How to Change Female Pre-Service Science Teachers' Self-Efficacy and Attitudes Toward Science

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Abstract

Female pre-service teachers' negative attitudes, attributes, and efficacy toward science are created over long-term enculturation as they matriculate from elementary school through science pedagogy classes. This narrative will explore the causes of low confidence, negative attitudes, and reduced efficacy that many female pre-service elementary teachers have toward science and science instruction. The discovery that all my pre-service elementary Science Pedagogy students not only disliked science as a subject but disdained the idea of teaching it caused me to reflect on my own teaching practices as a teacher educator. It caused me to thoughtfully deliberate and provide support and admiration to my students by design. From this deliberation, I employed techniques to change their perceptions. I changed their paradigm by building their teaching efficacy through simplifying science pedagogy expectations, creating an environment of exploratory learning with frequent encouragement, wonderment, and admiration. This article provides practical tips for changing the perceptions of female pre-service teachers about science with proven strategies from my own classroom.

Keywords: Female pre-service teacher, negative attitudes, attributes, efficacy, Science pedagogy, expectations, exploratory learning, encouragement, wonderment, admiration

Introduction

"How many of you like Science?" I asked my Science Pedagogy students on the first day of class last semester. Every one of my elementary and secondary aspiring teachers answered in the nil 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." My Science Pedagogy class was composed entirely of young ladies. 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. All of my students had experienced some type of environment in their past schooling that caused them to have an entire perspective of aversion to science and science instruction. The research on girls' and pre-service female teacher attitudes towards science verifies this observation as we will see. My mission was clear though, these future teachers were going to like, hopefully love, Science by the end of the semester and have confidence in their ability to engage elementary students. I changed their paradigm by building their teaching efficacy through simplifying science pedagogy expectations, creating an environment of exploratory learning with frequent encouragement, wonderment, and admiration.

Adolescent Female Attitudes Toward Science

"Many parents and teachers believe that boys are more capable in math and science than girls and some evidence indicate that adult stereotypes influence children's self-perception of ability and decision about math and

ISSN: 2166-0190 online

science-related education and careers" (Kurtz-Costes et al., 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 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. 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). They often report 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 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 an 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 impacts 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 "hog" 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, that 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 judgements. This success expectancy as defined by Watt (2004) is the perception of how well one perceives they will perform an impending task. During the course of a school year, girls perceived themselves as better at non-science subjects and tasks. By the time that 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 girl's 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

ISSN: 2166-0190 online

surprising that girls are turning to other areas in which to excel as they reach adolescence" (Kurtz-Costes et al., 2008, p. 405).

Female Pre-Service Teacher Attitudes Toward Science

"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). From this and the above research, 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. 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 a negative affect and anxiety were less confident in their teaching abilities.
3. Education courses that helped teachers explore and understand their own personalities 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 author 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 pre-service teachers this observation holds true. With the research supporting what I initially observed when every one of my students stated they did not like science, I will impart the techniques I employed to change their perspectives and efficacy.

Method

This inquiry and research started with an informal assessment of my 10, female, elementary Science Pedagogy students. After asking my students if they liked science and discovering that none of them did, I embarked on a mission to change this perspective. The techniques that I employed were not based on research into best practice but rather based on student needs and previous teaching experience. I had never experienced students with such a disenfranchised attitude towards science, their own abilities, and science instruction in the past. I determined that it was first imperative that my students knew what was required in the science testing standards that formed the course content. We used the excellent reference "Visible Learning for Science: What works best to optimize student learning" as our guide by (Almadore et al., 2018). I then focused on my students' efficacy by simplifying science pedagogy expectations, creating an environment of exploratory learning, encouragement, wonderment, and admiration.

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Clear Course Expectations

One of the requirements for this course was to expose students to the content test which they would take as a part of their certification. The contents of this section of their certification test and the study materials for it is easy to obtain from the Pearson Test Preparation Manual on their website. These competencies created the very structure, or outline of my course content. While these competencies are commonplace to a seasoned science teacher, they are quite daunting and would discourage any future science teacher. On the first day of class, after asking if anyone liked science, we examined these competencies together. Rather than get overwhelmed by the details, I had my students devise one or two words that best described the competency to them. So, competency 001 became science safety, 002 became science inquiry, 003 became science impact, and 013 became adaptations for example. I then demonstrated 3 to 4 of the competencies in very simple, visual, and interesting terms. The scope and sequence of the course and assignment calendar aligned to 12 of the 18 competencies. Operationally, this equated to two science themes per week with supporting and aligned demonstrations and labs. From the first day of class, students had clear expectations of what we would cover and simple, fun demonstrations to operationalize the competencies. The eighteen Science competencies are presented in Table 1 (Pearson, 2021).

