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A Study of High School Students' STEM Attitudes: Analyzing Changes by Gender and Grade

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ABSTRACT

This study investigated high school students' attitudes toward Science, Technology, Engineering and Mathematics (STEM). The research employed a pre- and post-test design following the implementation of a Project-Based Integrated STEM Program to examine potential changes in student attitudes. Assessment utilized a STEM attitude scale and a sub-scale measuring 21st-century skills. Data were collected from 10th, 11th and 12th-grade students across various high schools. The pre-test results showed no significant differences in STEM attitudes among students across grade levels, but male students demonstrated a notable improvement in their attitudes toward STEM. However, a comparative analysis between the pre- and post-tests revealed that participation in the program significantly improved students' perceptions of STEM and enhanced their confidence in applying STEM-related skills. These findings highlight the positive impact of project-based learning methods in fostering STEM interest in high schools. The study suggests the critical importance of integrating similar initiatives into the national curriculum to promote long-term engagement in STEM fields.

Keywords: STEM education, high schools, gender differences, grade levels

INTRODUCTION

STEM education has emerged as a crucial approach to develop 21st-century skills and meet the demands of the modern global economy. It integrates science, technology, engineering and mathematics to foster critical thinking, creativity, communication and collaboration-known as the "Four Cs" (Fajrina et al., 2020). By promoting interdisciplinary learning, STEM initiatives aim to prepare students for competitive job markets and real-world challenges (Widya et al., 2019). The Partnership for 21st Century Skills framework emphasizes these core competencies alongside traditional subjects to equip students for the knowledge-intensive economy (DeJarnette, 2012). Overall, STEM education is vital for developing a skilled workforce and driving economic growth.

Research indicates a growing emphasis on STEM education and 21st-century skills in K-12 schools, with studies developing surveys to measure student attitudes towards STEM subjects and careers. While STEM programs have been implemented across various disciplines and educational levels, there is an increasing need to emphasize STEM curricula at the high school level, where students' career interests and academic self-efficacy become more defined. Recent research highlights that the sense of belonging within STEM environments significantly shapes students' attitudes and persistence in STEM pathways (Dost, 2024). Furthermore, gender differences in attitudes towards STEM have been observed, though grade level does not significantly impact these attitudes (Perdana et al., 2021; Grewe, 2025). Interestingly, 21st-century skills have a significant effect on students' attitudes towards engineering and technology, but not science and mathematics (Istihat et al., 2020). These studies highlight the importance of understanding student attitudes before implementing skill-based learning (Perdana et al., 2021).

Despite the vital role of STEM education, the declining interest in STEM among students in many countries presents a significant threat to labor force development and economic competitiveness (Hernández-Pérez et al., 2024). This disengagement often begins during secondary schooling, driven by students' perceptions of subject difficulty and persistent misconceptions about future career prospects (Arztmann et al., 2023). To counter this trend, scholars recommend reforming STEM pedagogy through innovative methods such as gamification (Zeng, 2024) and strengthening school-industry partnerships and teacher professional communities to embed real-world contexts into instruction (Ruiz et al., 2024).

This challenge also extends to higher education, where the issue of STEM attrition remains a serious concern. Recent research indicates that introductory courses in the first year of college, especially general chemistry, often function as critical filters that contribute to students leaving or switching from STEM fields (Basu et al., 2025). Furthermore, students' confidence in their academic abilities and their sense of belonging within STEM learning environments are significant predictors of whether they continue to pursue STEM majors (Hedge, 2024). Studies have also demonstrated that preparation in mathematics during secondary education, academic ability, self-efficacy, and early exposure to STEM identity are among the strongest factors influencing persistence in STEM fields, even more so than many college experiences (Shortlidge et al., 2024).

Recent analyses raise concerns that many educational systems are still falling short in equipping learners for the demands of twenty-first century STEM careers. To improve the situation, scholars and policymakers emphasize the importance of strengthening early secondary STEM foundations, redesigning introductory university STEM courses to reduce attrition, and prioritizing robust teacher development in STEM pedagogy (Costa et al., 2022). In this context, a systematic review of STEM teacher education programs highlights that enhancing teacher content knowledge, integrating design-based learning methods, and shifting attitudes toward interdisciplinary instruction are key strategies (Agudelo Rodríguez et al., 2024; Fernández et al., 2024). Together, these recommended reforms aim to cultivate a more resilient STEM education pipeline that not only introduces STEM knowledge but also supports students in continuing along STEM pathways throughout their educational journeys.

Therefore, this study seeks to examine high school students' attitudes toward STEM and 21st-century skills, a critical stage where career interests and academic self-efficacy become more defined. Specifically, it aims to identify how factors such as gender and different dimensions of 21st-century skills influence students' attitudes toward STEM learning. The findings are expected to provide valuable insights for enhancing curriculum design, teacher professional development and educational policies that promote sustained engagement in STEM pathways at the secondary education level.

