science and I love learning and everything, but I feel that I can do that outward. So, I can also teach my kids to love science and … I feel … I'm more prepared to teach a science lesson to kids that's … user friendly and it sparks your interests.

Similar to Nancy, Amanda also referred to how the instructor of the course modelled for her the kind of teaching she wanted to engage in:

> [The instructor] showed … Having [an instructor] that's passionate about something changes the game completely. If you're a teacher and you don't show passion about what you're teaching, it doesn't work, so there's a disconnect.

Amanda also referred to specific activities around learning about static electricity using learning technologies that stood out to her in helping her not only gain better science content knowledge but also that she could use in her own teaching:

> The static electricity one, so the picture of the little girl [with her hair standing up after going down the slide] I'm … first you saw it and then we did the John Travoltage PhET simulation and we tested ourselves with a balloon and the little granules [to investigate static electricity] … So I feel … I could carry that into my own classroom, just … the other activities but specifically that one, because of kids and they go on the playground and they've experienced this. Everyone's experienced it. That [static electricity example] got my attention because it happened to me, but I didn't really think about why, it happened, so knowing how user friendly it is to teach people was really good and it made this complex idea [of static electricity] come back down to … a liquefied version of where our kids could understand, which I thought was cool.

DAS scores showed that Amanda was more confident in her science content knowledge (Q13; *Neutral (2)* to *Agree (3); mean = 2.5*), and her ability to teach it well because of this course (Q15; *Neutral (2)* to *Agree (3); mean = 2.5*).

Carrie's ability to deal with questions from students about science more effectively (Q14; *Neutral (2)* to *Agree (3)*) and her response to her ability to teach science well because of this course (Q15; *Neutral (2)* to *Agree (3); mean = 2.5*) reveal that her views changed as well. When asked about what made an impact on her the most, she referred to a hands-on activity lesson with tuning forks where she used them to move objects at a distance as well as the oobleck lesson: 'I thought that was really an interesting lesson cause it's not, it's hard to tell if it's liquid or solid or whatever'. Carrie's was the only respondent who was vocal about 'hating' science and attributing it to her own personal science experiences:

> Before I got into this class, I absolutely hated science. I'd had bad experiences. My teachers that I had in high school were either fantastic but never did anything with us or they were just awful all the way around … They didn't make it interesting at all. And then we didn't really do any science in elementary school that I can remember … So, to come in and find a teacher that actually wants to do hands-on and wants us to be passionate about it, it was so much more eye opening than … the old school way of that. I used to have it where it was just sit down and lecture, take notes, take the test. It was, I mean it actually made me kind of start being interested.

What Carrie appreciated about the course were the hands-on activities that allowed her to be 'curious and ask questions and not feel stupid when [she] didn't understand'. In high school, she did not feel confident asking questions in class for 'fear of being laughed at for not knowing'.

Megan mentioned particularly enjoying the CPM experience of the lesson planning activity and the CCM experience of using web-based learning environments such as WISE:

> I really liked those because the whole concept of 'I'm in charge of teaching these people's science and that kind of thing'. Because I was okay at science, and … I enjoyed it to a certain extent, but I didn't feel very prepared to teach science. I especially … the aspect of the standards and everything like that. But I think, having the WISE activities and then having the lesson plan, I engaged in that kind of thing, and going over all of the standards like the Kindergarten through 6th grade in this class really helped me feel more ready to step into a classroom and not feel like I'm doing everything wrong.

Megan's self-efficacy improved as a result of how well she knew the standards to teach, along with how well she felt prepared to teach science. The instructor's use of the WISE activities (e.g. building a xylophone) offered her examples of activities for teaching concepts around science and how it can relate to lesson planning. DAS scores indicate Megan believed she had a stronger science content knowledge to teach it well as a result of the course (Q13; *Disagree (1)* to *Agree (3); mean* = *4*).