Table 1

Subject Exam IV—Science (804) Competencies

Competency	Content
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.
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.
003	(Impact of Science): The teacher understands how science impacts the daily lives of students and interacts with and influences personal and societal decisions.
004	(Concepts and Processes): The teacher knows and understands the unifying concepts and processes that are common to all sciences.
005	(Students as Learners and Science Instruction): The teacher has theoretical and practical knowledge about teaching science and about how students learn science.
006	(Science Assessment): The teacher knows the varied and appropriate assessments and assessment practices for monitoring science learning in laboratory, field and classroom settings.
007	(Forces and Motion): The teacher understands forces and motion and their relationships.
008	(Physical and Chemical Properties): The teacher understands the physical and chemical properties of and changes in matter.
009	(Energy and Interactions): The teacher understands energy and interactions between matter and energy.
010	(Energy Transformations and Conservation): The teacher understands energy transformations and the conservation of matter and energy.
011	(Structure and Function of Living Things): The teacher understands the structure and function of living things.
012	(Reproduction and the Mechanisms of Heredity): The teacher understands reproduction and the mechanisms of heredity.
013	(Adaptations and Evolution): The teacher understands adaptations of organisms and the theory of evolution.
014	(Organisms and the Environment): The teacher understands the relationships between organisms and the environment.
015	(Structure and Function of Earth Systems): The teacher understands the structure and function of Earth systems.

ISSN: 2166-0190 online

016	(Cycles in Earth Systems): The teacher understands cycles in Earth systems.
017	(Energy in Weather and Climate): The teacher understands the role of energy in weather and climate.
018	(Solar System and the Universe): The teacher understands the characteristics of the solar system and the universe.

"Scientific literacy, or the knowledge and understanding of the scientific concepts and processes necessary for active engagement in society is essential for all of us to make informed decisions in our personal lives…." (Almarode et al., 2018, p. 10). Not only do pre-service teachers need tools for their toolbox but they need to understand how children learn science. *Visible learning for Science* provided my pre-service teachers with techniques and the impact or magnitude of specific techniques. This effect size describes the power of the tool used. Simply put, pre-service teachers must understand what techniques have the biggest bang for the buck. But more importantly, aspiring science teachers must understand how best to engage students in science. Almarode et al. (2018) made it very clear that students learn through a progression of surface, deep, and transfer phases. My ten pre-service science teachers were beginning to get the picture by day 2 that surface learning is developing conceptual knowledge and comprehension levels of understanding. At this level, they described and explained the formation of the Grand Canyon. Understanding deep learning helped them to realize that relationships exist in science. So, they applied their basic knowledge to analyze the relationship between erosion and weathering in the formation of the canyon. Finally, through transfer learning, my pre-service teachers understand that creating and evaluating similarities and differences for children solidifies their understanding. For example, when comparing the Grand Canyon and Palo Duro Canyon, learners begin to see the same processes working in a different setting. They transfer the processes that created the Grand Canyon to the context of another canyon. My pre-service teachers began to become scientifically literate and began to think like scientists. Once my students understood what they must know in simple, non-threatening terms and how to deliver it, I began working on their science and instructional self-efficacy. The techniques I used were not research-based at the time, they were techniques that fit my student needs. However, research supports the use of exploratory learning, encouragement, the wow factor, and admiration.

Exploratory Learning

My mission again, was to get my pre-service science teachers, all of whom expressed disdain for science, to like, hopefully love, Science by the end of the semester. Science preparation courses are weak in science, technology, engineering, and math (STEM) course requirements. Clear and consistent guidelines, content, rigor, and textbooks for science pedagogy classes are lacking across states. The use of exploratory and inquiry-based learning for pre-service teachers is supported by best practice research. Activities that require students to make observations, use their senses, ask questions, and predict outcomes are most engaging (Schmidt & Fulton, 2016). This is the approach that we took as a classroom team. We did many exploratory learning activities and demonstrations with unknown outcomes. Every week I modeled 4 demonstrations and 1 full lab. Modeling good science teaching techniques shows that we know what we are talking about, and that science teaching is attainable (Aleccia, 2011). By the end of the course, the students had a toolbox of 24 demonstrations, and 6 labs with associated reflections covering The Nature of Science, Matter, and Energy, Forces in Motion, Earth Science, Life Science, and Astronomy. Students created their own demonstration and lab plan for submission. This culminated in each student presenting their own demonstration and lab in the context of their classmates as elementary students. The overarching theme in each of these was that they required predictions, observations, and reactions with various acceptable outcomes.

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Encouragement

Successful or not, I provided encouragement to every student in their demonstrations so that even if they were not entirely effective, they felt a high level of success and support in their effort. The perception that performance has been a failure lowers self-efficacy beliefs, which contribute to the expectation that future performances will also be inept. Organizations where teachers are encouraged by their leaders and where teachers encourage one another can reverse a cycle of low self-efficacy. Performance feedback that focuses on the positive achievements of student teachers and that encourages attributes that are controllable, have a positive effect on their development of efficacy (Tschannen-Moran et al., 1998). I consciously designed and provided performance feedback that was non-judgmental. In a discussion about food chains and energy pyramids, my pre-service teachers did not know what a predator-prey relationship was. Nor could they identify an example of a predator for rabbits. This scenario was repeated in discussions about matter, planets, galaxies, and magnetism. Rather than take a critical approach to feedback, I took the path of grace, providing gentle guidance rather than negative body language, facial expression, and critique. After their demonstrations and labs, feedback focused on positive attributes while ineffective techniques or information became opportunities for change. During opportunities for classmate feedback, this atmosphere of encouragement was expected and reciprocating. So, by the end of the semester, students experienced many opportunities for success, bolstered by support, confidence, and hope.

