A PROCESS TO DESIGN AND DELIVER A SCIENCE CONTENT COURSE FOR ELEMENTARY AND SECONDARY PRE-SERVICE TEACHERS

Doug Monk, Ed.D..
Schreiner University

Abstract

This practitioner-based reflection will explore female pre-service teacher attitudes toward science, research on pre-service teacher (PST) science content knowledge, and a process to create a Science Content course. Many science content courses are discouraging to new teachers and part of the negative experience that detracts from their self-concept about teaching science. If not carefully designed, PSTs will go out into their teaching positions internalizing that they do not know science content and believing that they are not equipped to teach science. The following process is my methodology for creating, a Science Survey of Content and Test Preparation course (EDUC 3350) for Core Subjects 4-8, EC-6, and Science 4-8 pre-service teachers.

Keywords: Course design, course alignment, Science content course, female pre-service teacher, scope and sequence, assessments, efficacy, attributes, attitudes, confidence

The impetus for this narrative on how to design and deliver a Science Content course for Pre-service Teachers (PSTs) comes from a discussion that I had over two semesters with my students in a new Science Pedagogy class which was composed entirely of young women. During these semesters, I interviewed my PSTs seeking certification in core subjects of Early Childhood through 6th grade, 4th through 8th grade (EC-6, 4-8) levels about their beliefs, understandings, and confidence in teaching science to elementary and secondary children (Monk 2021). It was clear that they had a low self-expectancy for teaching science. "How many of you like Science?" I asked my Science Pedagogy students on the first day of class each semester. Every one of my elementary and secondary aspiring teachers answered in the negative as if drinking a bitter cocktail.

My passion and former teaching field, so it seemed, scared each of my students in different ways. "I don't know anything about Science." "I am afraid I will look dumb to my students." "I was never good at Science." "It is too complicated to understand." "It never interested me." "All my science teachers were boring." And the coup de gras, "All we ever did was worksheets." It became apparent to me upon asking "how many of you like Science?", that there was more to not liking the subject than an aversion to the topic. It was evident that all my students had experienced some type of negative environment in their past schooling that caused them to have an aversion toward science Author (date). Concurrently, our department began seeing a trend of disproportionate failure rates on teacher certification tests in science content knowledge. As a teaching departmental team, in the Spring of 2021, we determined that a course on science content specifically for teachers was necessary and needed to be provided in the Fall of 2021. This may seem counterintuitive, but, as an education department we do not teach subject content, we discover the art and science of the profession of teaching. I was, therefore, gifted with the creation of a new, appropriate, and effective Science Content course for teachers in 3 months. This instructional reflection will explore female PST attitudes toward science, research on PST science content knowledge, and the process to create a Science Content course.

Literature Review

Female and PST attitudes towards science

The research on girls' and PST female teacher attitudes from Kurtz-Costes, Rowley, Harris-Britt, & Woods, 2008 regarding science verifies my observations in class that female PSTs have an aversion towards science as we will

ISSN: 2474-3976 online

see. My mission was clear though, these future teachers were going to like, hopefully, love, Science by the end of the Science Content course. Furthermore, they would pass their science content certification exam and have confidence in their ability to engage elementary and secondary students in science.

Influential adults often confirm what girls and PSTs believe about their competency in Science. "Many parents and teachers believe that boys are more capable in math and science than girls and some evidence indicates that adult stereotypes influence children's self-perception of ability and decision about math and science-related education and careers" (Kurtz-Costes, Rowley, Harris-Britt, & Woods 2008, p. 389). This self-perception begins very early. When asked to draw a picture of scientists in elementary school, girls drew men as the icon twice as often as they drew women. Early school perpetuates the subconscious images of men as scientists. Thus, females enter STEM (Science, Technology, Engineering, and Math) fields at a much lower rate than males. Through her research, Berwick (2019) found that girls take advanced science courses on par with boys as they move into high school but drop dramatically as they enter college. Berwick (2019) called this a *stereotype threat*. Girls continually get subtle social and cultural messages about male superiority in math and science. It is no secret that most elementary teachers are female. Bergman and Morphew's research indicates that many elementary teachers feel unprepared and uncomfortable teaching science. When surveyed, 72% of elementary teachers did not feel competent to teach science (Bergman & Morphew, 2015). The authors' research found insecurities, and these are reinforced by teachers who are anxious about teaching science. Teachers with this feeling of inadequacy may ultimately teach science poorly or avoid it altogether.

The researchers found that these insecurities can be created by the context of science teaching and assessment of girls. A study of admission tests to the most rigorous and elite schools in New York City found that girls guess less frequently than boys on the predominant multiple-choice tests that are used in science (Ennever, 2006). Girls perform better on open-ended questions, written answers, and assessments that allow them to demonstrate writing proficiency. Girls also report greater self-competence in verbal activities. This response suggests that science assessments in the classroom, which are predominantly multiple-choice, should take the form of open-ended assessments in a more blended way. But this is not happening, and girls continue to be exposed to the environment where multiple-choice tests dominate high school chemistry classes (Ennever, 2006). When considering the context of the science experience for girls, informal assessments have an impact as well. Because teachers still have the perception that girls are less knowledgeable than boys in science, they call on boys more often to answer verbal questioning in the classroom. Kurtz-Costes et al., (2008) found that the type and extent of feedback that children receive about performance greatly impact attributional beliefs, especially in girls. This reduction in attention and experience causes low confidence in girls in the classroom environment. These self-concepts impact interests, behaviors, and values. This translates into girls believing they are not adequate to respond to questions and this is perpetuated as they less willingly respond (Javanovic & King, 1998).

Fostering positive attitudes towards science is important for girls. Compared to boys, Javanovic and King (1998) found that girls seem less interested in and attach less importance to science subjects. "These attitudes are a stronger predictor of science achievement in girls than in boys" (Javanovic & King, 1998, p. 478). The authors further found that girls do not take advantage of the learning opportunities available to them in science classrooms. Javanovic and King (1998) found that boys are more active, involved, and leading participants in experiments than girls. Girls more often take passive roles in experimentation such as organizing equipment or logging data. Boys had their hands on equipment more than girls. This reflects the traditional idea that boys tend to monopolize resources. The result is that girls sit back and observe, rather than take active roles. The good news is, that when girls took active, leading roles such as explaining a task, their science ability perception improved.