LITERATURE REVIEW

Gender Influence on Students' Attitudes Towards STEM Education

Research on student attitudes toward STEM across genders presents a complex picture of mixed results and nuanced variations. While some studies, particularly among middle school students, find no significant gender differences in overall STEM attitudes (Kucuk & Sisman, 2020; Çiftçi et al., 2020; Awoniyi & Jokotagba, 2025), others report that males hold more positive general attitudes (Weinburgh, 1995; Christensen & Knezek, 2016). Conversely, an Indonesian study found female students demonstrating more positive attitudes toward STEM components than males (Widyastuty et al., 2025). Further insights from (Papadakis, 2018) provide a qualitative content analysis of Greek computer science textbooks used in general lyceum, identifying elements of sexism and gender role stereotyping. These study underscores that textbooks often perpetuate traditional gender roles, which may influence students' perceptions of who belongs in the field of computer science. Such stereotypical portrayals can contribute to the reinforcement of gendered expectations and limit girls' sense of belonging in the discipline. This complexity is present even at the elementary level, where both genders show medium attitudes toward science, technology and 21st-century skills, but low attitudes toward mathematics (Wulandari & Putri, 2024; Hussim et al., 2024).

The most notable differences emerge in specific STEM domains and career interests, with these attitudes tending to stabilize during secondary education (Wiebe et al., 2018). Gender disparities are consistently observed, as males express higher interest in physical sciences, engineering and technology careers (Wiebe et al., 2018;

Çiftçi et al., 2020) and display greater desire and confidence in robotics (Kucuk & Sisman, 2020). Conversely, females show a preference for biological sciences and social/health-related contexts (Wiebe et al., 2018; Kahveci, 2014; Hibbard, 1983). This gender gap widens significantly by the end of high school, with boys increasingly favoring physics, technology and girls preferring biology (Baram-Tsabari & Yarden, 2011; Baram-Tsabari & Yarden, 2008). The reality in higher education shows that women are consistently underrepresented in computer science globally and at the University of Crete (Papadakis et al., 2018). Although the aptitude and achievement levels between men and women are equal, the participation rate remains unbalanced, likely due to course preferences and the potential impact of the educational environment.

This persistent underrepresentation of girls in STEM fields is linked to several factors, including social influences (Raabe et al., 2019), lower expectations of success in mathematics and a decreased likelihood of viewing mathematics positively compared to boys (McMaster et al., 2023). A significant contributing factor is the perception that STEM careers are less likely to fulfill communal goals, which women often prioritize (Diekman et al., 2010). Furthermore, female students reported more negative views of the classroom emotional climate and attitudes toward integrated STEM projects compared to males (Koul et al., 2021). Interestingly, some research suggests the intrinsic motivation toward STEM may not differ significantly between genders and females appear to respond more positively to hands-on STEM activities (Christensen & Knezek, 2016). Given the positive correlation found between STEM attitudes and career interests (Çiftçi et al., 2020), these findings highlight the urgent need for targeted interventions to address disparities. Researchers recommend strategies such as eliminating classroom bias, introducing female role models, helping girls accurately assess their abilities (Meadows, 2016), contextualizing science learning, modeling cooperative teamwork (Dare & Roehrig, 2020) and providing greater support and clearer feedback for female students during STEM projects (Koul et al., 2021).

The Influence of Age on Students’ Attitudes Towards STEM Education

Science education is a crucial component of the high school curriculum, providing a foundational understanding of STEM. At this level, it is essential to move beyond merely imparting knowledge and skills to actively cultivating a positive attitude toward STEM. This includes fostering a sense of enjoyment in the subjects, nurturing curiosity and stimulating an interest in related careers. Research indicates that students' attitudes toward STEM, particularly their enjoyment of the subjects and aspirations for future science and engineering careers, can shift significantly across grade levels (Zhou et al., 2019; Ribeirinha et al., 2025). However, a concerning trend has been observed where students' positive attitudes toward STEM tend to decline as they progress through higher grades in high school (Gok, 2021; Middleton et al., 2019). This highlights the pressing need for more engaging and inspiring STEM learning experiences, particularly during their final years of secondary education.

