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Exploring the Factors Influencing Teachers' Perceptions and Students' Attitudes in STEM Education Development

Arifin Septiyanto[1]*, Eka Cahya Prima[2], Annisa Nur Khasanah[3], Arip Nurahman[2]

[1] Science Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Sunan Ampel, Surabaya, Indonesia
[2] Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Bandung, Indonesia
[3] Science Education, Faculty Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia

*Corresponding author: arifin.septiyanto@uinsa.ac.id

ABSTRACT The rapid evolution of information and communication technologies, combined with the growing demand for a skilled workforce in science, technology, engineering, and mathematics (STEM) fields, has underscored the importance of STEM education in shaping the future workforce. Despite its critical role, a persistent gap remains between students' academic performance in STEM subjects and their interest in pursuing STEM careers. This study investigates the dynamics of teachers' perceptions and students' attitudes towards STEM education in secondary schools in Indonesia. Using a quantitative approach with a cross-sectional design, this study examines the impact of demographic factors, including gender, educational background, and teaching experience, on teachers' perceptions, as well as how gender and grade level influence students' attitudes towards STEM. The study employed a questionnaire to measure students' attitudes toward STEM across four dimensions (science, mathematics, technology, and engineering) and teachers' perceptions across four indicators (STEM understanding, STEM competencies, STEM knowledge, and implementation challenges). The study involved 125 teachers and 447 students, with data analyzed through descriptive statistics, correlation analysis, and ANOVA. Results show that while teachers hold positive perceptions of STEM education, challenges related to resource limitations and the complexity of interdisciplinary teaching remain significant. Students' attitudes towards STEM varied, with a notable decline in positive attitudes as grade levels increased, especially in mathematics. The findings contribute to the development of more adaptive STEM education policies and practices in Indonesia, providing insights for future educational reforms.

Keywords: STEM education development, Teacher perceptions, Student attitudes, Gender differences, Grade level

1. INTRODUCTION

The rapid development of information and communication technologies in response to the global challenges of the 21st century has had a profound impact on social, economic, and educational transformations in various countries (Ergün, 2019). In an increasingly digitized global landscape, mastery of 21st-century skills, including science, technology, engineering, and mathematics (STEM) literacy, has become a key 16 prerequisite for a nation to compete sustainably (Atabey & Topcu, 2021; Firda et al., 2021). STEM is not only the foundation for technological advancement, but also plays a key role in creating superior human resources capable of driving innovation, creating new jobs, and strengthening national economic competitiveness (Ardianto et al., 2023). Therefore, the development of STEM education is a strategic priority across various 21st-century development agendas, at both the national and international levels. However, academic achievement in STEM fields is not always aligned with students' interests in pursuing careers in these fields. For example, although Vietnamese students ranked eighth in science literacy in the 2015 Programme for International Student Assessment (PISA) results, follow-up studies indicate that their interest in pursuing science- and technology-oriented professions remains relatively low (OECD, 2016). A similar situation is observed in Indonesia, where students perform well in the National Examination and the Minimum Competency Assessment (MCA). Still, enthusiasm for STEM professions has not shown a significant increase (Yamtinah et al., 2022). This finding highlights a gap between academic capabilities and

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career aspirations, which could pose a substantial obstacle to meeting future STEM workforce needs.

The gap becomes even more complex when examined in the context of global workforce dynamics. Rapid economic growth and the Industrial Revolution 4.0 have driven a significant increase in demand for STEM professionals across sectors, including renewable energy and digital technology (WEF, 2022). Unfortunately, this trend is not matched by an increase in the number of STEM graduates. Instead, some countries are experiencing a decline in student interest in science and technology fields, which may hinder long-term economic growth (Mau et al., 2019). One of the main factors contributing to this is students' low interest in STEM careers-a phenomenon exacerbated by gender inequality, professional stereotypes, and a lack of positive representation in educational settings and society (Ardianto et al., 2023; Atabey & Topcu, 2021; Balta et al., 2023; Ünlü et al., 2016). Data from the United States shows that gender inequality in the world of STEM work is still very real, where men dominate with a percentage of 65% compared to women who only reach 35% (National Center for Science and Engineering Statistics, 2023). Similar conditions exist in Indonesia, where the percentage of women in engineering programs at higher education institutions does not reach 30%. In fact, male dominance remains evident at the higher education level, particularly in master's and doctoral programs in STEM fields (Shin et al., 2018; Tamba & Chiang, 2021). This suggests that challenges in STEM development are not only cognitive but also sociocultural and structural, shaping learners' career preferences and identities from an early age. In fact, sustainable development and national economic transformation require the active involvement of young people in science and technology.

The Sustainable Development Goals (SDGs), particularly SDG 4 on quality education, emphasize the importance of an education system that not only imparts basic knowledge but also equips learners with skills and values to support sustainable development (García-González et al., 2020). In this context, STEM education is seen as a strategic vehicle for developing cross-disciplinary competencies relevant to real life and future needs. In addition to improving student learning achievement in core subjects such as math and science, the STEM approach can also foster critical thinking, collaboration, and creativity skills needed in a high-tech society (Perdana et al., 2021). Empirical studies demonstrate that implementing STEM project-based learning fosters increased interest in learning, active participation, and career readiness among students across countries (Bybee, 2013; Honey et al., 2014). However, the successful implementation of STEM education does not solely depend on the curriculum or policy. Still, it is strongly influenced by the readiness and perception of the leading actors in schools, namely, teachers and students. Teachers' role as facilitators of interdisciplinary learning is crucial to ensuring STEM principles are effectively integrated into daily learning activities. Teachers not only act as curriculum implementers, but also as agents of change who shape the culture of STEM learning in schools (Wang et al., 2011). Teachers' perceptions and beliefs about the relevance and urgency of STEM education will determine the quality of its implementation in learning. Previous studies show that teachers' perceptions of STEM can be influenced by their academic background, teaching experience, subjects taught, and exposure to STEM training or practices in the field (Nugraha et al., 2023; Rahman et al., 2023; To Khuyen et al., 2020). For Example, Margot & Kettler (2019) found that experienced teachers tend to have more positive attitudes towards STEM learning than novice teachers. However, these results were not consistent across contexts. Another study reported that teachers' perceptions of STEM did not differ significantly across groups based on experience or area of expertise (Stohlmann et al., 2012). The inconsistency of these findings suggests that the factors influencing teachers' perceptions require further exploration in a contextual setting. On the other hand, students are also important subjects in the implementation of STEM education. Their attitude towards STEM learning largely determines engagement, motivation, and future career interest. International research indicates that students' positive attitudes towards STEM subjects decrease with age or grade level (Potvin & Hasni, 2014; Zhou et al., 2019), but contextual data on this trend in Indonesia remain limited.