This classroom experience is exacerbated by the social and cultural experiences that girls have. Girls make comparative judgments about their academic interests and performance. Consequently, boys do not make these kinds of comparative judgments. This success expectancy as defined by Watt (2004), is the perception of how well one perceives they will perform an impending task. During a school year, girls perceived themselves as better at non-science subjects and tasks. By the time they have reached middle school, a significant number of girls have formed identity beliefs that science and mathematics careers are not interesting or valuable. Adults other than teachers and parents can impact girls' science competence beliefs as well. For example, a neighboring parent expressing displeasure at their daughter's friend enrolling in advanced placement biology will have a social, cultural, and emotional impact. As if this were not enough, peers and social grouping also impact girls' perception of their interests, values, and worth. "As long as ability in mathematics and physical sciences is viewed as incongruous with a feminine identity, it is not surprising that girls are turning to other areas in which to excel as they reach adolescence" (Kurtz-Costes et al., 2008, p. 405).

Female PST Attitudes Toward Science

The PSTs in my class support the research that they have low self-confidence in their science teaching abilities. "Teacher efficacy is a self-judgment of his or her capabilities to bring about desired outcomes of student engagement and learning even among those students who are difficult or unmotivated" (Arigbabu & Oludipe, 2010, p.28). We see that as girls matriculate to college, many of them chose non-science courses, degrees, and professions. Much of this decision-making is influenced by life experiences, school experiences, and envisioning oneself as successful and effective. Personality characteristics pre-dispose people to view their life experiences in certain ways (Arigbabu & Oludipe, 2010). Students entering professions in education further build their views of inquiry and self-image as future teachers during pedagogy and most importantly, science teaching methodology courses. Those female pre-service teachers who are better at envisioning themselves as science teachers gained more from their programs (Roberts-Harris, 2014). Those that are confident in their scientific competence and abilities have a high self-efficacy. Decker (2008) found that:

1. Outgoing pre-service teachers had a higher self-efficacy than those who were not outgoing.
2. Those with negative affect and anxiety were less confident in their teaching abilities.
3. Education courses that helped teachers explore and understand their own personality proved helpful in their efficacy.

Efficacious teachers persist longer with difficult children, plan more frequently, and are less critical of student errors (Arigbabu & Oludipe, 2010). As I observed in 30 years of teacher observations, students learn more from teachers with high self-efficacy.

The fact that I am a male professor teaching a class of all-female pre-service, elementary science teachers has an impact on this self-efficacy as well. Having same-gender instructors at the college level increases the performance of college students. Furthermore, a same-gender instructor can influence higher student outcomes by increasing expectations, motivation, and adjusting to learning styles that are aligned with gender (Artz & Welsch, 2014). The authors found that female college students learn better with female professors. The good news is that as the female proportion in a class increases, the negative impact of a male instructor decreases to the point of no effect at all. I can say that after having a class of only female PSTs this observation holds. With the research supporting what I initially observed when every one of my students stated they did not like science, and why science content knowledge is limited, I will describe the techniques I employed to create and deliver a Science Content course.

PST Science Content Knowledge

Long, (2019) found that a common refrain from PSTs, and that I have heard repeated from all my aspiring teachers is that science is difficult, intimidating, and/or uninteresting. Long further references several studies that confirm these beliefs and verify what I heard from my PSTs before teaching my content course (Appleton, 2006, Howes, 2002, Kazempour & Sadler, 2015, Kelly, 2000, Liang & Gabel, 2005). Furthermore, PSTs with positive dispositions toward science and the ability to envision themselves as effective science teachers allowed them to remedy these negative beliefs, gain more from their education programs, and become a professional educator (Roberts-Harris, 2014). These negative beliefs can best be mitigated with effective science content courses for aspiring teachers.

A source of this low self-efficacy for pre-service teachers comes from several indicators about their knowledge base in science domains. Davis et al (2006) found that new teachers hold a spectrum of inaccurate science concepts and inadequate conceptions about science. As we discovered in our department examination of PST science content test performance, Davis also found that in a study of 645 preservice elementary teachers, 64% had incorrect responses on astronomy topics. The subjects of this study had misconceptions about science that mirror school-aged students. Lederman et al. (1993) found that PSTs lacked an understanding of connections between concepts in science disciplines they were to teach. Rice and Roychoudhury (2003) found that 60% of 52 preservice elementary science teachers felt their subject matter knowledge was weak. "Pre-service teachers seem, for the most part, to lack adequate understandings of science content. This trend is especially pronounced at the elementary level" (Davis et al., 2006, p.615). Davis also found that negative experiences with science alienate new teachers from science. This could lead to unsophisticated knowledge of science topics, and this knowledge would be inadequate to prepare them for teaching and could cause difficulties in portraying science appropriately.

Science Content Courses

As I prepared a Science Content course for our PSTs, it was important to understand current PST perceptions about existing science content courses. Many science content courses are discouraging to new teachers and part of the negative experience that detracts from their self-concept about teaching science. PSTs describe science content courses as one-sided, intimidating, and impersonal, with an emphasis on memorization of facts (Smith et al., 2019). Avard (2010) found that after completing college-level science courses, elementary majors could not organize an investigation to answer a scientific question. From this experience, students further report that in science content courses they felt like "second class citizens and frequently emerged with low grades and low self-esteem from what they often stated was going to be their sole exposure to science in college" (Reisert Kielbassa, 1999, p. 278). Although these indicators are discouraging, there seems to be a significant positive impact from science content courses. Smith et al. (2019) found that after a single semester of learning in a science content class focused on elementary PSTs, the students showed a statistically significant increase in their self-efficacy and outcome expectancy for teaching science.