The influence of age on students’ attitudes toward STEM education appears to be a nuanced area with limited direct research; however, valuable insights can be drawn from related studies examining attitudes across different populations and contexts. For instance, Ridgway et al. (2018) conducted a longitudinal study with UK undergraduate nurses, revealing a significant increase in positive attitudes toward older people over the course of their program (from 75% to 98%). Although this study focused on attitudes toward aging rather than STEM specifically, it suggests that educational exposure and experience can positively influence attitudes over time, providing an analogy for age-related shifts in STEM attitudes. In the context of high school students, Martín-Ramos et al. (2017) explored the impact of peer-coaching and hands-on projects involving Arduino on students’ attitudes toward programming, a core STEM skill. While the study primarily targeted high school students' engagement, it implicitly indicates that early exposure and active participation can foster positive STEM attitudes, potentially varying with age and developmental stage. The active engagement strategies used in these initiatives could be particularly effective for younger students, suggesting that age may influence receptivity to STEM education through the level of engagement and experiential learning offered. Furthermore, Siani and Dacin (2018) highlighted that pupils’ attitudes toward STEM disciplines are influenced by their desire to understand real-life applications and interactions with scientists. These factors can themselves be affected by age-related curiosity and motivation. The study underscores the importance of contextual and experiential factors that may interact with age to shape attitudes, even though it does not explicitly analyze age as a variable. Conversely, Olujide (2008) found that demographic factors such as age did not significantly influence farmers’ attitudes toward health education programs. However, this context differs significantly from student populations and the findings may not be directly transferable. Nonetheless, it serves as a reminder that in some settings, age alone may not be a decisive factor in attitude formation. Overall, the reviewed literature indicates that age can influence students’ attitudes toward STEM education, often mediated by factors such as exposure, engagement strategies and developmental stage. Educational interventions that incorporate active participation and real-world relevance appear to be particularly effective in fostering positive attitudes across different age groups, although further targeted research is still needed to delineate the specific effects of age on STEM attitudes.

STATEMENT OF THE PROBLEM

Research Focus

STEM education has been increasingly recognized as a critical driver for equipping students with the competencies necessary to thrive in a technology-oriented and innovation-driven economy (Xia et al., 2024). High school represents a pivotal phase in students' educational trajectories, where they make important academic and career decisions that can shape their future participation in STEM-related fields (Ho et al., 2025). During these years, students' attitudes towards STEM subjects strongly influence their motivation, persistence and eventual career aspirations. Existing research has examined STEM attitudes across various educational levels; however, many studies have concentrated on early secondary or postsecondary populations, leaving a gap in the literature on the nuanced differences among high school students by gender and grade level (N. Wang et al., 2023; Hermans et al., 2022). Given that adolescence is a period of cognitive, social and emotional development, gender-related and grade-related variations in STEM attitudes may have significant implications for equity and access to STEM education. This study seeks to address these gaps by investigating the differences in STEM attitudes among high school students across grades 10 to 12 and between male and female students. Furthermore, the findings aim to provide evidence-based insights to inform the design of targeted interventions, curriculum enhancements and policy strategies that foster equitable STEM engagement.

1. The research is guided by the following questions:
2. How do high school students' attitudes towards STEM differ by gender?
3. How do high school students' attitudes towards STEM differ by grade level?

Project-based Integrated STEM Program for High School Students

The Project-based Integrated STEM Program at the high school level is increasingly recognized as an effective educational strategy to simultaneously enhance students' knowledge, skills and positive attitudes toward STEM. Unlike traditional approaches, this method organizes learning activities around interdisciplinary projects, enabling students to apply integrated STEM knowledge to address real world problems, thereby fostering autonomy and creativity. Recent empirical studies and reviews show that STEM PBL improves students' achievement, critical thinking, problem solving and attitude in high school physics and mathematics contexts (Han et al., 2016). Research indicates that project-based learning within the STEM context at the high school level not only improves critical thinking and problem-solving skills but also boosts engagement and motivation especially among students who were previously less interested in science (Santhosh et al., 2023). By engaging in tasks situated in authentic contexts students develop teamwork communication time management and design thinking skills essential competencies for twenty first century careers. However, implementing this model in high schools poses certain challenges. Teachers must be proficient in designing interdisciplinary lessons coordinating across subject areas and managing projects effectively. Studies from Vietnam and other developing contexts report that teachers face obstacles including lack of professional competence, limited time for planning, insufficient facilities and resources, and inflexible curricula (Aslam et al., 2023; Le et al., 2021). Additionally adequate facilities technological resources and sufficient instructional time are critical to ensure that students can produce high quality project outcomes. Overall, the Project based Integrated STEM Program at the high school level offers dual benefits bridging the gap between theory and practice and equipping students with lifelong learning abilities and creative capacities needed to thrive in the future workforce.

In the context of the 2018 General Education Curriculum reform, STEM education has been identified by the Ministry of Education and Training of Vietnam (MOET, 2018) as a key approach to developing competencies, qualities and 21st-century skills for high school students. In particular, the project based integrated STEM model aligns closely with the competency-based education orientation, as it encourages students to synthesize knowledge from multiple subjects such as Physics, Chemistry, Biology, Mathematics, Informatics, and Technology to address real world problems (McLure et al., 2022; Nordlöf et al., 2025). The project based integrated STEM program is designed to support STEM teaching activities at the high school level. The program includes ten projects for students in grades ten through twelve (see **Table 1**, for grade 10 projects, **Table 2**, for grade 11 projects, and **Table 3** for Grade 12 projects), and the learning process is divided into three phases:

1. Initiation and Project Orientation: Teachers introduce a topic connected to national realities (e.g., smart agriculture, renewable energy, coastal environmental protection). Students identify the problem and develop an initial research plan.
2. Implementation and Exploration: Students work in groups to design, build and test products while applying interdisciplinary knowledge. Teachers act as facilitators and advisors. This phase may last from two to four weeks, depending on the project's scope.