To date, there have been relatively few scholarly studies in Indonesia examining the simultaneous relationship between teacher and student characteristics and the implementation of STEM education. The majority of studies tend to focus on only one actor, namely, teachers or students, without examining the interaction between the two. Additionally, several quantitative studies have explicitly measured differences in teacher perceptions or student attitudes based on demographic characteristics, including gender, educational background, and grade level. Some studies suggest that teachers from science fields are more likely to adopt STEM approaches than those from non-science fields. Still, it is unclear to what extent this difference affects overall perceptions of STEM education (Permanasari et al., 2021). Similarly, research findings indicate that female students tend to have lower interest in technology and engineering than their male counterparts (Kijima & Sun, 2020); however, these findings remain highly dependent on cultural context and learning design. Thus, a research gap exists in integrating the dimensions of teacher perceptions and student attitudes within a comprehensive analytical framework. Based on this background, this study offers novelty by adopting an intersectional approach that integrates teacher and student perspectives in analyzing the dynamics of perceptions and attitudes towards STEM education. This study specifically aims to identify how the demographic characteristics of teachers (e.g., educational background and teaching experience) and students (gender and grade level) influence their views on key elements in STEM education, including mathematics, science, technology, and engineering, as well as 21st-century learning. Using a quantitative approach, this study is expected to make an empirical contribution to understanding the factors underlying attraction and resistance to STEM in the context of secondary education in Indonesia. The results of this study are not only relevant to education policymakers but also crucial for the development of teacher training programs, contextualized STEM curriculum design, and learning strategies that can sustain students' interest in science and technology. This research also provides a conceptual foundation for national efforts to build an inclusive, adaptive, and local culture-based STEM learning ecosystem. To achieve the objectives of this study and provide a comprehensive understanding of the dynamics between teachers' perceptions and students' attitudes toward STEM education, the following research questions were formulated:

1. What are the levels of students' attitudes toward STEM across the dimensions of science, mathematics, technology, engineering, and 21st-century skills?
2. What are teachers' perceptions of STEM in terms of STEM understanding, competencies, knowledge, and implementation challenges?
3. Are there significant differences in students' attitudes toward STEM based on gender and grade level?
4. Do teachers' perceptions of STEM differ according to educational background, teaching experience, and subject expertise?

2. METHOD

2.1 Research Design

This study employs a quantitative, descriptive, and comparative design to measure, describe, and compare students' attitudes toward STEM learning and teachers' perceptions of STEM education. This approach was chosen to provide an empirical picture of students' and teachers' readiness, understanding, and experience in the context of STEM education development. The primary focus of this study is to identify attitudinal and perceptual characteristics that may influence the effectiveness of STEM learning implementation, while accounting for differentiating factors such as gender, grade level, and teachers' professional backgrounds.

The survey design is a cross-sectional study, in which data are collected at a single point in time using a structured questionnaire (Cresswell & Clark, 2018). The students' attitudes toward STEM variables were measured through four main dimensions, namely: (1) attitudes toward science, (2) attitudes toward mathematics, (3) attitudes toward technology and engineering, and (4) 21st-century learning skills, which include critical thinking, collaboration, communication, and creativity in interdisciplinary learning. The analysis of students' attitudes was conducted not only in general, but also by gender category (male and female) and grade level (e.g., grade VII, VIII, or IX) to identify potential significant differences between groups. Meanwhile, the teachers' perceptions of STEM variable was measured through three leading indicators, namely: (1) perceptions of STEM education, which includes teachers' understanding of the concepts and characteristics of STEM learning; (2) perceptions of STEM competencies, which is teachers' perceptions of STEM skills (3) STEM knowledge, which discusses the knowledge that students must master in the STEM field; and (4) perceptions of STEM implementation challenges, such as limited facilities, training, and curriculum suitability. Through this design, the research aims to obtain a comprehensive picture of how students and teachers perceive STEM education from each group's perspective. Additionally, the comparative approach enabled the researcher to identify differences in students' attitudes by gender and grade level, as well as variations in teachers' perceptions across educational background, teaching experience, and subject area. The 10 results of this study are expected to contribute to the development of STEM education policies that are more adaptive, data-driven, and aligned with students' needs and educators' readiness in the field.

2.2 Participant

This study employed a random sampling approach, selecting participants from secondary schools across multiple provinces in Indonesia. Although the sampling covered several regions, the majority of participants were concentrated in Sumatra and Java, reflecting the demographic distribution of accessible schools during the data collection period. The respondents in this study consisted of two main groups: teachers and 15 students (Table 1). A total of 125 teachers participated in the survey, with women comprising 86 individuals (68.80%) and men 39 (31.20%).

2.3 Instrument Development and Validation

The instrument used in this study consists of two main parts: Perception towards STEM, based on To Khuyen et. al. (2020), and Students' Attitudes towards STEM, based on Faber et al. (2013). Before being used in data collection, both instruments have been validated by three experts (expert judgment) in the field of science education. The Perception towards STEM instrument was developed to measure teachers' perceptions of STEM education through four dimensions: STEM understanding, STEM knowledge, STEM competencies, and STEM difficulties. The STEM understanding dimension includes understanding the concept of STEM education as an integration of

Table 1. The distribution of teachers and students

Variables	n	percentage
Teacher		
Gender		
Male	39	31.20%
Female	86	68.80%
Education Background		
Science Education	51	40.80%
Biology Education	40	32%
Chemistry Education	4	3.20%
Physic Education	23	18.40%
Non-STEM Subject	7	5.60%
Teaching Experience		
< 5 year	49	39.20%
5-10 year	15	12%
11-15 year	23	18.40%
16-20 year	21	16.80%
> 21 year	17	13.60%
Student		
Gender		
Male	150	33.60%
Female	297	66.40%
Grade Level		
7th	202	45.20%
8th	130	29.10%
9th	115	25.70%

knowledge, skills, and logical thinking relevant to STEM careers, the view that STEM 11 teaching does not have to cover all four fields simultaneously, the importance of scientific inquiry and engineering design, and the notion of technology that is not limited to digital devices in the classroom. All 58 items in this instrument were valid, and the reliability test yielded a Cronbach's Alpha of 0.87, indicating excellent internal consistency. The Consistency, reliability, and construct validity of the instrument are evident in Table 2.