In sum, science content courses for preservice elementary teachers, especially, have a positive impact on their science knowledge and teaching confidence. But my students report another reason for their gap in science knowledge. At the end of my science pedagogy and subsequently, the beginning of a new science content course, I asked my students why these courses bolstered their confidence levels. Every one of them reported a similar reality. Their gap in science knowledge came from a large gap in time and exposure to science concepts. All my students were juniors at the time they took the science pedagogy and content courses. They all attest that the last time they had a science class in high school was 4 to 5 years previously when they were sophomores and rarely a junior. This time gap, in addition to their experiences in high school science classes, exacerbates their feeling un-preprepared and weak in their knowledge of science. Discovering their reality and that of students in the research of science content courses, I sought to design a more engaging, empowering, impactful, and wonder-filled science content course.

A Process to Create a Science Content course

Rationale

"We need a science content course for our preservice teachers!" The education department came to this conclusion in May 2021 as we graduated a new group of future teachers. It became apparent that, while most of them earned their certification, most of our EC-6 and 4-8 Core Subject students were failing the science section of the TExES certification test. The root implication of this problem is that school-aged students suffer in the long run. We have future teachers who are seeing their assumptions about science content and teaching science come true. In their perception, they will go out into their teaching positions internalizing that they do not know science content and believing that they are not equipped to teach science. As educational preparation program mentors, coaches, and professors, we know that this is not the case and that our students are much more than a score on a state assessment. So, to improve pre-service teachers' efficacy and confidence we decided it was time to create a science survey of content and test preparation course in conjunction with a subsequent course on science pedagogy. In other words, our PSTs would first learn what to teach in science, and then, how to teach it to children. The following process is my methodology for creating from scratch, a Science Survey of Content and Test Preparation course (EDUC 3350) for Core Subjects 4-8, EC-6, and Science 4-8 pre-service teachers.

Course Design Process

1. Course Description and Proposal

To start the process of designing a course to prepare PSTs to teach elementary and middle school science, I had to first, create a course description, and propose the course to our faculty affairs committee for approval in May 2021. The course had to fit into our 71/2-week semester framework. While this may be unusual for EPPs using a

15-week semester model, our university moved to this framework in December 2019 to better accommodate our students during COVID. This condensed timeframe was familiar to us and lent itself to having a survey of content rather than an immersion in it. As stated in the course proposal, this was also a certification test preparation course, aligned to the Texas Essential Knowledge and Skills (TEKS) for those grade levels. In creating the course proposal, I knew that we only had 6 weeks to cover the content. So, as seen in figure 4, I loaded each week with competencies from the testing parameters that aligned with the TEKS.

The course was approved in June 2021 and renamed EDUC 3350, Survey of Science Content and Test Preparation. It would be offered on October 2, 2021, to Juniors which aligned well with their content test dates in January 2022. Time was now of the essence because from the approval date in June to the implementation date on October 2, the course had to be created in four months.

2. State Science Competencies

The Texas Educator Certification Examination Program is an excellent resource for PSTs seeking certification. It has very clear preparation materials including Domains and Competencies. This type of certification test in Texas covers five content areas including English Language Arts and Reading, Mathematics, Social Studies, Science, and Fine Arts. Each certification test is 5 hours long and composed of 200-210 response questions. Twenty percent of the test covers science competencies 1-18 or approximately 40 questions.

3. Course Content

With these very specific competencies, we determined that the best answer to the question: “What science content do we cover in a pre-service teacher preparation course?” was “the tested competencies.” In other words, the tested competencies became the course. Working from the test back to the curriculum is exactly what Fenwick English (2010) refers to as alignment of the curriculum through backloading. The test then becomes the curriculum which assures direct alignment between what is taught and tested. This is the proper positioning of parts in relation to each other. In modeling curriculum design for our PSTs, ideally, we match what is taught, the curriculum, to what is tested. The parts, the components of content, match up with the contents of the assessment being given. If we do not do this, then how can we properly determine the quality or fidelity of our teaching and that of the curriculum? As we compare EC-6, and 4-8 competencies from figure 1 below we see that there are 18 tested competencies in EC-6 and 23 in 4-8. This was a point of concern because I did not want to put EC-6 students at a disadvantage.

4. Content Alignment

To rectify this initial concern over missing content, I compared the 4-8 with the EC-6 competencies and found that they are the same, just numbered differently. The goal was to have 18 competencies for both tested areas so that they could fit logically into 6 weeks of instruction. As we look at the figure below, we can see where the differences lie. EC-6 competency 1 has two requirements in 4-8, competency 2 has two requirements in 4-8, competency 8 has two requirements in 4-8, competency 14 has two requirements in 4-8, and competency 16 has two requirements in 4-8. All other EC-6 competencies have a direct “partner” in 4-8. This solved the problem of missing content for EC-6 PSTs and allowed us to cover all competencies in the 6-week delivery of content.