Discussion

In this study, we sought to answer the following research questions: (1) In what ways do PSETs' attitudes towards science change after engaging in an inquiry-based science content and methods course? (2) In what ways do PSETs' self-efficacy in teaching science change after engaging with an inquiry-based science content and methods course? Like McDonald et al. (2019), our findings show that the greatest changes in PSETs' attitudes towards science were around their feelings towards teaching science and their self-efficacy and confidence in teaching science. After the course, PSETs expressed less anxiety and more enjoyment towards teaching science. When we followed up with the focus group participants, two of them (Carrie and Erin) attributed changes in their self-efficacy to the CPM mastery experience of hands-on inquiry activities. Carrie and Erin mentioned that engaging in the CPM mastery experience of hand-on activities 'brought back the joy' in science and allowed them to be 'curious' about learning and teaching science. Amanda and Megan also indicated that the use of the CCM mastery experience of learning technologies through online environments (such as WISE and PhET) increased their self-efficacy and improved their attitude towards science.

Like other studies, our results (based on the focus group interviews) indicated that the PSETs with higher self-efficacy also described the most positive experiences in science (Hulings, 2022; Yürük, 2011) and more interest in science (Novak et al., 2022).

This can be seen with Amanda, who was the participant who came in with the most positive science experiences. In our study, five out of six of the focus group participants alluded to how they lost interest in science due to personal science experiences in middle school, high school, or at the undergraduate level that made them feel anxious about science learning.

Our findings also are consistent with other studies in that engaging in inquiry-based investigations in teacher education courses and creating and implementing inquiry-based lessons in the field can be effective in increasing PSETs' science teaching self-efficacy (Gunning & Mensah, 2011; Menon & Sadler, 2016; Soprano & Yang, 2013; Velthuis et al., 2014). Our findings reveal that the increase in self-efficacy and improved attitude towards teaching science was accompanied by positive *physiological and emotional reactions* (Bandura, 1997) – the joy of engaging with hands-on experiences. This research has found that part of promoting PSETs' CCM is providing them with opportunities to learn about science concepts and do science through engaging in inquiry-based online science units and learning technologies. This can enhance their self-efficacy towards teaching science and bring about a sense of enjoyment while learning. The findings speak to the benefit of how a science content-methods course that integrates online units such as WISE and learning technologies can impact PSETs' self-efficacy towards teaching science.

We agree with Wilder et al. (2019) that emotions are an important indicator of how PSETs feel about science. However, we find that emotions alone do not provide a holistic view of other influential factors, such as their attitudes and beliefs about the importance of teaching science and their self-efficacy towards teaching science nor their interest in teaching science (Novak et al., 2022; Senler, 2016). It is important to note that the DAS questionnaire (Qs 1–5) did not show a shift though in PSETs' attitudes about the importance of teaching science. Although changes after the course were found in the feelings that PSETs attached to teaching science (where they expressed less science teaching anxiety), questions remain regarding PSETs' understanding of the importance of teaching science, how this might translate in their own classroom and what interventions might support a shift in outlook. We argue for a need to prepare elementary teachers in a way where they see the importance of teaching science in elementary schools grounded on empathy towards their future students – one where they tap into how poor science instruction in elementary school ends up negatively impacting their own students in both the short and long term. Teacher educator programs could consider providing space for their PSETs to share their negative emotions towards science teaching, especially their science teaching anxiety. When we allow PSETs to unpack what Hulings (2022) refers to as the 'baggage' they bring with them to methods courses about their own negative science experiences, they can reframe these past experiences to make their future students' science experiences better than their own.