3. Reporting and Evaluation: Groups present their results, analyze data and receive feedback from teachers and peers. Products are evaluated based on criteria such as knowledge application, skills, creativity and practical relevance.

Table 1. Ten Project-Based Integrated STEM Topics – Grade 10

No.	Project Topic	Interdisciplinary Connections	Suggested Learning Products
1	Designing a Rainwater Harvesting System for School Use	Physics (water pressure), Technology (storage design), Mathematics (volume & flow calculations), Environmental Science	Rainwater collection model, water use report
2	Mini Solar Oven for Cooking	Physics (heat transfer, reflection), Chemistry (food safety), Mathematics (temperature measurement), Technology	Solar oven prototype, cooking experiment results
3	Organic Fertilizer from School Food Waste	Biology (decomposition), Chemistry (nutrient composition), Environmental Science, Mathematics (ratio calculations)	Fertilizer samples, composting process report
4	Model Bridge Using Local Materials	Physics (force & stress), Mathematics (geometry, load calculation), Technology (construction techniques)	Scale bridge model, load-bearing test results
5	Low-Cost Air Purifier Using Natural Materials	Physics (airflow principles), Chemistry (filtration), Biology (dust & allergen control), Mathematics (flow rate)	Air purifier prototype, air quality measurement report
6	Hydroponic Vegetable Garden in a Small Space	Biology (plant growth without soil), Chemistry (nutrient solutions), Physics (water circulation), Mathematics (growth data)	Hydroponic model, growth logbook
7	DIY Solar-Powered Water Pump	Physics (energy conversion), Technology (circuit design), Mathematics (efficiency calculation), Geography (water resources)	Working pump prototype, energy output report
8	Converting Used Cooking Oil into Soap	Chemistry (saponification reaction), Biology (skin safety), Mathematics (ingredient ratios), Environmental Science	Soap samples, chemical reaction analysis
9	Energy-Saving Classroom Fan Design	Physics (aerodynamics, motor efficiency), Technology (fan design), Mathematics (power consumption), Environmental Science	Fan prototype, cost-saving report
10	Mobile App for Reducing Plastic Waste in School	Informatics (app programming), Environmental Science, Mathematics (data analysis), Social Science (behavior change)	App prototype, waste reduction plan

Table 2. Ten Project-Based Integrated STEM Topics – Grade 11

No.	Project Topic	Interdisciplinary Connections	Suggested Learning Products
1	Designing an Automated Irrigation System Using Sensors	Physics (fluid mechanics), Technology (sensor programming), Mathematics (flow rate calculation), Biology (plant needs)	Working irrigation prototype, efficiency report
2	Generating Biogas from Agricultural Waste	Chemistry (anaerobic fermentation), Biology (microorganisms), Environmental Science, Mathematics (gas volume measurement)	Biogas system model, gas production data
3	Creating Biodegradable Packaging from Natural Materials	Chemistry (biopolymer formation), Biology (material degradation), Environmental Science, Mathematics (durability tests)	Packaging samples, biodegradability analysis
4	Smart Traffic Light System for School Zone Safety	Physics (light control), Informatics (Arduino programming), Mathematics (timing optimization), Technology	Traffic light prototype, simulation report
5	Water Desalination System Using Solar Energy	Physics (heat transfer, evaporation), Chemistry (salt removal), Mathematics (efficiency calculations), Environmental Science	Desalination unit model, water purity report
6	Designing a Low-Cost Earthquake-Resistant Building Model	Physics (vibration analysis), Mathematics (geometry & load calculation), Technology (model construction), Geography (seismic risk)	Building model, structural stability test
7	Converting Organic Waste into Biochar for Soil Improvement	Chemistry (carbonization process), Biology (soil microbes), Environmental Science, Mathematics (carbon content measurement)	Biochar samples, soil fertility report
8	Smart School Energy Monitoring System	Physics (electrical measurement), Technology (IoT sensors), Mathematics (data analysis), Environmental Science	Monitoring dashboard, energy usage report
9	Designing a Floating Farm for Flood-Prone Areas	Physics (buoyancy), Biology (aquaponics), Mathematics (area & yield calculation), Technology (construction methods)	Floating farm model, productivity report
10	Producing Bioethanol from Agricultural By-products	Chemistry (fermentation), Biology (enzymes & yeast), Mathematics (yield measurement), Environmental Science	Bioethanol samples, chemical analysis report