Figure 1. *4-8 & EC-6 Core Science Competency Comparison and Alignment*

Subject Exam IV—Science (809) 4-8 Core, Science 4-8	Subject Exam IV—Science (904) EC-6
Competency 001—The teacher understands how to manage learning activities to ensure the safety of all students. Competency 002—The teacher understands the correct use of tools, materials, equipment, and technologies.	Competency 001—(Lab Processes, Equipment, and Safety): The teacher understands how to manage learning activities, tools, materials, equipment, and technologies to ensure the safety of all students.
Competency 003—The teacher understands the process of scientific inquiry and the history and nature of science. Competency 022—The teacher understands the process of scientific inquiry and its role in science instruction.	Competency 002—(History and Nature of Science): The teacher understands the history and nature of science, the process, and role of scientific inquiry, and the role of inquiry in science instruction.
Competency 004—The teacher understands how science impacts the daily lives of students and interacts with and influences personal and societal decisions.	Competency 003—(Impact of Science): The teacher understands how science impacts the daily lives of students and interacts with and influences personal and societal decisions.
Competency 005—The teacher knows and understands the unifying concepts and processes that are common to all sciences.	Competency 004—(Concepts and Processes): The teacher knows and understands the unifying concepts and processes that are common to all sciences.
Competency 021—The teacher has theoretical and practical knowledge about teaching science and about how students learn science.	Competency 005—(Students as Learners and Science Instruction): The teacher has theoretical and practical knowledge about teaching science and about how students learn science.
Competency 023—The teacher knows the varied and appropriate assessments and assessment practices to monitor science learning in laboratory, field, and classroom settings.	Competency 006—(Science Assessment): The teacher knows the varied and appropriate assessments and assessment practices for monitoring science learning in laboratory, field, and classroom settings.
Competency 006—The teacher understands forces and motion and their relationships.	Competency 007—(Forces and Motion): The teacher understands forces and motion and their relationships.
Competency 007—The teacher understands physical properties of and changes in matter. Competency 008—The teacher understands chemical properties of and changes in matter.	Competency 008—(Physical and Chemical Properties): The teacher understands the physical and chemical properties of and changes in matter
Competency 009—The teacher understands energy and interactions between matter and energy.	Competency 009—(Energy and Interactions): The teacher understands energy and interactions between matter and energy.
Competency 010—The teacher understands energy transformations and the conservation of matter and energy.	Competency 010—(Energy Transformations and Conservation): The teacher understands energy transformations and the conservation of matter and energy.
Competency 011—The teacher understands the structure and function of living things.	Competency 011—(Structure and Function of Living Things): The teacher understands the structure and function of living things.
Competency 012—The teacher understands reproduction and the mechanisms of heredity.	Competency 012—(Reproduction and the Mechanisms of Heredity): The teacher understands reproduction and the mechanisms of heredity.
Competency 013—The teacher understands adaptations of organisms and the theory of evolution.	Competency 013—(Adaptations and Evolution): The teacher understands adaptations of organisms and the theory of evolution.
Competency 014—The teacher understands regulatory mechanisms and behavior. Competency 015—The teacher understands the relationships between organisms and the environment.	Competency 014—(Organisms and the Environment): The teacher understands the relationships between organisms and the environment.
Competency 016—The teacher understands the structure and function of Earth systems.	Competency 015—(Structure and Function of Earth Systems): The teacher understands the structure and function of Earth systems.
Competency 017—The teacher understands cycles in Earth systems. Competency 020—The teacher understands the history of the Earth system.	Competency 016—(Cycles in Earth Systems): The teacher understands cycles in Earth systems.
Competency 018—The teacher understands the role of energy in weather and climate.	Competency 017—(Energy in Weather and Climate): The teacher understands the role of energy in weather and climate.
Competency 019—The teacher understands the characteristics of the solar system and the universe.	Competency 018—(Solar System and the Universe): The teacher understands the characteristics of the solar system and the universe.

Pearson Education, Inc.: Texas educator certification examination program, core subjects EC–6 (291), Subject Exam IV—Science (804). Retrieved January 19, 2021, from http://www.tx.nesinc.com/Content/StudyGuide/TX_SG_obj_291.htm#IV

5. Content Vocabulary

The natural tendency at this point in course development was to immediately create a scope and sequence for the course. But I still had content determination work to complete. There were 18 broad topics to cover in 6 weeks of delivery. For our students to be successful as future science teachers and succeed on the certification test, I determined they had to have foundational vocabulary. From interviewing our students, I found that all of them had a large gap in time from their last science course in high school. Again, Fenwick English (2010) asserts that if an externally generated testing program causes negative consequences and if a certain outcome is not attained, backloading should be used in curriculum design. Two levels of alignment, Content, and Format exist in backloading. Content alignment matches the content of the test to the curriculum being delivered. Format alignment in the curriculum of a course requires that the test design also be taught. I wanted to do both for our students. They had to be exposed to content that was tested at a knowledge and comprehension level in this specific course. They had to know the vocabulary of the content to build teaching confidence and to be able to deliver it to EC-8 students. But they also had to be exposed to testing format to be successful on the state certification test, which was heavy on vocabulary recognition and recall. I determined, as demonstrated in figure 2 below, crucial vocabulary for each competency. These vocabulary words were extracted from the outcomes in each competency. Each competency had about twenty common words that were necessary to be conversant in the topic and effective as a teacher of the topic.

Figure 2. *Vocabulary for Science Competency 001: Lab Processes, Equipment, and Safety*

Vocabulary by Competency
Subject Exam IV—Science
Competency 001—(Lab Processes, Equipment, and Safety): The teacher understands how to manage learning activities, tools, materials, equipment, and technologies to ensure the safety of all students.
1 Classroom Safety Rules
2 Scientific sample
3 Sampling methods
4 Ethical care of organisms
5 Chemical disposal
6 Chemical inventories
7 Types of lab equipment
8 Scientific Precision
9 Scientific Accuracy
10 Collection of data
11 Communication of data
12 Display of data
13 Line plot
14 bar graph
15 Circle graph (Pie chart)
16 Histogram
17 Metric system, length, volume, weight
18 Meter
19 Liter
20 Tuskegee Experiments

ISSN: 2474-3976 online

6. Formative Content Assessments

To prepare students for their certification tests over science content, it was critical to create appropriate assessments about the content that closely mirrored state test question design. This also aided in the backward design of the course or aligning content to assessment. The state content tests are classic criterion-referenced tests meant to evaluate understanding and retention. These tests determine if a student-teacher is qualified to receive a license or a certification. As noted above, the TExES certification tests cover five content areas including English Language Arts and Reading, Mathematics, Social Studies, Science, and Fine Arts. Each certification test is 5 hours long and composed of 200-210 multiple-choice questions. Twenty percent of the test covers science competencies or approximately 40 questions. I also took into consideration that this was a survey of content course for elementary teachers. We studied and sampled many test versions and found that there were no comprehensive practice tests aligned to a specific content area. As in figure 3, I created six, twenty-question tests at knowledge, comprehension, and application levels. I arrived at six practice tests because we had six weeks to deliver the content with a practice test at the end of each week. To simulate state testing conditions, these formative evaluations were timed, taken on a computer, and aligned directly to the content from the previous week.