Meanwhile, the Students' Attitudes towards STEM instrument was used to measure students' attitudes towards four key areas in STEM, namely Mathematics, Science, Technology, and Engineering, as well as 21st-century learning skills. The instrument includes statements that measure students' interest, perceived relevance, and confidence in facing the challenges of each field. Attitudes towards math and science are measured through perceptions of the material's importance and confidence in solving problems. Attitudes towards technology and engineering include students' views on the application of technology in everyday life and their involvement in the design and innovation process. Additionally, the 21st-century learning aspect assesses students' openness to developing collaboration, communication, creativity, and critical thinking skills. Of the 37 items in this instrument, 35 were valid, and 2 were eliminated. The reliability test results showed a Cronbach's Alpha value of 0.871, indicating very high reliability. Both instruments were structured on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree) to measure perceptions and attitudes towards STEM education accurately.

2.4 Data Analysis

The data analysis in this study is structured to address the fourth problem formulation in a gradual, integrated manner. To address the first and second problem formulations, specifically regarding students' attitudes towards STEM learning and teachers' perceptions of STEM education development goals, descriptive statistical analysis was employed. Students' attitudes were analyzed based on four main dimensions: attitudes towards science, mathematics, technology, and engineering, as well as 21st-century skills. Meanwhile, teachers' perceptions were assessed through three dimensions: their understanding of the STEM education concept, their perceptions of the competencies students should possess, and their views on the challenges of implementing STEM learning in the classroom. For each dimension, the mean, standard deviation, and score distribution were calculated to provide an overview of the respondents' profiles from both the student and teacher sides.

The third and fourth problems, which focus on factors influencing students' attitudes and teachers' perceptions, were analyzed using two approaches. First, linear regression analysis was used to measure the contribution of each dimension to the dependent variable for both students and teachers. Second, a One-Way ANOVA was conducted to determine differences in teacher perceptions across educational background, teaching experience, and subjects taught. If a significant difference was found, it was followed by the Tukey Honestly Significant Difference (HSD) test. In addition, to assess the magnitude of influence between groups, the eta squared effect size (η^2) was used, with classifications of 0.01 (small), 0.06 (medium), and 0.14

Table 2. Consistency, reliability, and construct validity of the instrument

Indicators	Cronbach's alpha	rho_a	CR	AVE
STEM Competence	0.925	0.927	0.937	0.6
STEM Difficulties	0.801	0.812	0.868	0.623
STEM Knowledge	0.938	0.941	0.945	0.506
STEM Understanding	0.834	0.85	0.876	0.507
Attitudes towards the 21st Century	0.837	0.845	0.877	0.507
Attitudes towards Mathematics	0.876	0.895	0.903	0.609
Attitudes towards Science	0.905	0.918	0.923	0.573
Attitudes towards Technology	0.866	0.893	0.892	0.511

(large). The entire analysis process was conducted using SPSS version 25.

3. RESULT AND DISCUSSION

3.1 Teacher Perception of STEM Education

The mean scores for each domain were analyzed to provide a comprehensive picture of teachers' perceptions of STEM education, encompassing their understanding of STEM, knowledge of STEM dimensions, STEM competencies, and challenges in its implementation. The analysis (Figure 1) showed that in the STEM Understanding domain, the mean was M = 3.92 and the standard deviation was SD = 0.379. The first quartile (Q1) value of 3.6923 indicates that more than 75% of teachers have a good understanding of STEM education in general. In the STEM Knowledge domain, the mean of M = 3.96 with SD = 0.52 and the Q1 of 3.71 indicate that most teachers have a relatively high level of knowledge of basic STEM principles and concepts. The Opinion about the STEM Competence domain has the highest mean, M = 4.14, and the lowest standard deviation, SD = 0.52. The Q1 value of 4.00 indicates that more than 75% of teachers consider competence in STEM essential. The median of 4.10 reinforces this finding, i.e., half of the teachers perceive that STEM competencies are critical to master. Meanwhile, in the Difficulty in STEM Implementation domain, the mean was M = 3.36 with SD = 0.65. The Q1 value of 3.00 and the median of 3.33 indicate that most teachers still face various obstacles in implementing the STEM approach in learning activities.

Overall, teachers in Indonesia show positive, relatively high perceptions of their understanding and competence in STEM education. However, this finding also underscores that STEM implementation in the field still faces various obstacles, which are reflected in teachers' perceptions of implementation difficulties (Table 3).

Table 3. Means, standard deviations, and the 95% CI for the level of difficulty in STEM implementation

Variables	N	Mean	SD	95% CL	
				LL	UL
STEM domain integration	125	3.39	0.65	3.27	3.50
Student abilities	125	3.53	0.67	3.41	3.65
Learning facilities and media	125	3.10	0.94	2.93	3.27
Classroom management	125	3.24	1.04	3.05	3.42

Difficulties in implementing STEM learning are identified across four main aspects: integration among STEM domains, learners' abilities, availability of learning facilities and media, and classroom management. First, teachers face challenges in integrating various disciplines such as science, technology, engineering, and mathematics (M = 3.39; SD = 0.65), which requires cross-disciplinary understanding and integrated learning planning. The difficulty of implementing STEM education becomes even greater when teachers must align this approach with their long-established pedagogical models. This often leads to doubts and a lack of confidence, causing some teachers to feel unprepared to integrate STEM-based learning effectively in the classroom (Le et al., 2021).

One of the primary reasons for these barriers is that the concept of integrated STEM learning is still relatively new in Indonesia. Although most teachers are familiar with the term "STEM", many do not fully understand its basic

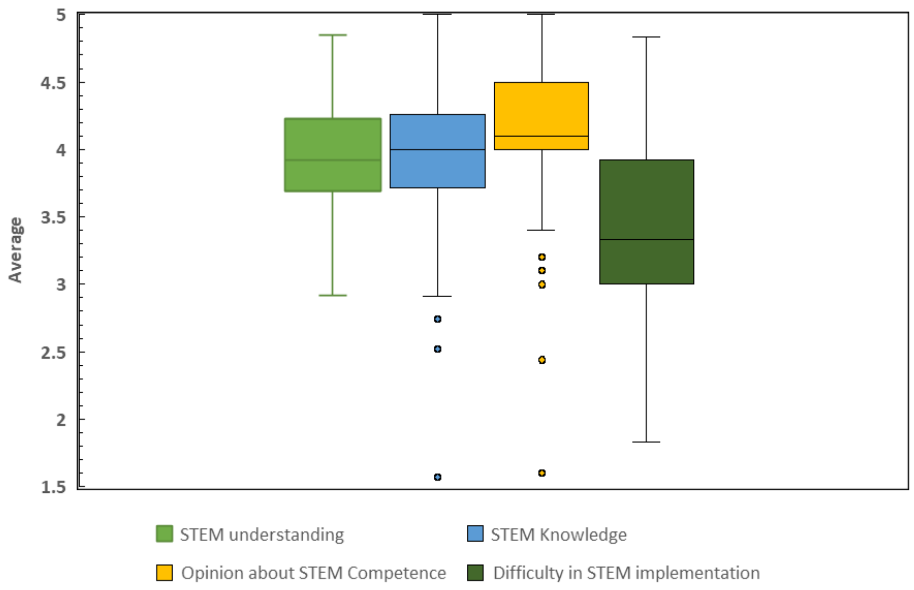

Figure 1. Mean of teacher perception on each indicator

philosophy and technical aspects (Farwati et al., 2021). This ignorance often leads to the perception that STEM is a complicated learning approach to implement, especially by teachers who have not received adequate training or experience (Tunc & Bagceci, 2020).