Table 3. Ten Project-Based Integrated STEM Topics – Grade 12

No.	Project Topic	Interdisciplinary Connections	Suggested Learning Products
1	Designing a Solar-Powered Water Purification System	Physics (solar energy conversion), Chemistry (filtration & disinfection), Environmental Science, Mathematics (efficiency analysis)	Working purification prototype, water quality report
2	Developing a Smart Greenhouse with Automated Climate Control	Physics (heat transfer), Biology (plant physiology), Technology (IoT control), Mathematics (data modeling)	Greenhouse model, growth performance report
3	Producing Hydrogen Fuel from Water via Electrolysis	Chemistry (electrolysis reactions), Physics (electricity), Environmental Science, Mathematics (yield calculation)	Hydrogen production setup, energy efficiency report
4	Designing a Drone for Environmental Monitoring	Physics (aerodynamics), Technology (drone control systems), Informatics (data transmission), Mathematics (flight optimization)	Functional drone prototype, monitoring data visualization
5	Building a School-Based Renewable Energy Microgrid	Physics (energy conversion & storage), Technology (electrical circuits), Mathematics (load balancing), Environmental Science	Microgrid model, energy usage optimization report
6	Creating an AI-Based Waste Sorting System	Technology (machine learning), Informatics (image recognition), Physics (automation), Mathematics (algorithm performance metrics)	Sorting machine prototype, accuracy analysis
7	Designing a Water-Powered Turbine for Rural Electricity	Physics (hydropower), Mathematics (turbine efficiency), Technology (mechanical design), Environmental Science	Turbine model, power generation data
8	Producing Natural Dyes from Local Plants	Chemistry (pigment extraction), Biology (botany), Environmental Science, Mathematics (color fastness testing)	Dye samples, chemical composition report
9	Developing a Flood Early Warning System	Physics (sensor systems), Geography (flood mapping), Informatics (alert system design), Mathematics (risk modeling)	Warning system prototype, flood risk report
10	Designing a Vertical Farming System for Urban Areas	Physics (light & irrigation), Biology (plant nutrition), Technology (automation), Mathematics (yield projection)	Vertical farm model, crop yield report

RESEARCH METHODOLOGY

The research was conducted at two high schools: one in Vinh City, Nghe An province and the other in Hanoi City. Both schools were well-equipped with specialized laboratories (Physics, Chemistry, Biology) and functional classrooms, thereby meeting the experimental requirements of the study. The researchers only needed to provide some specific tools and materials when implementing the program. A total of 472 high school students (grades 10, 11, and 12) from both schools participated in the survey. The class sizes at both schools ranged from 40 to 45 students. The sample consisted of students who voluntarily joined an extracurricular program on STEM-thinking development. This sample comprised 252 boys and 220 girls. The majority of participants were high-achieving students with a keen interest in Science, Technology, Engineering and Mathematics. Most of them had already been exposed to STEM concepts through formal curriculum or extracurricular activities at school (see **Table 4**).

In this study, the Project-based Integrated STEM Program was implemented during the second semester of the 2024-2025 academic year. The entire program, consisting of ten STEM projects for each grade level, lasted 12 weeks. To investigate how high school students' attitudes toward STEM differ by gender and grade, and what changes the proposed program might bring about, we administered a 45-minute pre-test and post-test on students' STEM attitudes. The pre-test was conducted in the first week, before the first STEM project began. The post-test was administered at the conclusion of the final STEM project in the 12th week. A questionnaire, Q-STEM, developed by a research team at Purdue University (Guzey et al., 2014), was utilized for both pre-test and post-test to measure student attitudes toward science, technology, engineering, and mathematics. The items on attitudes toward 21st-century skills were sourced from the Wulandari & Putri (2024) questionnaire. The entire questionnaire comprised 27 items (V1-V27) assessing students' STEM attitudes, while the remaining 11 items (V28-38) constituted the 21st-century skills subscale.

Table 4. General information about the survey sample

Variable	Item	Frequency	Percent
Gender	Male	252	53.4
	Female	220	46.6
Educational level	Tenth grade	160	33.9
	Eleventh grade	160	33.9
	Twelveth grade	152	32.2
Tenth grade	Male	85	18.0
	Female	75	15.9
Eleventh grade	Male	85	18.0
	Female	75	15.9
Twelveth grade	Male	82	17.4
	Female	70	14.8
Total		472	100

DATA ANALYSIS

Data from students' Q-STEM performance were described using mean scores and standard deviations. The reliability of the Q-STEM questionnaire for both the pre-test and post-test was estimated using Cronbach's alpha coefficients. The Cronbach's alpha coefficients were 0.896 and 0.907 for the pre-test and post-test, respectively, indicating sufficient consistency in the results of the two tests in this study. The data supported the use of the Q-STEM questionnaire for the research. A t-test was applied to examine whether there were significant differences between male and female students, or between lower and upper primary school students. Additionally, a t-test was also used to test for significant differences between the pre-test and post-test.

Research Findings

The overall mean score of students on the Q-STEM pre-test was generally positive. A central objective of this study was to investigate whether high school students demonstrate differential attitudes toward science, technology, engineering and mathematics. To this end, student performance on the Q-STEM pre-test was compared across gender and grade level. **Table 5** reports the mean scores for each subgroup along with the results of independent-samples t-tests. The findings revealed no statistically significant differences between male and female students ($t = 0.26$, $p = 0.812$; males: $M = 7.65$, $SD = 0.68$; females: $M = 7.64$, $SD = 0.57$) or between students in tenth grade and twelveth grade ($t = 1.65$, $p = 0.121$; tenth grade: $M = 7.74$, $SD = 0.59$; twelveth grade: $M = 7.56$, $SD = 0.65$).