Figure 3. *Excerpt from Created Practice Test: Competency 007*

Practice Test 4: Forces and Motion, Physical and Chemical Properties, Energy Interactions and Transformations
Question 1
5 pts
An object is being acted upon by a force of 20N directed to the left and a force of 30N directed towards the right. What is the net force on the object?
Correct Answer 10 N to the right
50 N to the left
10 N to the left
50 N to the right
Question 2
5 pts
A rocket burns fuel in bursts out of a nozzle, allowing it to maneuver and turn in the vacuum of space. Which of Newton's Laws of Motion explains how this maneuvering is possible?
Correct Answer For every action, there is an equal and opposite reaction.
An object in motion stays in motion unless an outside force acts upon it.
Fast-moving air has low pressure
An object at rest stays at rest until an outside force acts upon it.
Question 3
5 pts
Students in your class are rolling a toy convertible car down an inclined plane with a brick at the end of it. They place a small stuffed animal in the convertible unrestrained and then let the car roll down the ramp. The car hits the brick and stops but what happens to the stuffed animal and why?
Correct Answer The stuffed animal flies forward because an object in motion remains in motion unless acted upon by a force.

7. Summative Content Assessments

These six formative assessments created a bank of 120 questions from which to create a final, summative assessment at the end of the course. This culminating evaluation was again meant to simulate state testing rigor and environment. The final was a timed, 50 question assessment with each question being taken from the bank of 120 questions created by 6 formative practice tests.

8. Scope and Sequence

After identifying the required science competencies, content to be covered, foundational vocabulary, engagement techniques, and assessments, the scope and sequence of the course were created. Our university has embraced the model of two 71/2-week semesters for each fall and spring semester. As stated above, we chose 18 competencies that cover both EC-6 and 4-8 science content. These 18 competencies cover every teacher's outcome on the certification examination and align with the essential knowledge and skills of the state. With these parameters, the course sequence became a math problem.

71/2 weeks at 4 meetings per week equates to 27 face-to-face class meetings. Therefore, I needed to create 27 individual and replicable classes. These 18 competencies would be aggregated into 6 modules. I identified natural breaks in the competencies which formed the core of each module so that the content was not overwhelming for the students. In the scope and sequence, you can see the general theme for each module: 1: Science overview, 2: Science Structure, 3: Physical Science, 4: Life Science, 5: Earth Science, 6: Astronomy. At the end of each module, students took the formative assessment described above.

9. Lesson Plans

Preliminary, background, research, and planning were completed in two months. The remaining two months before launch date was dedicated to individual class planning, delivery timing, technique, and resources. All the research indicated that PSTs report content courses to be intimidating, uninteresting, confusing, one-sided, impersonal, and rote (Appleton, 2006, Avard, 2010, Davis et al., 2006, Howes, 2002, Kazempour & Sadler, 2015, Kelly, 2000, Liang & Gabel, 2005, Smith et al. 2019). To best serve our students I had to create a course that was none of, or as little as possible, like the courses described by PSTs in the research. Each class had to balance demonstration of good teaching techniques and lesson cycles and the direct presentation of science content.

10. Lesson Cycle

Each 80-minute class consistently had an anticipatory set, direct instruction, guided practice, independent practice, and closure. As seen in the example lesson plan, I allotted approximately 45 minutes of each class to content delivery and demonstration of content. Introductory and hooking activities typically received 10 minutes, and student interaction and closure 25 minutes. To alleviate students' pre-conceived attitudes toward science content courses we mandated student involvement, presentations, interaction, and reflection in each class for 35 minutes. These engaging components were strategically placed at the beginning and end of every class. The "Who am I" presentations and team reviews at the end of each module served to involve students, empower them, and tap into their creativity.

At the beginning of each module with a theme, students were issued vocabulary lists (figure 2) corresponding to competencies covered and directly aligned to content. The content focal point of each class was one of 18 power points aligned to and dependent upon content vocabulary and formative assessment. The was a very tightly aligned and interdependent system of assessment, vocabulary, and visual delivery.

Figure 4. *Scope and Sequence for EDUC 3350 Science for Teachers, Survey of Content*

Mod,Class# Date	Scope and Sequence
MOD 1 1 T O 5	Intro
2 Th O 7	**Competency 1.** (Lab Processes, Equipment, and Safety): The teacher understands how to manage learning activities, tools, materials, equipment, and technologies to ensure the safety of all students. Who am I? Professor
3 F O 8	**Practice Test 1 Comp. 1 in canvas. No class meeting**
4 M O 11	**Competency 2.** (History and Nature of Science): The teacher understands the history and nature of science, the process, and role of scientific inquiry, and the role of inquiry in science instruction. Who am I? Student Quizlet 1: Group 1
5 T O 12	**Practice Test 2 Comp. 2 in canvas. No class meeting**
MOD 2 6 Th O 14	**Competency 3.** (Impact of Science): The teacher understands how science impacts the daily lives of students and interacts with and influences personal and societal decisions. Who am I? Student
7 F O 15	**Competency 4.** (Concepts and Processes): The teacher knows and understands the unifying concepts and processes that are common to all sciences. Who am I? Student
8 M O 18	**Competency 5.** (Students as Learners and Science Instruction): The teacher has theoretical and practical knowledge about teaching science and about how students learn science. Who am I? Prez Student **Competency 6.** (Science Assessment): The teacher knows the varied and appropriate assessments and assessment practices for monitoring science learning in laboratory, field, and classroom settings. Who am I? Student Quizlet 2: Group 2
9 T O 19	**Practice Test 3 Comp. 3-6 in canvas. No class meeting**
MOD 3 10 Th O 21	**Competency 7.** (Forces and Motion): The teacher understands forces and motion and their relationships. Who am I? Student
11 F O 22	**Competency 8.** (Physical and Chemical Properties): The teacher understands the physical and chemical properties of and changes in matter. Who am I? Student
12 M O 25	**Competency 9.** (Energy and Interactions): The teacher understands energy and interactions between matter and energy. Who am I? Student
13 T O 26	**Competency 10.** (Energy Transformations and Conservation): The teacher understands energy transformations and the conservation of matter and energy. Who am I? Student Quizlet 3: Group 3
14 Th O 28	**Practice Test 4 Comp. 7-10 in canvas. No class meeting**
MOD 4 15 F O 29	**Competency 11.** (Structure and Function of Living Things): The teacher understands the structure and function of living things. Who am I? Student
MOD 5 16 M N 1	**Competency 12.** (Reproduction and the Mechanisms of Heredity): The teacher understands reproduction and the mechanisms of heredity. Who am I? Student
17 T N 2	**Competency 13.** (Adaptations and Evolution): The teacher understands adaptations of organisms and the theory of evolution. Who am I? Student
18 Th N 4	**Competency 14.** (Organisms and the Environment): The teacher understands the relationships between organisms and the environment. Who am I? Student Quizlet 4: Group 4
19 F N 5	**Practice test 5 Comp. 11-14 in canvas. No class meeting**
MOD 5 20 M N 8	**Competency 15.** (Structure and Function of Earth Systems): The teacher understands the structure and function of Earth systems. Who am I? Student

