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The Impact of Phenomena-Based Teaching Strategies on High School Female Students' Perceptions and Attitudes on Future Career Goals in STEM

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Abstract

Persistent gender disparities continue to limit female participation in science, technology, engineering, and mathematics (STEM), particularly in physics, engineering, and computer science. This study examined how instructional strategies, specifically phenomena-based learning (PBL), influence high school female students' perceptions, self-efficacy, and career aspirations in STEM. Guided by Bandura's Social Cognitive Learning Theory, the research was conducted at a suburban high school in Pennsylvania, where female students were notably underrepresented in physical sciences.

Using a mixed-methods, improvement-science approach, a Plan-Do-Study-Act (PDSA) cycle was implemented. Ninth-grade science teachers collaboratively designed and implemented a three-month PBL-integrated curriculum, connecting real-world phenomena to classroom content. Pre- and post-intervention surveys were used to measure changes in students' attitudes and self-efficacy, complemented by semi-structured interviews and open-ended reflections.

Quantitative findings showed that while PBL improved students' engagement and understanding of STEM concepts, it did not yield significant gains in overall self-efficacy or career aspirations. However, qualitative data revealed that hands-on, collaborative, and inquiry-based learning environments fostered more positive perceptions of STEM and increased students' confidence in their problem-solving abilities. Female students highlighted the importance of supportive teachers, relatable role models, and real-world applications in developing their interests.

The study concluded that while PBL enhances engagement, systemic interventions, including professional development for teachers, mentorship programs with female STEM professionals, and increased STEM career awareness, are essential to sustain long-term impact. This work contributes to the growing evidence that equitable STEM participation requires both instructional innovation and institutional support to empower female students as future STEM professionals.

Introduction

The underrepresentation of female students in STEM (science, technology, engineering, and mathematics) remains a persistent issue in the United States (U.S.). Despite increased efforts to promote gender equity in STEM education, data reveal that fewer female students pursue advanced physical science coursework, particularly in physics and engineering (National Science Board, 2022; Veldman et al., 2021). At Shore High School (pseudonym), a suburban high school in south-central Pennsylvania, this trend is evident in the enrollment patterns of science courses, where female students are more likely to take advanced placement (AP) biology and anatomy courses while avoiding all levels of physics and AP chemistry courses. The implications of this gender disparity are significant, as it limits female students' access to high-paying STEM careers and reduces diversity in scientific perspectives, which can impact innovation and technological advancement (Clark Blickenstaff, 2005).

National statistics support this concern, indicating that while females make up a growing share of STEM graduates, their representation in specific fields remains disproportionately low (National Science Board, 2022; Veldman et al., 2021). According to the National Science Board

(2022), women represent only 26% of computer science graduates and 16% of engineering graduates. Similar patterns are observed at the high school level, where gendered course selection affects students' trajectories into college and career pathways. Research suggests that factors contributing to this disparity include societal stereotypes, lack of female role models in STEM, and differences in self-efficacy between male and female students (Chan, 2022; Espinosa et al., 2019; Miller et al., 2018; Nugent et al., 2015). Master and Meltzoff (2020) emphasize the importance of understanding when and why female students lose interest in STEM fields to develop targeted interventions that encourage persistence and success.

Within Shore High School’s science department, an analysis of enrollment data over multiple years reveals a consistent trend: female students are underrepresented in physics and other physical science courses, despite these subjects being taught by female educators. This raises critical questions about the factors influencing female students’ academic choices. Are students avoiding these subjects due to a perceived lack of ability, the teaching methodology used, or the absence of visible career pathways? Moreover, how do teaching strategies influence female students’ perceptions of their own abilities and their motivation to pursue STEM careers?

To solve this problem, the state has issued new standards that must be implemented in K-12 classrooms. The new standards are designed to provide a more comprehensive, interdisciplinary approach to STEM education. The primary goals of the standards are to ensure that students develop critical thinking, problem-solving, and inquiry-based learning skills while fostering a deeper understanding of scientific concepts. To accomplish this, phenomena-based learning, an inquiry-driven, hands-on learning approach that has been shown to enhance student confidence and interest in STEM disciplines, is now part of the new standards and must be incorporated into all classrooms.

Phenomena-based learning has emerged as a promising strategy for increasing engagement and confidence in STEM subjects. Research suggests that PBL provides students with hands-on, real-world problem-solving experiences that can enhance motivation and persistence, particularly for female students who may feel disengaged from traditional STEM instruction (Han et al., 2014). Each PBL unit can be broken into sections, including identifying a science theme, clarifying a problem to be solved, providing an authentic role for students to play, creating an authentic scenario in which the problem occurs, and creating a culminating activity to serve as the assessment (Navy & Kaya, 2020). Many researchers agree that PBL has many advantages for teachers and students (Saad & Zainudin, 2022). Research suggests that project-based learning is a tool that can be used to improve students' self-efficacy and perception of STEM (Han et al., 2014; Saad & Zainudin, 2022). By integrating PBL into the curriculum, educators can create a more interactive and supportive learning environment that encourages female students to explore STEM fields.

This study seeks to explore the role of teaching methodologies in shaping female students’ engagement with STEM subjects, with a particular focus on the impact of phenomena-based learning (PBL) on student self-efficacy. By investigating the connection between instructional strategies and female students’ attitudes toward STEM, this research aims to identify actionable solutions for increasing female participation in STEM courses at Shore High School. Ultimately, addressing this issue has the potential to contribute to broader efforts in fostering gender equity in STEM education and the workforce. This study is guided by three primary research questions that aim to explore the relationship between teaching methodologies and female students' engagement in STEM courses:

1. Does phenomena-based learning affect high school female students' perceptions and attitudes toward pursuing higher-level science courses?
2. Does phenomena-based learning influence high school female students' self-efficacy in STEM disciplines?
3. Does phenomena-based learning have an impact on high school female students' future career goals in STEM?