We also note that three participants (Amanda, Carrie, and Nancy) alluded to how the instructor played a role in adding to their self-efficacy by encouraging their interest in science teaching through modelling emotions of joy in teaching and interest in science. This is also consistent with *vicarious learning experiences* as one of the four primary sources of self-efficacy experiences that Bandura (1997) suggested, where PSETs are provided a point of reference and gain positive feedback from their instructor. This type of *vicarious learning experience* could increase their teaching self-efficacy and as Bandura (1997) stated could cause the PSETs to transfer this model of learning science in joyful ways into their own classroom. We argue that another source of self-efficacy could be the instructor showing 'genuine care and interest' in the PSETs, which three participants alluded to in focus group interviews. The DAS questionnaire could be further adapted to include questions about other possible external sources of self-efficacy or positive influences (e.g. methods course instructors, peers, teachers, or family members) that Hulings (2022) found to contribute to a higher self-efficacy towards teaching science.

Even though there were positive findings from our study, there are limitations that need to be highlighted. The sample is large enough to speak to transferability (Tracy, 2010) and inferential generalisations (Lewis & Ritchie, 2014), but limits the broad generalisability of findings due to the fact that participants were all female, and the age range was limited. Additionally, the instrument used to measure PSET attitudes towards science used a Likert scale, which has limitations on understanding contextual aspects that factor into PSETs attitudes towards science and relies on self-reporting. In addition, some of the focus questions may have been somewhat leading (e.g. 'Based on this course, do you feel you have a better ability to teach science?'). Limitations of the study reveal the need to examine a larger population of PSETs to understand how courses targeting PSETs impact their attitudes towards science over a longitudinal period.

Findings from the study point to the opportunity for future studies of PSETs' attitudes towards science. The DAS questionnaire was designed to measure different aspects of PSETs attitudes towards science in order to provide a reference for researchers and science educators in future studies. Similar to McDonald et al. (2019), understanding PSETs views of science can be informative for course developers to understand what to focus on in changing them to a more positive view. The DAS analysis provided further support for PSETs attitudes found in the focus group interviews. Responses from the focus group showed that there are aspects of PSETs' attitudes towards science that need to be further examined (such as context and the importance of teaching science in elementary school). PSETs in the study had low confidence in teaching science to begin with, based on a range of factors including poor experiences in their K-12 schooling with science. Going forward, future research in science education could design courses that focus on how to teach elementary science to students in ways that leverage and foster PSETs' own wonder, enjoyment, and curiosity – all important habits of mind associated with positive emotions that can be developed in their own elementary students.

Disclosure statement

No potential conflict of interest was reported by the authors.

Ethical statement

The institutional review board approved the study entitled, *Developing Preservice Elementary Teachers' Self-Efficacy Toward Teaching Science*, with approval number 28578. The study met the ethics/human subject requirement of the institution at the time the data was collected. The study was classified under Exempt 45 CFR 46.101(b)2.

Human subjects research that is classified as 'exempt' means that the research qualifies as no risk or minimal risk to subjects and is exempt from most of the requirements of the Federal Policy for the Protection of Human Subjects but is still considered research requiring an IRB review for an exemption determination.

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Appendix

Course Syllabus

WK	GUIDING QUESTIONS	LABS AND ACTIVITIES IN CLASS
1	Course Overview: What will I do and learn in the course? Topics: What are the characteristics of the nature of science? What does it mean to be a scientist? To learn and do science? Why is it important to teach science in elementary classrooms?	
2	Going over: State Science Standards. CPALMS Using Models to represent Atoms. Concepts: Matter. What are the different science process skills? A new vision for science education: Science as practice	Introduction to the State Science Standards; and Next Generation Science Standards. Go over learning progressions and big ideas; Science and engineering practices and cross-cutting concepts. Unpacking learning goals activity