Furthermore, there are also many misconceptions regarding the meanings of "technology" and "engineering" in the context of STEM. Many teachers associate them with sophisticated devices or systems that require a high level of mastery, leading them to assume that these components are not relevant to their learning conditions (Diana et al., 2021). In fact, the STEM approach enables the use of simple technology and engineering based on readily available practical tools and materials in the surrounding environment. In fact, many teachers have implemented STEM elements indirectly through simple tools and methods, even though they have not identified them as part of STEM learning strategies. Unfortunately, negative stigma and misconceptions can reduce teachers' motivation to explore and develop their STEM competencies. As a result, interest in integrating STEM into the learning process is low, hampering efforts to strengthen STEM literacy in schools (Arlinwibowo et al., 2023).

Second, learners' ability is also an obstacle (M = 3.53; SD = 0.673), as some students have not demonstrated readiness for project-based learning, critical thinking, and collaboration. Third, classroom management is a challenging aspect (M = 3.24, SD = 1.04), particularly in managing group dynamics, allocating time effectively, and promoting active student engagement during the learning process. One of the primary causes is students' limited understanding of fundamental concepts in science, technology, engineering, and mathematics. This makes it difficult for them to apply cross-disciplinary concepts meaningfully (Margot & Kettler, 2019). In addition, learning practices that still separate STEM subjects also hinder students' ability to build connections between fields, despite this being a primary characteristic of integrated STEM education (English, 2016). This problem is exacerbated by teachers' lack of preparedness and confidence in delivering integrated STEM learning, primarily due to a lack of professional training and unclear curriculum guidelines (Nadelson & Seifert, 2017)

Furthermore, many students view STEM learning as abstract and difficult to understand, especially if it is not linked to real-life contexts. This view results in low student motivation and engagement in the learning process (Honey et al., 2014). This challenge is also exacerbated by limited learning facilities, such as laboratories, technological tools, and practical materials needed for inquiry-based activities, which show the lowest mean scores (M = 3.10; SD = 0.94). In addition, the assessment system in many educational institutions still focuses on mastery of material by subject rather than on interdisciplinary problem-solving skills. This also hinders the development of a holistic STEM mindset in students (Beers, 2011). This condition shows that the success of STEM implementation is highly dependent on adequate school facilities and infrastructure.

3.2 Student Attitudes towards STEM Education

The average for each domain was analyzed to interpret students' overall attitudes toward STEM education, encompassing attitudes toward the fields of mathematics, science, technology, and engineering, as well as 21st-century learning. The analysis (Figure 2) showed that attitudes towards mathematics had the lowest mean, M = 3.26, with SD = 0.70. The first quartile value (Q1) of 2.83 indicates that only a small proportion of students showed a very positive attitude towards mathematics. In the science domain, the average student attitude was M = 3.64 (SD = 0.68), with a Q1 of 3.11, indicating that more than half of

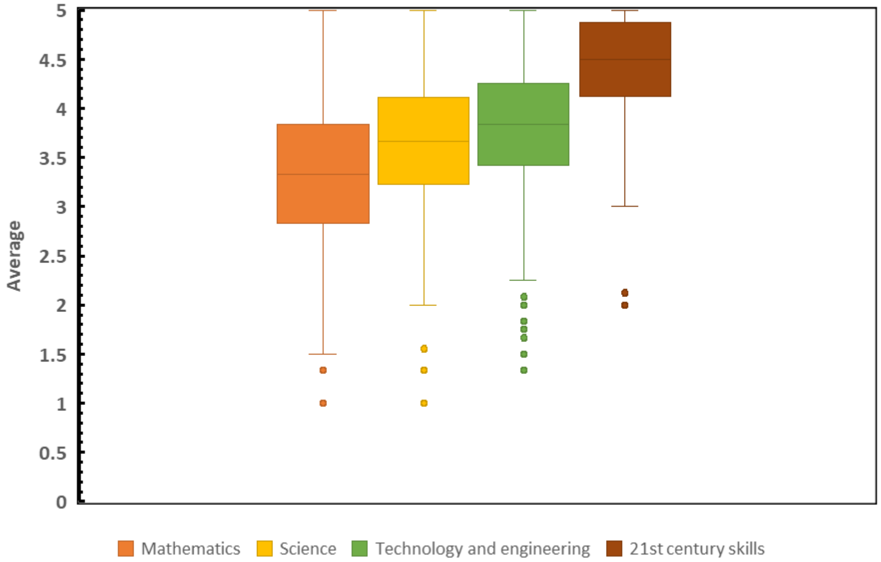

Figure 2. Mean of students' attitudes on each indicator

Table 4. Means, standard deviations, and the 95% CI for the level of student attitudes towards mathematics

Variables	N	Mean	Std. Deviation	95% CL	
				LL	UL
Enjoyment of Mathematics	447	3.49	0.92	3.40	3.58
Self-Perception of Math Ability	447	2.98	0.86	2.90	3.06
Academic Confidence in Math	447	3.38	0.77	3.30	3.45
Self-Efficacy in Understanding Math	447	3.49	0.81	3.42	3.57
Career Interest in Mathematics	447	3.12	0.88	3.04	3.20

the students had a moderately optimistic view of this area. Meanwhile, attitudes towards technology and engineering obtained an average of M = 3.77 (SD = 0.652), with a Q1 of 3.50 and a median of 3.75, reflecting a relatively positive attitude towards the applied approach in STEM learning. The highest-scoring domain was attitudes towards 21st-century learning, with a mean of M = 4.42 and a standard deviation of SD = 0.47. The Q1 score of 4.12 indicates that more than 75% of students strongly support learning that emphasizes skills such as collaboration, creativity, digital literacy, and critical thinking.

Considering all the data, it can be concluded that the attitude towards mathematics is the weakest of the four domains analyzed. This suggests that students' motivation, interest, or positive perception of mathematics still needs improvement. Therefore, innovative, context-based, and problem-solving-oriented learning strategies need to be developed to increase students' attraction to and engagement with the mathematics field as an essential foundation in STEM education. The results on students' attitudes toward the field of mathematics are presented in Table 4.