Intervention Setting

Shore High School serves 944 students in grades 9 - 12. Of the total students enrolled, 53.5% are males and 46.5% are females. The students in the school are predominantly White (78.5%), with Hispanics (11.8%) as the next largest ethnicity. 26.5% of the students in the high school are classified as economically disadvantaged, 13.7% are in the special education program, and 6.5% are classified as gifted (Pennsylvania Department of Education, 2024). Table 1 summarizes the demographic student profile at Shore High School.

Table 1

Demographic Student Profile of Shore High School

Demographic Group	Percent (%) 2023-2024
Gender	
Male	53.5
Female	46.5
Race/Ethnicity	
White	78.5
Hispanic	11.8
2 or More Races	4.4
Black	2.7
Asian	2.3
American Indian/Alaskan Native	0.3
Select Populations	
Economically Disadvantaged	26.5
Special Education	13.7
English Language Learner	1.3

Note: Demographic data was retrieved from the Pennsylvania Department of Education (2024).

Students are required to complete four science credits to graduate. Two credits come from the mandatory courses, Principles of Science (9th grade) and Biology (10th grade). Additional science credits are earned through elective coursework such as Chemistry, Physics, Environmental Science, Anatomy and Physiology, and Agricultural or Veterinary Science sequences. Despite equal access to these courses, enrollment patterns show notable gender disparities, particularly in upper-level physical science courses.

Within the science department, there are a total of eight teachers with varying levels of experience, ranging from novice to over 30 years, and multiple certifications across all science disciplines. Two of the teachers teach the 9th grade Principles of Science course, and three teachers teach the 10th grade Biology course. Both of these courses are required for all high school students, with the state-mandated high school science test given after completing the

Biology course. Two teachers teach Chemistry, and one of the eight teachers teaches Physics. In addition to the core courses offered, the department provides three advanced placement (AP) courses in biology, chemistry, and physics and electives in anatomy and physiology, as well as environmental science. Of the eight total department teachers, five are females, and three are males. All teachers in the departments identify as White.

Every student in the district has a Google Chromebook computer that they are responsible for bringing to school each day. Teachers use Schoology as the learning management system, where all assignments, notes, activities, tests, and quizzes are posted for students to access. Many teachers use either the Microsoft Suite (i.e., PowerPoint, Excel, or Word) or the Google Suite (Slides, Sheets, Forms, or Docs) for notes and activities for all students. This year, the district has focused on artificial intelligence (AI) within the classroom for many professional development sessions, on how AI can be used to help teachers create better lessons and lesson plans, and how AI can benefit students.

Subjects

This study focused on the 9th-grade course Principles of Science. Due to the changing state standards in Pennsylvania, the science department had been tasked to create a new course to align with the new state requirements. The new 9th-grade course started in the 2024-2025 school year and was renamed from Earth Science to Principles of Science.

Historically, the 9th grade course has a total of approximately 230 students divided into ten sections taught yearly (see Table 2). Each class averages approximately 23 students. The 9th-grade class demographics match the school demographic data (see Table 1).

Table 2

Number of 9th-grade students and types of sections available for school years 2021-2022, 2022-2023, and 2023-2024.

School Year	Number of Students	Sections Offered
2021 - 2022	234	4 On-Level 7 Accelerated
2022 - 2023	232	4 On-Level 6 Accelerated
2023 - 2024	232	4 On-Level 6 Accelerated

Note: Data adapted from District Enrollment Data (March 2024)

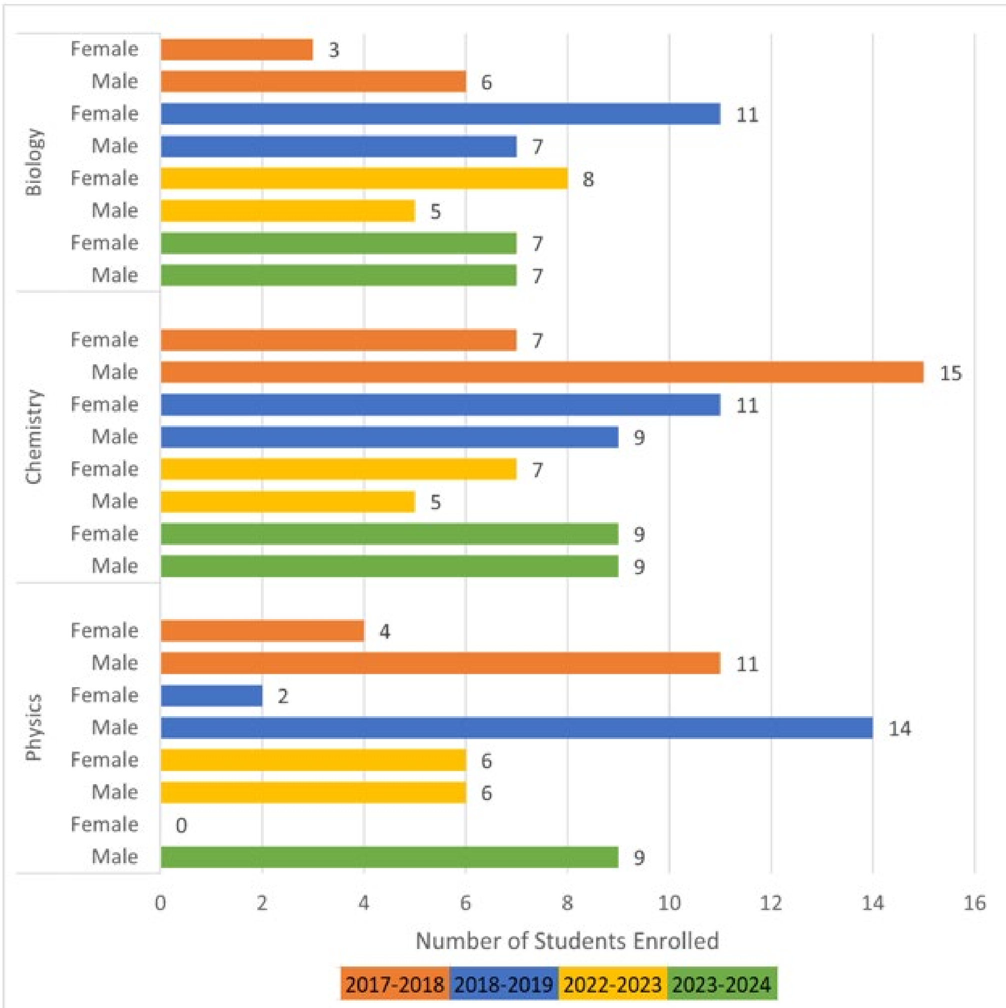
For this study, the researcher targeted all 9th-grade students taking Principles of Science in the Fall of the 2024-2025 school year. This was approximately half of the 9th-grade student population, or approximately 100 students. As this is a required course, and this data will be used by our department, all students will participate in the intervention.