Table 5. Q-STEM Pre-test Results by Group

Subscales	Groups	M (SD)	t	p	Effect Size
The whole Q-STEM	Males	7.65 (.68)	.26	.812	.041
	Females	7.64 (.57)			
	Tenth grade	7.74 (.59)	1.65	.121	.236
	Eleventh grade	7.57 (.65)			
	Twelveth grade	7.56 (.65)			
STEM	Males	7.65 (.66)	1.28	.214	.203
	Females	7.58 (.54)			
	Tenth grade	7.73 (.60)	2.09	.042	.311
	Eleventh grade	7.58 (.62)			
	Twelveth grade	7.59 (.64)			
21st century skills	Males	7.65 (.86)	-1.56	.137	-.245
	Females	7.89 (.79)			
	Tenth grade	7.78 (.82)	.35	.729	.054
	Eleventh grade	7.69 (.88)			
	Twelveth grade	7.67 (.89)			

To further examine the differences in students' performance across the STEM and 21st-century skills subscales of the Q-STEM, the data within each subscale were categorized into groups based on gender and grade level. For the STEM subscale, the statistical test ($t = 1.28$, $p = 0.214$) indicated no significant difference between male and female students, with males scoring $M = 7.65$, $SD = 0.66$ and females scoring $M = 7.58$, $SD = 0.54$. However, a statistically significant difference was observed across grade levels ($t = 2.09$, $p = 0.042$). Specifically, tenth-grade students ($M = 7.73$, $SD = 0.60$) scored significantly higher than eleventh-grade students ($M = 7.58$, SD = 0.62) and twelfth-grade students (M = 7.59, SD = 0.64). For the 21st-century skills subscale of the Q-STEM, no statistically significant differences were identified between male and female students (t = -1.56, p = 0.137; males: M = 7.65, SD = 0.86; females: M = 7.89, SD = 0.79) or across grade levels. Notably, male students tended to outperform female students on the overall Q-STEM and the STEM subscale, whereas female students scored higher on the 21st-century skills subscale. Nevertheless, all of these differences were statistically nonsignificant.

Another objective of this study was to examine the extent to which the proposed project-based integrated STEM program influenced high school students' attitudes toward STEM. The post-test for all students was administered after the completion of ten STEM projects in the program during the twelfth week. The mean scores and standard deviations for each group in the post-test are presented in **Table 6**. A preliminary comparison of the pre-test and post-test data indicates that students performed better in the post-test than in the pre-test. Specifically, male students had identical mean scores of 7.65 on the overall Q-STEM, the STEM subscale and the 21st-century skills subscale in the pre-test; however, their mean scores in the post-test increased substantially to 7.97, 7.86 and 8.15, respectively. With respect to the 21st-century skills subscale, the mean scores for all groups approached 9, with values of 8.15, 8.12, 8.15, 8.18 and 8.19 for male students, female students, tenth graders, eleventh graders and twelfth graders, respectively.

Independent-samples t-tests were employed to examine significant differences between the pre-test and post-test, as presented in **Table 7**. For clarity, negative effect size values reported in **Table 5** and **7** should be interpreted as indicating an increase in the measured outcome at post-test (i.e., the post-test mean exceeded the pre-test mean). This convention arises because the pre-post difference was computed in the direction that produces negative values when scores improve after the intervention). Overall, a significant difference was observed on the total Q-STEM between the pre-test and post-test (t = -3.26, p = .001), indicating that high school students performed substantially better in the post-test than in the pre-test. Regarding gender, the difference was statistically significant for male students (t = -3.62, p < .001), with higher scores on the total Q-STEM in the post-test, whereas the performance of female students showed no meaningful change between the two tests (t = -0.03, p = .980). With respect to grade level, students across both lower and upper grades performed better on the total Q-STEM in the post-test compared to the pre-test (Tenth grade: t = -1.76, p = .075; Eleventh grade: t = -2.64, p = .010; Twelveth grade: t = -2.67, p = .015). These findings suggest that, with the exception of female students, all other groups demonstrated significantly improved performance on the total Q-STEM in the post-test.