21 T N 9	**Competency 16.** (Cycles in Earth Systems): The teacher understands cycles in Earth systems. Who am I? Student
22 Th N 11	**Competency 17.** (Energy in Weather and Climate): The teacher understands the role of energy in weather and climate. Who am I? Student
23 F N 12	**Competency 17.** (Energy in Weather and Climate): The teacher understands the role of energy in weather and climate.
MOD 6 24 M N 15	**Competency 18.** (Solar System and the Universe): The teacher understands the characteristics of the solar system and the universe. Who am I? Professor Quizlet 5: Group 5
25 T N 16	**Competency 18.** (Solar System and the Universe): The teacher understands the characteristics of the solar system and the universe.
26 Th N 18	**Practice Test 6 Comp. 15-18 in canvas. No class meeting**
27 F N 19	Review
28 T N 23	Science Final: Taken in Canvas

Figure 5. *Example lesson plan for Forces and Motion*

CLASS 10 Forces and motion
100 Science Fun Fact: **There are more trees on Earth than stars in our galaxy** NASA experts believe there could be anywhere from 100 billion to 400 billion stars in the Milky Way galaxy. However, a 2015 paper published in the journal *Nature* estimated that the number of trees around the world is much higher: 3.04 trillion.
SLO: The teacher understands forces and motion and their relationships.
100-110 10 Who Am I: Liz F: **Sir Isaac Newton: force and motion**
Key Concepts and Vocab **110-215 65 Competency 7**. (Forces and Motion): The teacher understands forces and motion and their relationships. **110- 130** 20 PWP **130- 155** 25 Demonstrations 1. Demonstrates an understanding of the properties of universal forces (e.g., gravitational, electrical, magnetic). 2. Understands how to measure, graph, and describe changes in motion by using concepts of position, the direction of motion, and speed. 3. Analyzes the ways unbalanced forces acting on an object cause changes in the position or motion of the object. 4. Analyzes the relationship between force and motion in a variety of situations (e.g., simple machines, geologic processes). **155-215 20** Turn and talk vocabulary from this competency. Complete vocab chart.
215-220 5 Closure discussion How do forces and motion impact the geography of the earth? 4m Summary video: https://www.youtube.com/watch?v=hjIptNnEguI
Force and motion resources
https://www.daviesskyschools.org/userfiles/1822/Classes/27665/13-14%20Forces%20%20Motion%20Vocab.pdf
https://sciencetrek.org/sciencetrek/topics/force_and_motion/facts.cfm
https://p19cdn4static.sharpschool.com/UserFiles/Servers/Server_130900/File/What's%20new/Digital%20Learning%20Days/4th%20Grade%20Additional/Unit%206%20-%20FM%20and%20Simple%20Machines%20Reference%20Sheet.pdf

11. Content Engagement

PSTs describe science content courses as one-sided, intimidating, and impersonal, with an emphasis on memorization of facts (Smith et al., 2019). Lederman et al. (1993) found that PSTs lacked an understanding of connections between concepts in science disciplines they were to teach. Rice and Roychoudhury (2003) found that 60% of 52 preservice elementary science teachers felt their subject matter knowledge was weak. "Pre-service teachers seem, for the most part, to lack adequate understandings of science content. As I designed this course, I determined that my students not only needed to have foundational content knowledge in the form of vocabulary but that an understanding of the source of this vocabulary was important to inspire interest.

In each of the content areas from Lab Processes to Astronomy, founding scientists abound. I decided that an exploration of the scientists that created or discovered key elements of each competency would be important and engaging. Roach (1995) found that students do not embrace understanding of the nature of science. Using her story form model, historical vignettes focus on the lives of important scientists. This engagement model takes about ten minutes at the beginning of each class, provides an anticipatory set for the forthcoming content, and connects the present content with the past formation. I entitled the hooking activity as "Who am I?". Students selected a leading scientist from the list of founders of the content field. They presented a ten-minute discussion about the founding scientist and portrayed the character as if the person were present in the room. To make it even more captivating, students were required to have a "head on a stick" during their presentation. Therefore, while learning about the human connection to the nature of science, PSTs were also exposed to the content in the form of an anticipatory set.

To further engage students, the class was divided into 6 teams of 3 to create an engaging method of review before each formative practice test. The guidance for this activity was that it must include every student in the class while focusing on the vocabulary and content of the module. This was also intended to tap into creativity and fun in the classroom. The result was everything from baseball review to scavenger hunts.