An analysis of course enrollment data from the 2017–2018, 2018–2019, 2022–2023, and 2023–2024 school years (excluding COVID-19 years due to inconsistent enrollment patterns) indicates that female students are consistently underrepresented in physics-related courses. While enrollment in Advanced Placement (AP) Biology and AP Chemistry is relatively balanced by gender, AP Physics enrollment is disproportionately male. Over the four years analyzed, only 12 female students enrolled in AP Physics compared to 40 male students, with no female enrollment in the 2023–2024 school year.

Figure 1 illustrates these enrollment trends across AP science courses, highlighting the persistent gender imbalance in physics compared to the participation in biology and chemistry.

Figure 1

Number of students enrolled in Advanced Placement (AP) courses for school years 2017-2018, 2018-2019, 2022-2023, and 2023-2024, broken down by gender.



Note: Data adapted from District Enrollment Data (November 2023)

These patterns extend beyond AP coursework and reflect broader trends within the science department. Female students are more likely to enroll in life science–related electives such as Anatomy and Physiology or Veterinary Science, while male students are more represented in courses involving physical sciences and engineering concepts. This discrepancy persists despite the presence of female science teachers across all subject areas, suggesting that factors beyond teacher gender—such as student perceptions, confidence, and instructional approaches—may influence course selection.

At the time of this study, the science department was undergoing a transition to align with newly adopted Pennsylvania state science standards, which emphasize inquiry-based and phenomena-driven instruction. As part of this shift, the 9th-grade Earth Science course was redesigned into a new course titled *Principles of Science*, first implemented in the 2024–2025 school year. This course integrates phenomena-based learning as a central instructional approach, requiring students to engage in real-world problem-solving, collaborative inquiry, and application of scientific concepts.

The intervention for this study was implemented within five sections of the Principles of Science course, including both on-level and accelerated classes, with class sizes ranging from 20 to 25 students. This setting provided an opportunity to examine how a standards-aligned, phenomena-based instructional approach influences female students' perceptions, self-efficacy, and interest in STEM within a required, foundational science course.

The intervention consisted of a three-month implementation of phenomena-based learning within the 9th-grade Principles of Science course. Instruction was redesigned to center around real-world phenomena, requiring students to investigate scientific questions through collaborative, inquiry-driven activities. Across the intervention period, students engaged in multiple units that integrated core scientific concepts with authentic applications. Each unit followed a consistent structure: introduction of a phenomenon, development of guiding questions, collaborative investigation, and a culminating task or assessment. Rather than focusing on isolated lessons, the course emphasized sustained engagement with real-world problems, encouraging students to apply scientific reasoning, work collaboratively, and reflect on their learning.

Methods

This study was guided by the Plan-Do-Study-Act approach and conducted in accordance with institutional guidelines for research involving human subjects. PDSA is an iterative improvement cycle in which each phase informs the next (Hinnant-Crawford, 2020). The study aimed to address the lack of high school female students in upper-level physical science courses. The initial goal of the study included: "By the end of the 2024-2025 school year, 9th-grade female students' attitudes toward pursuing higher-level science courses and self-efficacy in STEM will increase by 10%." As I assess the impact of a new teaching methodology on students, I additionally looked at understanding other factors that contributed to both positive and negative attitudes, perceptions, and self-efficacy for students. To do this, the research study contained both quantitative and qualitative data collection approaches to investigate the current attitudes, perceptions, and self-efficacy of 9th grade high school students.

Data Collection Methods

S-STEM Survey

The Student Attitudes toward STEM (S-STEM) Survey was developed by the Friday Institute for Educational Innovation (2012), and is intended to "measure changes in students' confidence and efficacy in STEM subjects, 21st-century learning skills, and interest in STEM careers." The survey consists of 37 Likert-scale items across four domains: math (8 items), science (9 items), engineering and technology (9 items), and 21st-century learning (11 items), with responses ranging from Strongly Disagree to Strongly Agree.

Self-Efficacy Survey

The Science Motivation Questionnaire II was adapted from Glynn et al. (2011) for high school students. The 25 Likert-Scale questions are divided into five categories: intrinsic motivation, self-efficacy, self-determination, grade motivation, and career motivation. Each category has five questions, which have been randomly mixed together throughout the survey.