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WK	GUIDING QUESTIONS	LABS AND ACTIVITIES IN CLASS
3	Going over: Next Generation Science Standards and Science and Engineering Practices Concepts: Observations vs. inferences; Mixtures and solutions; Solubility	'Matter & Interactions: The Rising of Muffins' © Ambitious Science Teaching lesson, 2017 Activity 1: Students explore the investigation question of 'What makes a muffin rise?' Hands-on lab Observing ingredients used to make muffins. Activity 2: Develop a model to explain what makes a muffin rise when it bakes. Share and discuss different ways how to fill in the model including the qualitative observations. * Workshop: Unpacking learning goals workshop in class.
4	Concepts: Observations vs. inferences; Mixtures and Solutions; Solubility Heat and chemical reactions	Activity 4: Searching for the gas: Which ingredients are causing a gas to release? Demonstration - Test (indicators) which muffin ingredients were. acids and bases and what reacted with baking soda. Activity 5: Test what happens when baking powder is added to hot, medium, and cold. water (balloons on flasks) *Workshop: Exploring Experiences, Patterns, and Explanations (EPE) workshop in class
5	Exploring Experiences, Patterns, and Explanations (EPE) Process Skills: Inference and prediction. Claim, Evidence, and Reasoning (CER) and constructing evidence-based explanations and arguments.	Properties of Matter: 1) Measuring different types of matter and classifying it into solids and liquids 2) Students will explore oobleck and debate on whether it is a liquid or a solid. Then they will watch the Ellen video and engage in an interactive read aloud of Bartholomew and the Oobleck *Workshop: Exploring Experiences, Patterns, and Explanations (EPE) workshop in class
6	Concepts Matter, properties of matter, types of energy	Assignment in class: WISE Completion of unit: Chemical Reactions and Alternative Fuels: Making a Change. Part 1
7	Concepts Matter, properties of matter, types of energy Claim, Evidence, and Reasoning (CER) and constructing evidence-based explanations and arguments.	Assignment in class: WISE Completion of unit: Chemical Reactions and Alternative Fuels: Making a Change. Part 2
8	Concepts: Eliciting students' ideas Charging by induction and conduction.	Static Electricity Activity and Lab *Workshop: Lesson Identification and Learning Goals: workshop and peer feedback in class
9	Concepts: Electricity, fields, types of circuits Using Claims-Evidence-Reasoning (CER) Scaffolding Tool to scaffold students' construction of evidence-based explanations and arguments.	Batteries and Bulb Investigation 1 Students will draw and label four different ways to light up a bulb using a battery, wire, and bulb. Also draw four ways that don't work. Then, they will engage in answering the investigation question: How can you light a bulb using a wire, a battery, and bulb?
10	Concepts: Electricity, types of circuits, types of energy Looking at student thinking and focusing on understanding children's thinking as inquiry. Looking at high level discourse/talk moves that promote student thinking	Batteries and Bulb Investigation 2: How do multiple? Batteries affect the brightness of a bulb? (investigation); How can we build different circuits? Activity: Case-study of Kim's Class Exploring Electric Circuits: Looking at fourth/fifth graders' thinking and sensemaking around electric circuits and batteries.
11	No classes Students in classrooms co-teaching and teaching in mentor classroom	
12	Concepts: Sound, vibrations, amplitude, pitch, waves.	Assignment in Class: WISE Part 1: Completion of unit: Musical Instruments and the Physics of Sound Waves

(*Continued*)

Continued.

WK	GUIDING QUESTIONS	LABS AND ACTIVITIES IN CLASS
13	Concepts: Sound, vibrations, amplitude, pitch, waves.	Assignment in Class: WISE Part 2: Completion of unit: Musical Instruments and the Physics of Sound Waves
14	Concepts: Sound, vibrations, amplitude, pitch, waves. How can we differentiate a lesson on sound and teach it for all our diverse learners?	In-Class Activity: Sound Stations *Workshop: Equitable Science Teaching and Drawing from Students' Funds of Knowledge
15	Eliciting and interpreting individual students' thinking around force and motion, potential and kinetic energy, gravity. Teacher talks moves	*Workshop: Responsive teaching and looking at students' ideas around force and motion, gravity, and types of energy and teacher talk moves (types of questioning). http://ase.tufts.edu/education/responsiveteachinginscience/toytops.html