Students' attitudes towards mathematics were analyzed using five indicators: enjoyment of mathematics, self-perception of math ability, academic confidence in math, self-efficacy in understanding math, and career interest in mathematics. The results of the analysis showed that, in general, students showed quite positive attitudes in the aspects of self-efficacy in understanding math (M = 3.4989; SD = 0.81981) and enjoyment of mathematics (M = 3.4944; SD = 0.92757), which reflected the level of comfort and confidence in understanding mathematics material. However, the self-perception of math ability indicator obtained the lowest mean score (M = 2.9866; SD = 0.86008), even below the scale's mean, indicating that many students perceived their mathematical ability to be low. In addition, career interest in mathematics showed a relatively low value (M = 3.1219; SD = 0.88092), indicating that students have little interest in pursuing a career in mathematics, such as an accountant, statistician, or a profession based on numerical analysis. This suggests that many students feel inadequate in mathematics and lack interest in pursuing careers in these fields. Several factors may explain this. First, mathematics is often perceived as a complex, abstract, and challenging subject, which can form negative beliefs about one's ability (Fritz et al., 2019). Second, mathematics learning approaches that are not contextualized or fail to relate the material to real life make it difficult for students to understand its practical relevance (Asmara et al., 2019; Juliangkary, 2025). Finally, the lack of positive experiences and success in learning mathematics can decrease students' self-efficacy over time (Hall et al., 2005; Özcan & Kültür, 2021). Therefore, more contextually relevant, applicable, and career-oriented learning strategies are needed to improve self-perception and sustain students' interest in mathematics.

3.3 Factors Related to Teachers' Perceptions of STEM Education

To analyze factors related to teachers' perceptions of STEM education, a comparative test approach was employed, utilizing teachers' demographic characteristics as a basis for comparison. Before the test, a normality test was conducted using the Kolmogorov-Smirnov test, which showed that all teacher perception data were normally distributed ($p > 0.05$); therefore, parametric analysis could be applied. Furthermore, an independent-samples t-test was conducted to determine differences in teacher perceptions by gender (male and female). Meanwhile, to test differences in teacher perceptions based on educational background and teaching experience, a One-Way Analysis of Variance (ANOVA) was used. Eta-squared calculations followed significant ANOVA results to determine the effect size of group differences. Post hoc tests were conducted as needed to determine specific differences between groups. The results of the analysis are shown in Table 5.

The analysis revealed that gender differences did not have a statistically significant impact on the three primary dimensions of STEM literacy. The p values obtained for STEM Understanding ($p = 0.30$; $\eta^2 = 0.01$), STEM Knowledge ($p = 0.50$; $\eta^2 = 0.00$), and STEM Competence ($p = 0.82$; $\eta^2 = 0.00$) indicate that the effect of gender differences on these three dimensions is minimal to non-existent. However, STEM Difficulties showed a near-significant difference ($p = 0.06$; $\eta^2 = 0.02$), with higher mean scores in male (M = 3.52) than in female (M = 3.29) participants, indicating that males tend to report higher levels of STEM learning difficulty, although the effect

Table 5. Teachers ’ perceptions based on gender, educational background, and teaching experience

Variables	n	STEM Understanding				STEM Knowledge				STEM Competency				STEM Difficulties			
		M	SD	p	η^2	M	SD	p	η^2	M	SD	p	η^2	M	SD	p	η^2
Gender																	
Male	39	3.97	0.41	0.30	0.01	4.01	0.57	0.50	0.00	4.15	0.60	0.82	0.00	3.52	0.75	0.06	0.02
Female	86	3.89	0.36			3.94	0.49			4.13	0.49			3.29	0.59		
Educational background																	
Science Education	51	3.95	0.35	0.18	0.05	3.95	0.39	0.24	0.04	4.13	0.47	0.13	0.05	3.43	0.76	0.19	0.03
Biology Education	40	3.98	0.40			4.08	0.50			4.28	0.45			3.37	0.62		
Chemistry Education	4	4.00	0.27			4.01	0.09			3.96	0.25			4.00	0.68		
Physic Education	23	3.80	0.35			3.83	0.70			4.00	0.74			3.17	0.42		
Non-STEM Subject	7	3.71	0.43			3.72	0.71			3.88	0.45			3.19	0.45		
Teaching Experience																	
< 5 years	49	3.89	0.34	0.29	0.04	3.94	0.42	0.16	0.05	4.13	0.50	0.29	0.04	3.36	0.65	0.31	0.03
5-10 years	15	3.92	0.45			3.95	0.47			4.02	0.55			3.22	0.79		
11-15 years	23	3.95	0.33			3.96	0.56			4.16	0.38			3.61	0.51		
16-20 years	21	3.80	0.42			3.79	0.71			4.01	0.72			3.24	0.69		
> 21 years	17	4.07	0.39			4.22	0.41			4.35	0.42			3.33	0.62		

Table 6. Students’ attitudes based on gender and grade level

Variables	n	Mathematics				Science				Technology and Engineering				21st-century learning			
		M	SD	p	η^2	M	SD	p	η^2	M	SD	p	η^2	M	SD	p	η^2
Gender																	
Male	150	3.19	0.74	0.13	0.00	3.57	0.69	0.08	0.01	3.87	0.70	0.02*	0.01	4.37	0.52	0.12	0.00
Female	297	3.30	0.67			3.68	0.67			3.72	0.61			4.45	0.44		
Grade level																	
7th	202	3.36	0.68	0.04*	0.02	3.80	0.65	0.00***	0.05	3.87	0.66	0.01**	0.02	4.49	0.47	0.01**	0.02
8th	130	3.26	0.67			3.55	0.67			3.70	0.61			4.41	0.44		
9th	115	3.09	0.74			3.47	0.68			3.66	0.65			4.32	0.49		

Note: Eta squared values >0.06 are in boldface. *p<0.05.**p<0.01. ***p<0.001

remains small. This is because when given equal opportunities, access to resources, and consistent encouragement, both women and men have equal potential to excel in STEM (Science, Technology, Engineering, and Mathematics) (Delaney & Devereux, 2019). The differences in performance often observed are due to social expectations, gender stereotypes, and inequalities in educational support rather than innate ability (OECD, 2025). Creating inclusive learning environments, implementing gender-responsive learning strategies, and presenting diverse role models can help reduce the gender gap in STEM (Brage-del-Río et al., 2025; Bustamante-Mora et al., 2025; David Adeline, 2024). Encouraging all students to explore their potential without bias will foster confidence, motivation, and long-term interest in STEM disciplines.