The surveys were given to all 9th-grade students taking Principles of Science in the Fall of 2024 using a Google Form. They were given at the beginning of the intervention as well as at the end of the intervention. This allowed the researcher to analyze the data to determine if student attitudes toward STEM have changed over the course of the intervention. All students' answers were anonymous, with each student getting a random identification number, allowing the researcher to compare data sets. The Google Form will automatically generate a spreadsheet with the data set to be analyzed. The data was then uploaded into SPSS for further analysis.

Interviews

Semi-structured interviews were done at the end of the intervention to capture students' perspectives. Purposeful sampling, specifically maximum variation sampling (Savin-Baden & Major, 2013), was used to select participants representing a range of performance levels and engagement. Although the initial goal was to interview multiple students per class, scheduling constraints resulted in a final sample of ten students. Interviews provided deeper insight into student experiences beyond survey data.

Free-Response Questions

Free-response questions were given to all 9th-grade students and analyzed qualitatively, as only a small portion of the students were to be interviewed. Therefore, these questions were used to get an overall consensus of how students were before the intervention and how their thoughts, feelings, and perceptions changed after the intervention. Responses were coded and used to find commonalities among students. Emerging ideas were grouped into themes, which were refined into three overarching themes representing students' perceptions and experiences.

Data Analysis Plan

Quantitative Data Analysis

This study used descriptive statistics, correlated t-tests, and MANOVA tests to analyze data from pre and post-intervention surveys. For the surveys, students were assigned a randomly selected number that would be unknown to the researcher but would allow for the pre- and post-survey results to be compared.

The Student Attitudes toward STEM (S-STEM) Survey (Friday Institute for Education Innovation, 2012) was used to analyze students' attitudes and career aspirations in STEM. This survey allowed students to assess themselves on each question using a 5-point Likert scale ranging from 1=strongly disagree to 5=strongly agree, with 3=neither agree nor disagree. Responses from the survey were exported into an Excel file and further uploaded into SPSS for analysis. Using the Likert scale, descriptive statistics were used to calculate the mean, median, mode, and standard deviation. These results were broken down into the four subsections of this survey: math, science, engineering and technology, and 21st-century learning.

The Science Motivation Questionnaire II, or Self-Efficacy Survey, was used to measure a change in student self-efficacy. It was adapted from Glynn et al. (2011). All students assessed themselves on a 5-point Likert scale ranging from 0=never to 4=always. Students took this survey pre- and post-intervention, and their responses were exported to an Excel file and further uploaded into SPSS for analysis. Student answers were compared using descriptive statistics to allow the researcher the opportunity to observe how student self-motivation changed over the course of the intervention.

Pre- and post-intervention data was analyzed with a *t*-test. Carroll and Carroll (2002) describe the purpose of a *t*-test as a way to "determine if there is a statistically significant difference between the mean scores of two groups" (pg. 81). As the individuals in this study are the same in both the pre-intervention survey and the post-intervention survey, a paired *t*-test was used. Data with p-value < 0.05 are determined to be statistically significant. A multivariate analysis of variance (MANOVA) test was also used to compare the effect of gender and class level on pre- and post-intervention attitudes. The calculated F-value and the F-value from the distribution table will be compared using a p-value < 0.05.

Qualitative Data Analysis

Thematic analysis was done using the semi-structured interview data and the students' free-response questions. The data collected was analyzed collectively to identify patterns. Those patterns were turned into themes named and defined, and connections and interconnections between codes were identified.

Interviews**.** Semi-structured interviews were done at the end of the intervention. The goal was to interview three female students from each of the different 9th-grade classes in Fall 2024, giving a total of fifteen student interviews. Due to timing constraints, only two students from each class were interviewed for a total of ten female student interviews. All interviews were recorded and transcribed using Otter.Ai. After each interview, the transcripts were reviewed for accuracy, and additional phrases like um, and, as well as repetitive phrases were removed. Data was then analyzed for the initial or open codes and then refined for final coding, or axial codes, by making connections and interconnections.

Free-Response Questions. Three free-response questions were included in survey administered to all 9th-grade students on paper at the beginning of the intervention. Students were given time during class to answer these questions to allow the researcher to gain insight into initial attitudes (question one), perception of science as it relates to themself (question two), and self-efficacy (question three). The questions were designed to allow students to discuss their thoughts, ideas, and feelings regarding STEM. All questions were collected and analyzed. Students used their randomly assigned code, given by their teacher and unknown to the researcher, to allow the researcher to compare their pre-intervention responses to the four post-intervention questions.

Just like with the semi-structured interviews, each question was analyzed for significant ideas and patterns. As each question was written to address a research question for this study, the themes of self-efficacy, attitudes, and perceptions of STEM are already identified, and the coding for each question will fit into one of these themes.

Validity and Trustworthiness

Quantitative validity for the two surveys was measured using Cronbach's Alpha as initially published. Cronbach's Alpha was developed in 1951 to measure the internal consistency of a test (Tavokol & Dennick, 2011). This test is used to measure the items and to what extent they all measure the same concept. Cronbach's Alpha ranges from 0 to 1, with many researchers recommending alpha values between 0.65 and 0.8, unacceptable values of 0.5 or less, and a maximum alpha value of 0.90 (Goforth, 2015; Tavokol & Dennick, 2011). In the S-STEM Survey, Cronbach's alpha was used to measure the internal consistency and reliability of the four constructs. Using the data collected in the study by Unfried et al. (2015), all four STEM constructs were found to have levels of reliability with Cronbach's alphas between 0.89 and 0.92. The Science Self-Efficacy Survey (Glynn et al., 2011) conducted reliability tests on each of the five factors. Cronbach's Alphas were found to be 0.92 for career motivation, 0.89 for intrinsic motivation, 0.88 for self-determination, 0.83 for self-efficacy, and 0.81 for grade motivation.

0.92 was found when analyzing all 25 survey items. By using the surveys as they were written and only adapting them from written to electronic, the validity and reliability of the intervention increase.