Figure 6. *Excerpt from "Who am I" Founding Scientists resource for students*

WHO AM I? Scientists by Competencies
Competency 001—(Lab Processes, Equipment, and Safety): The teacher understands how to manage learning activities, tools, materials, equipment, and technologies to ensure the safety of all students.
Dr. Thomas Parran: Tuskegee Syphillis experiment https://en.wikipedia.org/wiki/Thomas_Parran_(surgeon_general) **Specimen Handling:** https://horizon.documentation.ird.fr/exl-doc/pleins_textes/divers18-05/010071550.pdf **Scientific collecting** https://en.wikipedia.org/wiki/Scientific_collection
Competency 002—(History and Nature of Science): The teacher understands the history and nature of science, the process, and role of scientific inquiry, and the role of inquiry in science instruction.
Sir Francis Bacon: Scientific Method https://en.wikipedia.org/wiki/Francis_Bacon
Competency 003—(Impact of Science): The teacher understands how science impacts the daily lives of students and interacts with and influences personal and societal decisions.
Dr. Thomas Malthus: Population growth https://en.wikipedia.org/wiki/Thomas_Robert_Malthus

12. Demonstrations/Materials

As discussed in the rationale above, the course was intended to be a survey of content and test preparation. Demonstrations were, therefore, very simple, using household materials, yet directly aligned to the vocabulary and content presentations. Demonstrations were designed to reinforce and operationalize content, vocabulary, and science concepts. In almost every case, these demonstrations were no more complex or rigorous than a typical high school Physical Science class. Classroom arrangement was the primary limiting factor in creating demonstrations. This course did not take place in a science lab because none were available. Furthermore, the classroom was separated from the education department building so that all equipment and materials had to be transported in an equipment cart. This necessitated light,

ISSN: 2474-3976 online

durable, mobile, re-useable, simple, and familiar items. Especially in the case of Physical, Chemical, Living, Earth, and Space sciences, simple kitchen supplies, toys, balls, pipe cleaners, cups, water, food coloring, play doe, wheels, and Styrofoam were primary resources. Elaborate demonstrations need not be the norm in this type of class or setting. Simple demonstrations further empowered PSTs to see that household items could be as engaging as elaborate or complex lab material. The classroom setting also empowered PSTs to see that a typical elementary classroom can function as an engaging science lab and place of discovery. As often as was possible, with space permitting, student involvement and interaction were used to heighten efficacy levels for students.

13. Classroom Layout

The Survey of Science Content course was delivered in a non-science classroom setting. The course was viewed by the registrar to be a survey course, one which did not need to be in a laboratory setting. This proved to be a logical and effective determination because the focus of the course is exposure to 18 science competencies. In a seven-week format, with four classes per week, there simply was no time to conduct full labs and the depth of the material did not necessitate this type of classroom. Had this course been assigned to a science lab, elementary PST anxiety levels would have increased and been a detractor from the goal of making this a non-threatening introduction to basic science content. When asked where I wanted to conduct the class, my choice was a non-science classroom to create a conducive environment for female students who entered with negative, pre-conceived notions of science, content courses, and labs.

The classroom layout, therefore, consisted of 10, two-person, black-top tables, a computer station, wall-mounted TV monitors, whiteboards, and a demonstration table in the front of the classroom. As discussed earlier, all demonstration material was transported to class in a wheeled cart and set up for each class meeting in the front of the classroom. When content such as forces and motion, living things, or Astronomy necessitated it, we used hallways, foyers, and external micro-environments. This type of classroom facilitated the simplicity of the demonstrations, lack of hazardous materials, and focus on content.

Results

Certification Test scores

This course was offered in Fall 2, October to November 2021. Fifteen students took the course and 7 had a science content test in December 2021 while 4 had one scheduled in Spring 1 of 2022. Every student who took their elementary content test passed the science portion of their content test. I followed up with each of the students who took their content test and asked them how the course helped them. To a person, each PST stated that they went into the test much more confident in their science knowledge. Most stated that it had been five years since they had seen any of this content and that this short survey of content filled in their knowledge gaps. While the content of these content tests is not known directly, every student conferred that many of the questions closely mirrored the content covered. Additionally, almost every student reported that, in their recollection, every course competency was covered on their test. Finally, while the exact wording of each question is never known, students also reported that the rigor and wording of the course practice test questions closely aligned with those on the test.

Efficacy

When we review what PSTs report about their perceptions, confidence in, and efficacy for science content, aspiring female teachers report low measures in each of these areas. I found that my aspiring teachers believe that science is difficult, intimidating, and uninteresting. Long, (2019) found that a common refrain from PSTs and repeated by all of my aspiring teachers is that science is difficult, intimidating, and/or uninteresting. Long further references several studies that confirm these beliefs and verify what I heard from my PSTs before teaching my content course (Appleton, 2006, Howes, 2002, Kazempour & Sadler, 2015, Kelly, 2000, Liang & Gabel, 2005). This low self-efficacy for pre-service teachers comes from several indicators about their knowledge base in science domains. Davis et al (2006) found that new teachers hold a spectrum of inaccurate science concepts and inadequate conceptions about science. PSTs also lack an understanding of connections between concepts in science and the discipline they are to teach Lederman et al. (1993). 60% of 52 pre-service elementary teachers feel their subject matter knowledge is weak Rice and Roychoudhury (2003). Finally, these negative perceptions are increased as the negative experiences with science in matriculation increase (Davis et al. 2006).

More important than any score on a standardized test is the building of confidence and efficacy in aspiring teachers. This survey of science content sought to build resilience and interest in science content for pre-service teachers. Robert-Harris (2014) found that female PSTs that are better at envisioning themselves as science teachers gained the most from their programs. Those that are confident in their science competence and abilities have a higher self-efficacy. Efficacious teachers persist longer with difficult children, plan more frequently, and are less critical of student errors (Arigbabu & Oludipe, 2010).

As I observed my PSTs in the final weeks of this course, I saw young women speaking with authority, presenting science topics with confidence, testing with reduced anxiety, and thinking like scientists.