Furthermore, ANOVA results based on educational background showed no statistically significant differences in the four dimensions of STEM perception. STEM and non-STEM educational backgrounds do not necessarily affect STEM teaching ability because teaching effectiveness is more determined by pedagogical training, teaching experience, and adaptability to the curriculum This is in line with the research of Septiyanto et al., (2024) which states that the science background of elementary school teachers does not affect the depth of concepts they teach nor their level of content knowledge (CK) in science. The practice of lifelong learning involves independent efforts to find and access various learning resources, thereby deepening their conceptual understanding. Despite not having a science education background, one can identify material needs, actively learn about them, and integrate this knowledge into the learning process. This demonstrates that a commitment to continuous learning enables teachers to teach science effectively without relying on others (Ekelemu, 2014).

The effect sizes (η^2) indicate small to medium effects, especially in STEM Understanding ($p = 0.18$; $\eta^2 = 0.05$) and STEM Competence ($p = 0.13$; $\eta^2 = 0.05$). Dimensions. This suggests that although differences were not statistically significant, educational background contributed to the variance in participants' STEM understanding and competence. Participants from Biology and Chemistry Education majors had higher mean scores than those from non-STEM majors. This finding suggests that educational backgrounds more closely aligned with scientific and experimental approaches may improve literacy and STEM skills. An academic background based on scientific and experimental approaches provides direct exposure to the scientific method, systematic observation, and data analysis, which are at the core of STEM learning (Muneer et al., 2025; Tan et al., 2023). Through laboratory experiences and evidence-based problem solving, learners develop critical, analytical, and reflective thinking skills (Deniş-Çeliker & Dere, 2022). This approach also promotes deeper conceptual understanding due to active engagement in the process of scientific exploration and verification (Chen & Chen, 2021; Quigley et al., 2017). As a result, STEM literacy and competence can grow stronger as they are built on authentic, applicable learning experiences.

Furthermore, differences based on teaching experience also did not show strong statistical significance on all STEM literacy dimensions. STEM Understanding. STEM Understanding ($p = 0.29$; $\eta^2 = 0.04$), STEM Knowledge ($p = 0.16$; $\eta^2 = 0.05$), STEM Competence ($p = 0.29$; $\eta^2 = 0.04$), dan STEM Difficulties ($p = 0.31$; $\eta^2 = 0.03$) all showed small effects. However, teachers with more than 21 years of experience had the highest mean scores in the STEM Knowledge ($M = 4.22$) and STEM Competence ($M = 4.35$) dimensions, reflecting the accumulation of STEM understanding and skills that increase with professional experience. This finding aligns with previous literature, which suggests that long-term experience in educational practice contributes to the simultaneous development of pedagogical and content competence. However, the effect is not always significant within a statistical framework (Khuyen et al., 2020).

A higher educational background tends to correlate with a more rational general understanding of STEM education and a greater valuation of STEM competencies. This finding is understandable, as postgraduate education contributes significantly to teacher learning, particularly in educational innovation. In other words, further study promotes not only professional growth but also teachers' personal development (Cotterill-Walker, 2012). A similar phenomenon was also found among teachers in Indonesia (Wahono & Chang, 2019), where those with higher educational backgrounds demonstrated greater mastery of STEM knowledge and rated STEM competence as a more valuable aspect. Postgraduate education offers teachers opportunities to become more familiar with various pedagogical innovations. Interestingly, the group with the highest level of education reported greater difficulty implementing STEM education. However, perceived difficulty is not necessarily related to teachers' willingness to engage in new practices (Weinstein, 1988), as long as they still perceive STEM education as valuable. Therefore, the sustainability of STEM education depends heavily on the availability of teachers with adequate academic qualifications and training (UNESCO, 2019).

3.4 Factors Related to Student Attitudes towards STEM Education

To analyze the factors related to students' attitudes towards STEM fields, a comparative analysis approach based on students' demographic characteristics, specifically gender and grade level, was employed. Before conducting the inferential analysis, a normality test using the Kolmogorov-Smirnov test indicated that all data were normally distributed ($p > 0.05$). Therefore, parametric analysis can be used. An independent-samples t-test was used to evaluate differences in students' attitudes by gender (male and female). At the same time, a One-Way ANOVA was used to test differences across grade levels. If significant differences were found, eta-squared calculations were performed to estimate the effect size, and post hoc tests were used to identify specific group differences. The results of the analysis are presented in the following table.

Based on gender, the analysis showed that there was no significant difference in students' attitudes towards Mathematics ($p = 0.13$, $\eta^2 = 0.00$), *Science* ($p = 0.08$, $\eta^2 = 0.01$), and *21st Century Learning* ($p = 0.12$, $\eta^2 = 0.00$), with effect size values that were in the tiny category. However, in the Technology and Engineering domain, a statistically significant difference was found ($p = 0.02$) with an η^2 value of 0.01. However, the effect size was still small. In general, these results suggest that gender has only a minimal impact on differences in students' attitudes in STEM learning contexts, with limited exceptions in the technology and engineering domains. Gender has no significant effect on students' attitudes towards STEM, as these attitudes are more influenced by internal factors such as interest, motivation to learn, prior learning experiences, and support for an inclusive learning environment (Lane et al., 2022; N. Wang et al., 2023). When men and women have equal access to engaging, relevant, and contextually relevant learning, attitudinal differences tend to fade (Pilotti et al., 2022). In addition, teaching approaches that integrate positive role models from both genders as well as gender-responsive learning strategies can help build positive perceptions equally (Canuto & Espique, 2023). Thus, it is not gender that determines attitudes towards STEM, but rather how learning experiences are equitably shaped and facilitated.

Meanwhile, analysis by grade level showed significant differences across all four aspects. Grade 7 students had the highest scores compared to grades 8 and 9 in all domains, namely *Mathematics* ($M = 3.36$, $SD = 0.68$), *Science* ($M = 3.80$, $SD = 0.65$), *Technology and Engineering* ($M = 3.87$, $SD = 0.66$), and *21st Century Learning* ($M = 4.49$, $SD = 0.47$). ANOVA test results showed that the difference was significant in Mathematics ($p = 0.04$, $\eta^2 = 0.02$), *Science* ($p < 0.001$, $\eta^2 = 0.05$), *Technology and Engineering* ($p = 0.01$, $\eta^2 = 0.02$), and *21st Century Learning* ($p = 0.01$, $\eta^2 = 0.02$). The eta squared values obtained were all in the small category, with science showing the highest value, close to the medium effect threshold.