Results

Results from the quantitative and qualitative analyses are presented to evaluate the changes in students' attitudes, self-efficacy, and STEM career interests. Survey data from pre- and post-intervention measures are supported by qualitative findings from interviews and free-response responses, offering a more comprehensive understanding of students' experiences with phenomena-based learning.

Attitudes Toward Science

Reliability. Reliability analysis was conducted to assess the internal consistency of each construct within the S-STEM Survey. Science, Technology and Engineering, and 21st Century Learning had Cronbach's alpha scores greater than 0.881, indicating excellent reliability (see Table 3). The Cronbach's alpha score for Math pre-intervention was reported to be $\boldsymbol{\alpha} = 0.318$, and the post-intervention score was $\boldsymbol{\alpha} = 0.009$. Both scores indicate poor reliability. Except for the Math construct, the reliability of the scale in this study is consistent with previous research (Science $\boldsymbol{\alpha} = 0.89$, Math $\boldsymbol{\alpha} = 0.90$, Technology and Engineering $\boldsymbol{\alpha} = 0.90$, and 21st Century Learning $\boldsymbol{\alpha} = 0.92$).

Table 3
Reliability Analysis of Constructs for Pre- and Post-Intervention

	Pre-Intervention	Post-Intervention
Science	0.886	0.881
Math	0.318	0.009
Technology and Engineering	0.912	0.903
21st Century Learning	0.941	0.917

Gender Differences Pre-Intervention. To understand how the student attitudes changed throughout the first marking period due to phenomena-based learning, it was necessary to know how male and female students initially scored comparatively on the pretest by gender and by STEM construct questions. The mean Likert scale score for each construct was found for each gender to account for the different number of questions within each construct, and the mean score was calculated for all individual survey results. Comparisons were made using an Independent T-Test (Table 4) to determine whether differences were found between male and female attitudes toward STEM overall and by construct on the pre-survey. The results show that male and female students entered high school with approximately the same attitudes towards STEM. Overall, the mean scores for male and female students were males ($n = 53$), averaging 119.9, and females ($n = 52$), averaging 119.88, resulting in a nonsignificant difference ($p = 0.870$).

Table 4
Independent T-Test Analysis of Attitudes Toward STEM and by Construct before Intervention using Likert Score Responses on S-STEM Pre-Survey by Gender.

	Male (n = 53) *M*		Female (n = 52) *M*				
Construct	Σ (*SD*)	Likert	Σ (*SD*)	Likert	*t*	*p*	Level of Significance
Science	28.04 (7.64)	3.1153	28.24 (7.21)	3.1378	-0.14	0.889	No Significance
Math	24.78 (4.69)	3.0979	24.63 (3.18)	3.0793	0.189	0.850	No Significance
Technology and Engineering	31.14 (8.75)	3.4602	25.76 (5.69)	2.8622	3.727	0.000317	Significant
21st Century Learning	35.94 (8.25)	3.5943	41.25 (5.85)	4.1250	-3.794	0.000250	Significant
Total Mean Score	119.9	3.3169	119.88	3.3011	0.163	0.870	No Significance

When each of the STEM constructs was analyzed independently, a significant difference was found in both Technology and Engineering, $t(103) = 3.727$, $p = 0.000317$, and 21st Century Learning, $t(103) = -3.794$, $p = 0.000250$ (Table 4). No significant differences were found within the Science and Math constructs.

Gender Differences Post-Intervention**.** Although the post-intervention survey results showed a growth in the mean score for male students ($n = 49$) due to phenomena-based learning and a decrease in mean scores for female students ($n = 49$), the difference was still not significant ($p = 0.059$) (see Table 5). However, Technology and Engineering, $t(96) = 5.311$, $p < 0.01$, and 21st Century Learning, $t(96) = -2.02$, $p = 0.046$ were both still significant.

Gender Comparison Pre- and Post-Intervention**.** A paired t-test was used to compare how phenomena-based learning affected pre and post-intervention survey data by gender. This test was chosen as the same group of students was surveyed at the beginning and end of the intervention. When comparing pre-intervention and post-intervention by construct by gender, it was found that there were no significant differences in any of the constructs for the male and female students (see Tables 6 and 7).

Table 5
Independent T-Test Analysis of Attitudes Toward STEM and by Construct after Intervention using Likert Score Responses on S-STEM Post-Survey by Gender.

Construct	Male (n = 49) M Σ (SD)	Likert	Female (n = 49) M Σ (SD)	Likert	t	p	Level of Significance
Science	28.33 (6.89)	3.1474	27.34 (7.02)	3.0374	0.705	0.483	No Significance
Math	25.30 (3.69)	3.1620	25.22 (2.54)	3.1531	0.112	0.911	No Significance
Technology and Engineering	31.57 (7.26)	3.5079	24.61 (5.60)	2.7347	5.311	7.04×10^{-7}	Significant
21st Century Learning	37.47 (6.35)	3.7469	40.07 (6.40)	4.0071	-2.02	0.046	Significant
Total Mean Score	122.67	3.3911	117.24	3.2331	1.913	0.059	No Significance

Table 6
Paired T-Test Analysis of Attitudes Toward STEM and by Construct Pre- and Post-Intervention using Likert Score Responses on S-STEM Survey for Female Students.

Construct	Pre-Intervention (n = 52) M Σ (SD)	Likert	Post-Intervention (n = 49) M Σ (SD)	Likert	t	p	Level of Significance
Science	28.24 (7.21)	3.1032	27.34 (7.02)	3.0374	0.464	0.644	No Significance
Math	24.63 (3.18)	3.0612	25.22 (2.54)	3.1531	-1.72	0.92	No Significance
Technology and Engineering	25.76 (5.69)	2.8345	24.61 (5.60)	2.7347	0.786	0.436	No Significance
21st Century Learning	41.25 (5.85)	4.1102	40.07 (6.40)	4.0071	0.884	0.381	No Significance
Total Mean Score	119.88	3.2773	117.24	3.2331	0.869	0.389	No Significance

Table 7

Paired T-Test Analysis of Attitudes Toward STEM and by Construct Pre- and Post-Intervention using Likert Score Responses on S-STEM Survey for Male Students.