Conclusion

Students entering professions in education build their views of ability and self-image as future teachers during pedagogy and most importantly, science teaching methodology courses. Those female pre-service teachers who are better at envisioning themselves as science teachers gained more from their programs (Roberts-Harris, 2014). But we see that as girls matriculate to college, many of them chose non-science courses, degrees, and professions. Much of this decision-making is influenced by life experiences, school experiences, and envisioning oneself as successful and effective. The female PSTs in my class verified the research that they have low self-confidence and efficacy in their science teaching abilities where teacher efficacy is a self-judgment of his or her capabilities to bring about desired outcomes of student engagement and learning. (Arigbabu & Oludipe, 2010, p.28).

PSTs in science content courses report that these preparation classes can be discouraging and part of the negative experience that detracts from their self-concept about teaching science. If not carefully designed, PSTs will go out into their teaching positions internalizing that they do not know science content and believing that they are not equipped to teach science.

Considering women's voices and perspectives, I sought to design a more engaging, empowering, impactful, and wonder-filled science content course. The process described in this practitioner-based perspective is but one possible solution to the challenge of engaging, affirming and preparing elementary female pre-service teachers for the rigors of teaching. By the end of this course however, the young women were standing taller, teaching with confidence, and speaking with conviction. Quantitatively, each one passed their content test and are now certified teachers. These results suggest that hearing women's voice and designing a course in response to those voices can, and do have a positive effect on the confidence, self-efficacy, and teaching abilities of our future teachers

References

Arigbabu, A., & Oludipe, D. (2010). Perceived efficacy beliefs of prospective Nigerian science teachers. *Journal of Science Education and Technology, 19*(1), 27-31. Retrieved January 13, 2021, from http://www.jstor.org/stable/2062774

Artz, B., & Welsch, D. (2014). The effect of peer and professor gender on college student performance. *Southern Economic Journal, 80*(3), 816-838. Retrieved January 12, 2021, from http://www.jstor.org/stable/23809653

Avard, M. (2009). Student-Centered Learning in an Earth Science, Preservice, Teacher-Education Course. *Journal of College Science Teaching*, *38*(6), 24–29. http://www.jstor.org/stable/42993313

Berwick, C. (2019). Keeping girls in STEM: 3 Barriers, 3 solutions. Retrieved January 11, 2021, from https://www.edutopia.org/article/

Bergman, D., & Morphew, J. (2015). Effects of a science content course on elementary preservice teachers' self-efficacy of teaching science. *Journal of College Science Teaching, 44*(3), 73-81. Retrieved January 13, 2021, from http://www.jstor.org/stable/43631942

English, F. W. (1992). *Deciding what to teach and test: Developing, aligning, and auditing the curriculum*. Newbury Park, Calif: Corwin Press.

Ennever, F. (2006). More than multiple-choice. *The Science Teacher, 73*(7), 54-56. Retrieved January 13, 2021, from http://www.jstor.org/stable/24140292

Gess-Newsome, Julie; Lederman, Norman G. (1993). Preservice Biology Teachers' Knowledge Structures as a Function of Professional Teacher Education: A Year-Long Assessment. *Science Education*, v77 n1 p25-45 Jan 1993

Jovanovic, J., & King, S. (1998). Boys and girls in the performance-based science classroom: Who's doing the performing? *American Educational Research Journal, 35*(3), 477-496. Retrieved January 11, 2021, from http://www.jstor.org/stable/1163445

Kelly, Janet (2000) Rethinking the elementary science methods course: a case for content, pedagogy, and informal science education, International Journal of Science Education, 22:7, 755-777, DOI: 10.1080/09500690050044080

Kurtz-Costes, B., Rowley, S., Harris-Britt, A., & Woods, T. (2008). Gender stereotypes about mathematics and science and self-perceptions of ability in late childhood and early adolescence. *Merrill-Palmer Quarterly, 54*(3), 386-409. Retrieved January 11, 2021, from http://www.jstor.org/stable/23096251

Liang, Ling & Gabel, Dorothy. (2005). Effectiveness of a Constructivist Approach to Science Instruction for Prospective Elementary Teachers. International Journal of Science Education. 27. 1143-1162. 10.1080/09500690500069442.

Mahsa Kazempour & Troy D. Sadler (2015) Pre-service teachers' science beliefs, attitudes, and self-efficacy: a multi-case study, Teaching Education, 26:3, 247-271, DOI: 10.1080/10476210.2014.996743

Monk, D. (2021). How to change female science teacher self-efficacy and attitudes toward science. *The Texas Forum of Teacher Education*. Retrieved July 6, 2022, from https://taote.wildapricot.org/Texas-Form

Pearson Education, Inc.: Texas educator certification examination program, core subjects EC–6 (291), Subject Exam IV—Science (804). Retrieved January 19, 2021, from http://www.tx.nesinc.com/Content/StudyGuide/TX_SG_obj_291.htm#IV

Reisert, P.S. , & Kielbassa, M. E. (1999). Improving science education for future teachers. *Journal of College Science Teaching. 28, 278-283.*

Rice, D.C., Roychoudhury, A. Preparing More Confident Preservice Elementary Science Teachers: One Elementary Science Methods Teacher's Self-Study. *Journal of Science Teacher Education* 14**,** 97–126 (2003). https://doi.org/10.1023/A:1023658028085

Roach, L. E., & Wandersee, J. H. (1995). *Who am I: Putting people back into science: Using historical vignettes.* School Science and Mathematics, 95(7),365-370.

Roberts-Harris, D. (2014). What did they take away?: Examining newly qualified U.S. teachers' visions of learning and teaching science in K-8 classrooms. *Teaching & Learning Inquiry: The ISSOTL Journal, 2*(2), 91-108. doi:10.2979/teachlearninqu.2.2.91

Smith, G. A., Stark, A., & Sanchez, J. (2019). What does course design mean to college science and mathematics teachers? *Journal of College Science Teaching*, *48*(4), 81–91. https://www.jstor.org/stable/26901303

Watt, Helen M. G. (2004). Development of adolescents' self-perceptions, values, and task perceptions according to gender and domain in 7th- through 11th-grade Australian students. *Child Development, 75*(5), 1556-1574. Retrieved January 13, 2021, from http://www.jstor.org/stable/3696500

ISSN: 2474-3976 online