These results indicate that grade level is significantly related to students' attitudes towards STEM fields and 21st-century skills. These results align with the research of

Table 7. Post hoc comparisons in student attitudes towards STEM education.

Dependent Variable	Grade level		ME (I-J)	SE	P
	(I)	(J)			
Mathematics	7th grade	9th grade	0.27131*	0.08138	0.003*
Science	7th grade	8th grade	0.25840*	0.07498	0.002*
		9th grade	0.33142*	0.07789	0.000***
Technology and Engineering	7th grade	9th grade	0.20565*	0.07557	0.019*
21st Century learning	7th grade	9th grade	0.16587*	0.05511	0.008*

*p<0.05.**p<0.01. ***p<0.001

(2018) and Zhou et al. (2019), which indicate that students' attitudes towards STEM at the primary school level exhibit a more positive trend than those at higher education levels. This suggests that as the grade level increases, students' attitudes towards STEM tend to decrease. This decline could be attributed to the increasing complexity of the material, academic pressure, and the reduction of fun and contextualized learning approaches as students progress through their educational careers. Therefore, it is essential to maintain engaging and relevant STEM learning approaches at all levels to maintain students' positive attitudes. The descriptive findings also indicate a downward trend in positive attitudes from Grade 7 to Grade 9, which may reflect a decrease in interest, engagement, or perceptions of STEM learning's relevance as students progress through their education. Thus, adaptive and sustainable learning strategies need to be specifically designed for each grade level to maintain students' positive attitudes towards STEM and future skills.

The decline in students' positive attitudes towards STEM learning from grade 7 to grade 9 is a consistent phenomenon observed across studies, and it is attributed to interrelated psychological, pedagogical, and social factors. In early adolescence, Grade 7 students tend to exhibit high intrinsic motivation and curiosity; however, this motivation declines with age due to academic pressures, emotional changes, and the development of self-identity. Increasingly abstract and theoretical STEM learning in higher grades, if not balanced with contextual approaches such as project-based learning, can make it difficult for students to relate the material to real-life experiences. Assessment systems that focus solely on exam results contribute to the pressure, diverting students' attention from meaningful learning to achieving grades. Social factors, such as peer influence and the emergence of gender stereotypes, can also hinder participation, particularly for female students. Therefore, adaptive and developmentally relevant pedagogical strategies are needed to maintain students' interest and positive attitude towards STEM. Furthermore, the differences are evident in the post hoc analysis presented in Table 7.

Further analysis using Tukey HSD post hoc was conducted to identify significant differences between grade groups after the ANOVA test showed significant results. The study showed that grade 7 students had significantly more positive attitudes than grade 9 students on several aspects of STEM. In the Mathematics domain, the comparison between Grade 7 and Grade 9 students showed a significant difference (mean difference = 0.271, p = 0.003). This finding indicates that grade 7 students tend to have more positive attitudes towards mathematics compared to grade 9 students. This may reflect a decrease in interest or an increase in perceived difficulty in mathematics as students progress through higher grade levels. For the Science domain, significant differences were found between grade 7 and grade 8 (mean difference = 0.258, p = 0.002) and between grade 7 and grade 9 (mean difference = 0.331, p < 0.001). This indicates that students' attitudes towards science decreased gradually from grade 7 to grade 9, with the steepest decline occurring between grades 7 and 9. This pattern may indicate a reduction in perceived relevance or interest in science at higher grade levels. In the Technology and Engineering domain, results showed that Grade 7 students had significantly more positive attitudes than Grade 9 students (mean difference = 0.206, p = 0.019). This suggests that students' engagement with and interest in technology and engineering aspects also decreased in grade 9, which may be related to the limited implementation of practice-based learning or real-world linkages in the curriculum. Meanwhile, in the 21st Century Learning domain, a significant difference was found between grade 7 and grade 9 (mean difference = 0.166, p = 0.008). Grade 7 students demonstrated more positive attitudes towards 21st-century skills, including collaboration, creativity, and communication. This finding supports the argument that these generic skills are more valued at younger ages and may be less explicitly addressed or reinforced in higher grades. Overall, Tukey HSD post hoc results showed a consistent pattern of decreasing positive attitudes towards STEM from Grade 7 to Grade 9, with significant differences repeatedly appearing in four domains. This underscores the importance of designing adaptive, context-specific STEM lessons at higher grade levels to sustain students' interest, motivation, and engagement in STEM fields.

The findings of this study must be interpreted within the broader cultural and policy context of STEM education in Indonesia. Despite teachers demonstrating generally positive perceptions of STEM, challenges such as limited facilities, interdisciplinary integration, and learner readiness reflect the structural realities of Indonesian schools, where STEM implementation remains emergent and uneven across regions. National policies, such as the *Merdeka Belajar* curriculum and Indonesia's 2020–2025 STEM education roadmap initiated by the Ministry of Education, have emphasized inquiry-based learning, digital literacy, and cross-disciplinary competencies. However, classroom practices continue to be influenced by deeply rooted exam-oriented traditions, hierarchical teacher-student relationships, and limited professional development opportunities, which may constrain the translation of positive teacher perceptions into innovative pedagogical practices. Furthermore, the decline in student attitudes toward STEM across grade levels aligns with cultural expectations that prioritize academic performance over creative experimentation, often intensifying pressure on older students. This pattern mirrors findings in other Southeast Asian contexts, such as Vietnam and Malaysia, where high academic standards coexist with a decline in STEM interest in later school years. Thus, while policy efforts signal a shift toward 21st-century learning, sustained systemic support, including infrastructure investment, school-based STEM coaching, and community-industry partnerships, is essential to bridge the gap between policy intent, teacher readiness, and student engagement in STEM learning.

4. CONCLUSION

This study reveals that secondary-level teachers hold positive perceptions of STEM education, particularly regarding the importance of cross-disciplinary competencies and the relevance of STEM to 21st-century needs. However, teachers face challenges in implementing STEM learning, particularly due to limited facilities, insufficient learner readiness, and the complexity of interdisciplinary integration. Teachers' perceptions do not show significant differences based on gender, educational background, or teaching experience, but teachers with a science background tend to have a more comprehensive view. On the other hand, students' attitudes towards STEM are selective: they show relatively positive attitudes towards technology and 21st-century skills, but low attitudes towards mathematics, especially in terms of perceived self-efficacy and career interests. The most influential factor for teachers' perceptions was academic background. At the same time, for students, grade level was the dominant factor influencing the decline in positive attitudes towards STEM, particularly from grade 7 to grade 9. These findings have important implications for the development of more adaptive and sustainable STEM education policies and practices. Strengthening institutional support for teachers through interdisciplinary training, capacity-building in STEM learning planning, and the provision of facilities that support the integration of science, technology, engineering, and mathematics are needed. In addition, STEM learning needs to be designed contextually and differentiated to support learner development at each grade level, preventing a decline in motivation and positive attitudes. The intervention's focus also needs to be on improving students' self-perception of mathematics through problem-solving-based approaches, applied projects, and the exploration of concrete STEM careers. Recommendations for future research include developing locality-based STEM learning models and conducting longitudinal studies to map the dynamics of sustainable changes in students' perceptions and attitudes within an inclusive and transformative learning ecosystem.