Construct	Pre-Test (n = 53) *M* Σ (*SD*)	Pre-Test Likert	Post-Test (n = 49) *M* Σ (*SD*)	Post-Test Likert	*t*	*p*	Level of Significance
Science	28.04 (7.64)	3.1451	28.33 (6.89)	3.1474	-0.13	0.989	No Significance
Math	24.78 (4.69)	3.1403	25.30 (3.69)	3.1620	-0.209	0.836	No Significance
Technology and Engineering	31.14 (8.75)	3.4830	31.57 (7.26)	3.5079	-0.151	0.881	No Significance
21st Century Learning	35.94 (8.25)	3.5755	37.47 (6.35)	3.7469	-1.129	0.265	No Significance
Total Mean Score	119.9	3.3360	122.67	3.3911	-0.507	0.614	No Significance

Further, a MANOVA Test was run to compare the effect of gender on the combined pre- and post-intervention scores for phenomena-based learning in both male and female students. The test revealed a significant difference between the pre-and post-intervention scores and gender, Wilk's Lambda = 0.580, $F(8,87) = 7.868$, $p < 0.01$ (See Table 8). The between-subjects effect of gender was significant in the pre-intervention for Technology and Engineering, $F(1, 98) = 12.459$, $p < 0.001$, and 21st Century Learning, $F(1, 98) = 9.738$, $p = 0.002$. The between-subjects effect of gender was significant in the post-intervention for Technology and engineering, $F(1, 98) = 22.151$, $p < 0.001$ (See Table 9).

Table 8

Multivariate Test Results for Gender and Class Level and Their Interaction on Pre- and Post-Intervention S-STEM Survey Results

Effect	Wilks' Lambda	*F*	*p*
Gender	0.580	7.868	<0.001
Class Level	0.534	9.477	<0.001
Gender x Class Level	0.962	0.434	0.897

Comparison of Class Level on Pre- and Post-Intervention Scores. Although the study did not specifically look at the class level of students (on-level versus accelerated), the MANOVA was able to test for relationships between this additional variable and how/if it was affected by phenomena-based learning in the classroom. The test revealed a significant difference between the pre-and post-intervention scores and class level of students, Wilk's Lambda = 0.534, $F(8,87) = 7.868$, $p < 0.01$ (See Table 8). The between-subjects effect of the class level of students was significant in the pre-intervention for science, $F(1, 98) = 12.718$, $p < 0.001$, math, $F(1, 98) = 39.533$, $p < 0.001$, and 21st Century Learning, $F(1, 98) = 4.748$, $p = 0.032$. The between-subjects effect of the class level of students was significant in the post-intervention for science, $F(1, 98) = 10.055$, $p = 0.002$, math, $F(1, 98) = 19.769$, $p < 0.001$, and 21st Century Learning, $F(1, 98) = 4.813$, $p = 0.031$ (See Table 9).

Table 9

Between-Subjects Effects of Gender and Class Level on Pre- and Post-Intervention S-STEM Survey: MANOVA Results

Dependent Variable	Effect	*F*	*p*
Pre-Intervention Science	Gender	0.214	0.645
	Class Level	12.718	<0.001
Post-Intervention Science	Gender	1.456	0.231
	Class Level	10.055	0.002
Pre-Intervention Math	Gender	1.131	0.290
	Class Level	39.533	<0.001
Post-Intervention Math	Gender	0.069	0.794
	Class Level	19.769	<0.001
Pre-Intervention Engineering	Gender	12.459	<0.001
	Class Level	0.481	0.489
Post-Intervention Engineering	Gender	22.151	<0.001
	Class Level	1.496	0.224
Pre-Intervention 21^{st} Century Learning	Gender	9.738	0.002
	Class Level	4.748	0.032
Post-Intervention 21^{st} Century Learning	Gender	2.916	0.091
	Class Level	4.813	0.031

Self-Efficacy Toward Science

Reliability. Reliability analysis was conducted to assess the internal consistency of the Science Motivation Questionnaire II Survey. Cronbach's alpha for the 25-item scale was $\boldsymbol{\alpha} = 0.935$, indicating excellent reliability. The scale's reliability in this study is consistent with previous research ($\boldsymbol{\alpha} = 0.92$).

Gender Comparison Pre- and Post-Intervention. An independent t-test was conducted to determine whether there was a significant difference in male and female students' self-efficacy in science based on phenomena-based teaching and learning before and after the intervention. The mean score before the intervention for females ($n = 52$) was $M = 67.05$, $SD = 13.50$, and after the intervention ($n = 49$) was $M = 59.12$, $SD = 20.52$. The mean score before the intervention for males ($n = 54$) was $M = 59.16$, $SD = 23.35$, and after the intervention (n = 52) was $M = 54.5$, $SD = 24.67$. The t-test showed no significant difference between pre-and post-intervention for male and female students, $t(95) = 1.466$, $p = 0.146$, with a medium effect size ($d = 0.65$) (see Table

10). These results suggest no evidence of a difference in self-efficacy between male and female students pre-and post-intervention.

Table 10
Independent T-Test Analysis of Self-Efficacy Pre- and Post-Intervention using Likert Score Responses on Science Motivation Questionnaire Survey for Male and Female Students.