Table 6. Q-STEM Post-test Results by Group

Groups	The whole Q-STEM M (SD)	STEM M (SD)	21st century skills M (SD)
All participants	7.97 (.58)	7.86 (.63)	8.15 (.68)
Males	7.98 (.57)	7.95 (.64)	8.17 (.67)
Females	7.89 (.53)	7.78 (.58)	8.12 (.71)
Tenth grade	7.95 (.63)	7.93 (.67)	8.15 (.73)
Eleventh grade	7.92 (.52)	7.82 (.56)	8.18 (.65)
Twelveth grade	7.91 (.52)	7.81 (.54)	8.19 (.63)

Table 7. T-test (pre-post) Results

Subscales	Groups	t	p	Effect Size
The whole S-STEM	All participants	-3.26	.001	-.320
	Males	-3.62	.000	-.423
	Females	-.03	.980	-.004
	Tenth grade	-1.76	.075	-.253
	Eleventh grade	-2.64	.010	-.357
	Twelveth grade	-2.67	.015	-.359
STEM	All participants	-2.61	.011	-.253
	Males	-3.02	.004	-.351
	Females	-2.35	.741	.063
	Tenth grade	-1.42	.182	-.194
	Eleventh grade	-2.21	.036	-.289
	Twelveth grade	-2.23	.034	-.285
21st century skills	All participants	-3.45	.001	-.342
	Males	-3.69	.000	-.429
	Females	-.68	.501	-.131
	Tenth grade	-2.12	.041	-.301
	Eleventh grade	-2.89	.004	-.391
	Twelveth grade	-2.91	.003	-.392

Discussion

The analysis of the pre-test yielded an interesting finding: high school students showed very little difference in their attitudes towards science, technology, engineering, and mathematics on the Q-STEM, regardless of gender and grade level. Recent international studies indicate that gendered responses to innovative STEM pedagogies vary considerably, depending largely on the characteristics of the intervention. Zourmpakis et al. (2024) reported distinct gender differences when contrasting adaptive gamification with traditional inquiry-based instruction, underscoring the role of pedagogical design in shaping engagement patterns. Likewise, longitudinal and structural research on educational leadership and equity shows that systemic and leadership dynamics influence how interventions yield equitable outcomes (Karakose et al., 2023). These findings suggest that the post-test gains observed among male students in this study may stem from both individual responsiveness and interactions among pedagogical design, classroom norms, and school-level leadership. Consequently, integrating adaptive or gender-responsive pedagogical strategies and reinforcing equity-oriented leadership may enhance benefits for female students in future implementations. Specifically, no significant differences were found between male and female students, or between students in the lower and upper high school grades. Analysis of the Q-STEM subscales indicated that male students demonstrated a slightly better attitude on the STEM subscale, but a slightly worse attitude on the 21st-century skills subscale compared to female students. However, neither of these differences was statistically significant.

Existing literature contains some findings related to gender differences in student attitudes towards STEM. Most studies indicate that male students have more positive attitudes towards STEM than female students (Mahoney, 2010; Suwono et al., 2019; Weinburgh, 1995). However, this research on high school students' attitudes towards STEM suggests that male and female students do not show differences in their attitudes toward either STEM or 21st-century skills. These findings align with previous research confirming similar attitudes toward STEM between male and female students (Ghasemi & Burley, 2019; Hutchinson, 2022; Erden et al., 2023; Stoet & Geary, 2018; Unfried et al., 2015).

From a grade level perspective, the pre-test yielded a discouraging finding: students in the upper high school grades performed worse than those in the lower high school grades on the entire Q-STEM, the STEM subscale, and the 21st-century skills subscale. A statistically significant difference was detected in the STEM subscale between the two groups, indicating that 10th-grade students had a much better attitude toward science, technology, engineering, and mathematics than students in Grades 11 and 12. These results strongly corroborate the finding in the literature that students' attitudes toward STEM consistently decline as grade level increases (Demi̇r et al., 2021; Al-Smadi et al., 2022; Bicer et al., 2020; Elliniadou & Sofianopoulou, 2023; Ing & Nylund-Gibson, 2017; Gok, 2021; Martinez-Borreguero et al., 2019). This highlights the limitations of the traditional education system in maintaining high school students' positive attitudes toward STEM. Consequently, it suggests that the education system needs to provide students with appropriate science and technology training to prepare them with the skills and employment needs of the 21st century.

The Effect of the Project-based Integrated STEM Program on High School Students' Attitudes Toward STEM

The Project-based Integrated STEM Program served as the core intervention to support STEM teaching activities for students from tenth to twelfth grade at the high school level in this research. The comparison between the pre-test and post-test clearly demonstrates that the Project-based Integrated STEM Program had a positive effect on students' attitudes toward STEM. Overall, students showed significant improvement in their attitudes not only on the entire Q-STEM but also on the STEM subscale and the 21st-century skills subscale in the post-test, compared to the pre-test results. Although various governments and organizations (e.g., in Australia and the United States) have emphasized the significance of STEM education and proposed different models (Ejiwale, 2013; Johnson, 2012; Murphy et al., 2018; Pressick-Kilborn et al., 2021), this study provides strong empirical evidence that the implementation of the Project-based Integrated STEM Program is effective for high school students. These findings are highly encouraging and suggest that more specialized STEM programs and integrated STEM curricula should be proposed and implemented more widely at all educational stages, including the high school level.