"Wow!" Factor

Wonder is a valid part of our knowledge experiences. Science may be able to tell us about stars, but, seeing them in the night sky can evoke astonishment and the desire to seek knowledge of them. The benefit of wonder and awe in education is that it motivates a person to explore and investigate (Kearns, 2015). By design, there was a "WOW" factor in every class meeting. I ensured that in every demonstration and exploratory activity students experienced a sense of wonder for two reasons. First, this made the subject interesting. Second, it caused my students to want to know more, to explore and investigate the world of science. The absorption spectrum and P and S waves are two deliberate subjects that instilled this sense of "wow, awesome, and so cool" in my students. In the Astronomy module of my science pedagogy class, we investigated main sequence stars on the HR diagram. This could have been a mundane, worksheet-oriented demonstration. To instill this sense of wonder, I created a simple spectrometer. Not many natural phenomena evoke that sense of wonder as a beautiful and intense spectrum from white light. With the spectrometer and six-foot separation for COVID, my students observed the mercury-gas absorption spectrum from the lights in the classroom and a simple white light source. Jaws actually dropped, and the word "wowwwww" came from each student as their interest and desire to investigate further was super-charged. They wanted to know more. This was no longer intimidating information, but a fascinating realization of naturally occurring information. The study of earthquakes is equally interesting if presented in an investigative fashion. As we plotted the travel time of earthquake waves from three recording stations on a world map, the ability to pinpoint the epicenter of a tremblor became a revelation. Each student looked up from their plot at different times with their mouth agape and uttered "Oh, my, gosh!" They were hooked. No more science fear just wonder and excitement to learn more.

Admiration

As mentors of aspiring teachers, we must humble ourselves before our students. Think less of our subject and self than we do our students. In this way, we can realize the power of admiration to our student efficacy (Weisman, 2012). Similar to the encouragement above, the demonstration of student admiration is a powerful ingredient. Again, even if students were not entirely effective in their demonstrations, I made it clear to them that their efforts were valuable steps to becoming successful and that I held them in esteem for being brave enough to take a chance. Admiration of our students involves an awareness of superior good in their actions. It also suggests a desire to emulate a certain characteristic or behavior (Zagzebski, 2015). While encouragement provides support to our students, admiration provides students with a sense of worth, value, and esteem. With each student demonstration, presentation, paper, prediction, and observation I made a point to provide individualized feedback in writing that expressed respect, marvel,

ISSN: 2166-0190 online

approval, and praise. Over the course of the semester, I could visibly see my students standing taller, speaking with conviction, and teaching with confidence. In one instance, a student was so sure that a solar eclipse was caused by the shadow of the earth that she confidently demonstrated a lunar eclipse. This was an opportunity for growth but weeks before she was not even sure what an eclipse was. I required each of my students to lead the class through a comprehensive lab in a science competency of their choosing. These labs were done in the last two weeks of the class as a benchmark assessment. By this time, all my female students were able to confidently present a lab introduction, hypothesis, procedures, observations, and expected outcomes in an effective presentation that could be duplicated. All of their labs would have been effective in an elementary classroom. Again, I deliberately focused on positive attributes in their written evaluations with an abundance of approval and praise.

Conclusion

On the last day of class, I asked the question that I had in the first class meeting. "How many of you like science now?" Every student proudly announced that "I am not afraid of science now. I am confident that I will not look dumb to my students. I love science now. I know what I need to do to teach science. How does gravitational lensing happen again?" This process caused me to reflect on my own teaching practices as a teacher educator. It caused me to thoughtfully deliberate and provide support and admiration to my students by design. As a public-school teacher and administrator for 30 years, I know the impact that these newly confident teachers will have on elementary students in the classroom. Their robust teacher-efficacy will translate into engaging, exciting, and effective classroom instruction. They will be able to scaffold their students from surface learning to deep, relational understanding, and finally to solving science problems through the transfer of concepts to differing contexts. They will be able to transfer the enthusiasm and wonder of interpreting the world with their senses to children who are just beginning to understand the world around them. Through the techniques employed and student feedback provided, it is evident that student science and teaching efficacy can be improved, strengthened, and perpetuated. In this example of a pedagogy class of all-female, pre-service teachers, it is also evident that these techniques can change attitudes and perspectives that have been encultured in these students over a long period of time. Both outcomes ultimately benefit the elementary science student in the classroom.

ISSN: 2166-0190 online

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ISSN: 2166-0190 online

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Volume 11, pp. 20-28
ISSN: 2166-0190 online