Gender	Pre-Test *M* Σ (*SD*)	Pre-Test *M* Likert	Post-Test *M* Σ (*SD*)	Post-Test *M* Likert	*t*	*p*	Level of Significance
Females	67.05 (13.50)	2.6819	59.12 (20.52)	2.5094	1.918	0.644	No Significance
Males	59.16 (23.35)	2.5419	54.5 (24.67)	2.4735	0.281	0.780	No Significance
Total Mean Score	65.26 (16.57)	2.6058	62.27 (14.86)	2.5081	1.466	0.146	No Significance

Although there was no significance between males' and females' overall scores based on the phenomena-based learning, further data analysis showed that when a paired t-test was run between the questions for pre- and post-intervention, a significant difference was found between two of the questions. First, question five asked students, "I put enough effort into learning science." The results showed a significant increase in scores after the intervention, $t(95) = 2.215$, $p = 0.029$, Cohen's d =0.76. Second, question seven asked students, "Learning science will help me get a good job." The results showed a significant increase in scores after the intervention, $t(96) = 2.614$, $p = 0.010$, Cohen's d =1.3277.

STEM Identity and STEM Careers

The final section of the S-STEM Survey asked students to answer questions regarding their interest in 12 STEM Careers. The pre-and post-intervention data was separated by gender and averaged. The top five careers for each gender, pre- and post-intervention, are found in Table 11. Four of the five top careers for males pre-intervention fall in the physical STEM (pSTEM) fields, with Biology/Zoology as the outlier. Post-intervention, all five careers fall within pSTEM. In both the pre-and post-intervention, male students ranked engineering as their top career choice.

Female students had the same top five career interests in both the pre- and post-intervention, all interests falling within biological STEM fields. In both the pre-and post-intervention, Biology/Zoology ranked female students' top interest in STEM fields, with Veterinary and Medicine switching spots from pre-intervention to post-intervention.

Table 11
S-STEM Survey STEM Career Interest Scores by Gender

	Pre-Intervention		Post-Intervention	
	M	Profession	*M*	Profession
Male	2.84	Engineering	2.80	Engineering
	2.50	Mathematics	2.46	Computer Science

	2.39	Biology/Zoology	2.36	Mathematics
	2.38	Energy	2.31	Physics
	2.28	Chemistry/Physics	2.28	Energy
Female	2.79	Biology/Zoology	2.65	Biology/Zoology
	2.66	Veterinary	2.59	Medicine
	2.54	Medicine	2.53	Veterinary
	2.35	Environmental Work	2.29	Medical Science
	2.34	Medical Science	2.21	Environmental Work

Student Perspectives and Thematic Findings

Through the ten semi-structured and focus group interviews with students, several themes emerged:

1. Lessons designed with hands-on, collaborative learning promote positive perceptions of STEM for female students.
2. Role models and real-world applications are pivotal in influencing STEM career aspirations.
3. Teacher engagement and influence are significant factors in female students' enjoyment and understanding of STEM.

Theme 1: Positive perceptions of STEM for female students are promoted through lessons designed with hands-on, collaborative learning.

Throughout the ten interviews, every female student discussed their preference for the new phenomena-based teaching and learning style. This is in line with previous studies done by Navy and Kaya (2020). In their study, teachers noted more student engagement and deeper learning during the phenomena-based learning units as students could make better connections across subject areas, which can help better prepare students for the real world. In one interview conducted. Female 3 stated how she initially entered high school with the idea of going into graphic design, but this year, through the activities, subjects, and material covered, she said, “It’s definitely sparked my interest to learn more about Chemistry.”

Many of the students expressed their preference for the hands-on activities as they not only make the material more engaging but also allow them to retain the concepts and content better. For example, Female 1 stated,

> Our labs are more like, independent. Like more group work and less like the teacher leading you step by step. So, if you make a mistake, you can fix it on your own, and the teacher will not let you make mistakes. Because I feel like that’s also part of learning, is like making a mistake and then learning how to fix it.

Throughout the interviews, the students commented on the benefits of collaborative work. The female students discussed important ideas, which included relying on their partner(s) to complement their strengths and complete the labs and assignments. Female 10 said, “Working together with other people so you can hear other people's thoughts and like, I don't know, sometimes interacting with other people and getting to know them better actually helps, like me learning."

Theme 2: STEM career aspirations are heavily influenced by role models and real-world applications.

Role models play an important role in everyone's life. A female STEM professional as a role model can help young female students learn they can excel in these fields and break gender stereotypes (Dulce-Salcedo et al., 2022; Nugent et al., 2015). Every female student interviewed talked about a role model they have had in their life and how those role models have impacted their decisions to pursue the classes and career choices. These role models range from teachers (Females 1, 3, 8, and 9), immediate family members (Females 2, 4, 5, and 7), to extended members (Females 6 and 10). When Female 1 discussed her role model, she expressed,

> I like seeing how big of an impact teachers can have on kids lives and, like, if you get close with a certain teacher, they can help guide you as what you want to do, and help you pick good classes to take for the next years, where to go for a good college.

Along with role models, students need to see how their learning in the classroom can be used in their everyday lives. Female 4 explained how connecting the material to how it would work in the real world is essential to her for making learning engaging and exciting.

Together, STEM role models and real-world applications of STEM content allow female students to challenge societal and gender norms like "STEM is too hard" or "it's not for females."

Theme 3: Female students' enjoyment and understanding of STEM depend heavily on teacher engagement and influence.

Many female students repeatedly mentioned that an engaging and approachable teacher significantly impacts their enjoyment and understanding of STEM. Female 8 said,

> But I think when teachers help you or, like, work with you to get you to dive deep and figure it out, rather than them just telling you the answer, I think that really helps because then you're like, you understand it more.