In a further analysis of the differences in student attitudes toward STEM between the pre-test and post-test, the findings revealed unique results from the perspectives of gender and grade level. Regarding gender, male students significantly improved their attitudes toward STEM in the post-test compared to the pre-test. They showed statistically significant improvement on the whole Q-STEM, the STEM subscale, and the 21st-century skills subscale between the two tests. However, the attitudes of female students on either the whole Q-STEM or the two subscales did not significantly differ from those in the pre-test. No significant difference was consistently detected between the pre-test and post-test for female students. While male and female students did not differ significantly in the pre-test, the data show that male students achieved much higher scores in the post-test than female students, especially on the whole Q-STEM ($t=3.57$, $p=0.001$) and the STEM subscale ($t=4.45$, $p=0.000$). From the perspective of the female students, who participated in ten STEM projects identical to those of the male students in the same grade, the Project-based Integrated STEM Program was not effective in fostering a positive change in their attitudes toward STEM. This outcome is consistent with previous research results suggesting that male students are often more inspired to succeed in science than female students (Hykle, 1993; Simpson & Oliver, 1985). Furthermore, this lack of improvement among female students aligns with previous studies, which found that female students tended to prefer fewer STEM lessons and report more unfavorable attitudes toward STEM (Ertl et al., 2017; Koul et al., 2021; Gardiner, 2023; Steffen et al., 2023; Goedecke, 2024; Widyastuty et al., 2025).

According to the data, all students showed a positive change on the entire Q-STEM. This indicates that the proposed Project-based Integrated STEM Program has achieved significant overall effectiveness in improving attitudes toward STEM for students in all grade groups. Specifically, the difference between the pre-test and post-test on the entire Q-STEM and the 21st-century skills subscale for upper high school students (Grades 11 and 12) was statistically significant ($p<0.01$). It was also observed that 11th and 12th-grade students showed significant gains on the STEM subscale in the post-test, while 10th-grade students did not show a statistically significant difference in their attitudes toward STEM between the pre-test and post-test. Despite the disappointing pre-test result that 11th and 12th-grade students performed worse than 10th-grade students on all three scales, the Program fostered more positive changes for 11th and 12th-grade students than for 10th-grade students in the post-test. This result is encouraging because it shows that even though upper high school students may initially show less favorable attitudes or interest in STEM, they can develop more positive attitudes and interest by studying STEM-related projects. Conversely, close attention must be paid to the 10th-grade students, who did not show significant improvement on the STEM subscale in the post-test. It is worth reflecting on why 10th-grade students achieved significant improvement on the entire Q-STEM and the 21st-century skills subscale, yet showed no positive change on the STEM subscale. All procedural details, including content settings, project implementation approaches, and schedule arrangements of the Project-based Integrated STEM Program, warrant review. For 10th-grade students, developing suitable programs to improve their attitudes toward STEM will be a challenging and encouraging task in future research.

The findings yield several implications for educators and policymakers seeking to strengthen STEM education in secondary schools:

- Integrate gender-inclusive teaching practices that challenge traditional stereotypes and highlight female role models in STEM disciplines.
- Adopt project-based and inquiry-driven learning models that emphasize collaboration, creativity, and real-world problem solving.
- Provide professional development for teachers to design equitable, competency-based STEM curricula aligned with national standards.
- Strengthen partnerships between schools and industry to increase student awareness of diverse STEM career pathways.
- These strategies can help bridge the gap between theory and practice, fostering more equitable and engaging STEM learning environments.

CONCLUSION

The present research explored attitudes toward science, technology, engineering, and mathematics among students across all high school grade levels using the Q-STEM questionnaire for the pre-test. The results showed that high school students exhibited almost no difference in attitudes on the Q-STEM, regardless of gender and grade level. After completing ten STEM projects of the Project-based Integrated STEM Program, students showed a positive change in their overall attitudes toward STEM in the post-test. However, a deeper analysis revealed nuances: male students showed significant improvement in their attitudes toward STEM, while female students did not. Furthermore, the program promoted greater positive gains for 11th and 12th-grade students compared to 10th-grade students.

Based on these findings, future work could focus on the following critical aspect: How can we effectively improve attitudes toward STEM for female students at the high school level? According to the research data, female students participated in ten STEM projects that were identical to those of male students in the same grade, yet the Project-based Integrated STEM Program proved ineffective in fostering a positive change in their attitudes toward STEM. Therefore, designing suitable projects or curricula specifically tailored to enhance STEM attitudes for female high school students represents a challenging yet essential task for future research.

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Ethical Statement

This study was conducted in accordance with established ethical standards for research involving human participants. All participants were fully informed about the purpose and procedures of the study, and their voluntary participation and confidentiality were ensured through informed consent.

Competing Interests

The author affirms that no competing interests exist in connection with the submission and publication of this manuscript.

Author Contributions

Conceptualization, data analysis, and manuscript writing. Hang: research design, editing, and proofreading. Oanh: data collection, technical support, and final approval. Phuong: data analysis and interpretation, and final approval. Dung: data collection, financial administration, and supervision of research progress.

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