Female 4 expressed that the more open and approachable the teacher was, the less scared she was of the subject and asking questions. This allows the teacher to create an environment that actively encourages the students and will enable them to see their potential in STEM fields, countering gender stereotypes and gender norms.

Discussion and Interpretation

The overall goal of this PDSA cycle was to determine if phenomena-based teaching and learning affected high school female students' perceptions, attitudes, and self-efficacy regarding STEM. The study found that creating an environment where female students can work on hands-on, collaborative assignments with applications to the real world will increase their perceptions of STEM. However, no impact was seen on female students' attitudes and self-efficacy toward STEM throughout the study. While the perceptions toward STEM increased, the intervention did not meet the overall aim of the study.

Additionally, one of the research questions explored how phenomena-based teaching and learning would impact female interest in STEM careers. The intervention had no effect on female students' interest in pSTEM careers. The findings from this study showed that female students were more passionate about careers in life sciences than physical sciences or engineering. The findings suggest that if the goal is to increase the number of female students entering pSTEM careers post-secondary, interventions must be started before students enter high school.

Although phenomena-based teaching and learning did not affect female students in ways in which the researcher was expecting, additional data was found through quantitative analysis of incoming attitudes toward different constructs of STEM. It was interesting to note that although engineering is not taught in Shore School District before high school, male students entered high school with higher attitudes toward engineering than female students.

This research study was intended to improve the attitudes, perceptions, and self-efficacy of female STEM students through a change in curriculum. The state sanctioned this change, and Shore School District proposed incorporating three-dimensional/phenomena-based learning a year early to allow our teachers to study how it affected the student population.

Quantitative data show no significant differences in attitudes, self-efficacy, and interest in STEM, especially within the pSTEM content. However, qualitative data support an increase in female students' perspectives of STEM throughout the intervention.

From the results of this study, there are several implications in the proposed state adoption of phenomena-based teaching and learning in the Principals of Science course for all 9th-grade students. The study indicates that the adoption of phenomena-based learning into the classroom may not lead to the hypothesized effects as proposed by the state. It is recommended that, for successful adoption, additional resources and training may be required prior to adoption. This is the first time students and many teachers have been exposed to this type of teaching and learning, and everyone needs time to adjust to it and excel in it.

Many modifications had to be made to each unit based on the skill level of students. In order to make sure we are meeting students where they are and growing their abilities, the high school teachers need to work with the middle school teachers to learn what content they teach, how they are teaching it, and what the estimated skill level of students would be as they enter high school. This would allow the 9th-grade teachers to update their unit plans.

The intervention should also be increased from only half the semester (nine weeks) to the whole semester (18 weeks). This would allow the research team to see a more accurate representation of how students' attitudes and self-efficacy have changed throughout the intervention. Although it was found that female students' perceptions of STEM increased with a longer intervention cycle, the data might show changes in the other two aspects of this study.

Another adaptation for future PDSA cycles would include studying the teachers. Many teachers were not familiar with this teaching methodology and therefore did not feel as comfortable teaching it. Additional teacher training on using phenomena-based strategies in the classroom seems to be needed. Along with additional training, a library of resources might help teachers find places to start when designing their unit plans.

Recommendations

To address the gender disparities in STEM participation at Shore High School, targeted interventions must be implemented to foster a more inclusive and supportive learning environment. Although an increase in students' attitudes and self-efficacy was not shown in this study, PBL is an effective teacher and learning tool in the classroom. Navy and Kaya (2020) described PBL as a type of teaching methodology with the potential to influence students' success. In their study, teachers saw a positive correlation between all students and PBL as it was integrated into the classroom. Teachers noted more student engagement and deeper learning during the PBL units as students could make better connections across subject areas.

Based on the study's findings, key recommendations focus on enhancing STEM education through professional development for educators, increasing student exposure to STEM career pathways, and integrating real-world experiences into curricula. By equipping teachers with the necessary skills to deliver interdisciplinary, phenomena-based learning activities, providing female students with role models and mentorship opportunities, and expanding hands-on STEM experiences, these initiatives aim to improve female students' perceptions, self-efficacy, and engagement in STEM fields. Overcoming existing barriers, such as resistance to change and time constraints, will require a collaborative effort among educators, administrators, and community partners to ensure long-term success and sustainability.

Future Directions

The findings from this study will serve as a foundation for future research and practice in educational leadership. One key area for future exploration is the long-term impact of PBL on female students' STEM persistence. While this study provided insights into short-term attitudinal changes, further research should investigate whether PBL leads to sustained enrollment in advanced STEM courses and, ultimately, STEM-related careers. Longitudinal studies tracking students' academic trajectories could provide valuable data on the lasting effects of PBL interventions.

Additionally, expanding the study to include a more diverse student population would enhance the generalizability of the findings. This research was conducted in a specific educational setting, and replicating the study in schools with different demographics, geographic locations, and socioeconomic conditions would provide a broader understanding of how PBL impacts female students in varied contexts. Examining intersectionality—such as the experiences of female students of color or those from low-income backgrounds—would be particularly valuable in identifying nuanced barriers and tailored interventions.

Another future direction involves increasing collaboration between schools and industry professionals to strengthen STEM career pathways for female students. Establishing partnerships with local businesses, universities, and STEM organizations can provide students with mentorship opportunities, internships, and real-world STEM experiences. Exposure to successful female role models in STEM can play a pivotal role in breaking down stereotypes and fostering confidence in young women considering STEM careers.

Finally, from a policy perspective, advocating for systemic changes in STEM education will be a priority. This includes promoting policies that mandate equitable STEM representation in curricula, supporting professional development programs that train teachers in inclusive pedagogy, and ensuring that schools have the resources needed to implement innovative teaching methodologies like phenomena-based learning. As an educational leader, I intend to use my research findings to inform district-level and state-level discussions on best practices for achieving gender equity in STEM education.

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