This study used randomly selected samples of teachers and students from various secondary schools in Indonesia. Although this sampling strategy strengthens the representativeness of the findings at a broad level, it also presents certain limitations. Because the teacher and student participants were not drawn from the same schools or matched within the same learning context, it was not possible to directly examine the relational influence between teachers' perceptions and students' attitudes toward STEM. Therefore, this study cannot establish whether teachers' positive perceptions translate into more favorable student attitudes within specific school environments. Future research should consider employing school-pair or classroom-based sampling designs to enable a more robust examination of the direct link between teacher perceptions, instructional practice, and student attitudes toward STEM learning.

REFERENCES

Ardianto, D., Rubini, B., & Pursitasari, I. D. (2023). Assessing STEM career interest among secondary students: A Rasch model measurement analysis. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(1), em2213. https://doi.org/10.29333/ejmste/12796

Arlinwibowo, J., Retnawati, H., Pradani, R. G., & Fatima, G. N. (2023). STEM Implementation Issues in Indonesia: Identifying the Problems Source and Its Implications. *Qualitative Report*, *28*(8), 2213–2229. https://doi.org/10.46743/2160-3715/2023.5667

Asmara, A. S., Hardi, H., & Ardiyanti, Y. (2019). Contextual Learning on Mathematical Subjects to Enhance Student Motivation for Learning in Vocational High School. *JPI (Jurnal Pendidikan Indonesia)*, *8*(2), 228. https://doi.org/10.23887/jpi-undiksha.v8i2.13499

Atabey, N., & Topcu, M. S. (2021). The Relationship between Turkish Middle School Students' 21st Century Skills and STEM Career Interest: Gender Effect. *Journal of Education in Science, Environment and Health*, *7*(2), 86–103. https://doi.org/10.21891/jeseh.739586

Balta, N., Japashov, N., Mansurova, A., Tzafilkou, K., Oliveira, A. W., & Lathrop, R. (2023). Middle- and secondary-school students' STEM career interest and its relationship to gender, grades, and family size in Kazakhstan. *Science Education*, *107*(2), 401–426. https://doi.org/https://doi.org/10.1002/sce.21776

Beers, S. Z. (2011). *What are the skills students will need in the 21 st century?* 1–6. https://cosee.umaine.edu/files/coseeos/21st_century_skills.pdf

Brage-del-Río, M., Martin-Núñez, J. L., & Pablo-Lerchundi, I. (2025). Educational Strategies to Reduce the Gender Gap in the Self-Efficacy of High School Students in STEM Teaching. *Frontiers in Education*, *10*(May). https://doi.org/10.3389/feduc.2025.1553001

Bustamante-Mora, A., Diéguez-Rebolledo, M., Díaz-Arancibia, J., Sánchez-Vázquez, E., & Medina-Gómez, J. (2025). Inclusive Pedagogical Models in STEM: The Importance of Emotional Intelligence, Resilience, and Motivation with a Gender Perspective. *Sustainability (Switzerland)*, *17*(10), 1–39. https://doi.org/10.3390/su17104437

Bybee, R. W. (2013). The case for education: STEM challenges and opportunities. *NSTA (National Science Teachers Assocation)*, 33–40. www.nsta.org/permissions.

Canuto, P. P., & Espique, F. (2023). Gender Equality in Science Classrooms: Examining the Implementation of Gender-responsive Approach and its Impact on Science Education. *International Journal of Learning, Teaching and Educational Research*, *22*(6), 659–678. https://doi.org/10.26803/ijlter.22.6.33

Chen, K., & Chen, C. (2021). Effects of STEM inquiry method on learning attitude and creativity. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(11), 1–6. https://doi.org/10.29333/EJMSTE/11254

Cotterill-Walker, S. M. (2012). Where is the evidence that master's level nursing education makes a difference to patient care? A literature review. *Nurse Education Today*, *32*(1), 57–64. https://doi.org/https://doi.org/10.1016/j.nedt.2011.02.001

Cresswell, J. W., & Clark, V. L. P. (2018). Designing and conducting mixed methods research. In *HERD: Health Environments Research & Design Journal* (third edit, Vol. 12, Issue 1, pp. 164–166). SAGE Publications Ltd. https://doi.org/10.1177/1937586719832223

David Adeline, W. (2024). Empowering Girls in Stem Education: Strategies to Address Gender Disparities. *Research Output Journal of Arts and Management*, *3*(3), 63–68. https://rojournals.org/roj-art-and-management/

Delaney, J. M., & Devereux, P. J. (2019). Understanding gender differences in STEM: Evidence from college applications☆. *Economics of Education Review*, *72*, 219–238. https://doi.org/https://doi.org/10.1016/j.econedurev.2019.06.002

Deniş-Çeliker, H., & Dere, S. (2022). The Effects of The Problem-Based Learnıng Supported by Experiments in Science Course: Students' Inquiry Learning and Reflective Thinking Skills. *Journal of Science Learning*, *5*(1), 14–27. https://doi.org/10.17509/jsl.v5i1.32076

Diana, N., Turmudi, & Yohannes. (2021). Analysis of teachers' difficulties in implementing STEM approach in learning: A study literature. *Journal of Physics: Conference Series*, *1806*(1). https://doi.org/10.1088/1742-6596/1806/1/012219

Ekelemu, E. (2014). Teacher attitude, experience and background knowledge effect on the use of inquiry method of Teaching IRJTE Teacher attitude, experience and background knowledge effect on the use of inquiry method of Teaching. *Global Research Journal of Education*, *2*(4), 198–206.

English, L. D. (2016). STEM education K-12: perspectives on integration. *International Journal of STEM Education*, *3*(1), 1–8. https://doi.org/10.1186/s40594-016-0036-1

Ergün, A. (2019). Identification of the interest of Turkish middle-school students in stem careers: Gender and grade level differences. *Journal of Baltic Science Education*, *18*(1), 90–104. https://doi.org/10.33225/jbse/19.18.90

Faber, M., Unfried, A., Wiebe, E. N., Corn, J., Townsend, L. T. W., & Collins, T. L. (2013). Student attitudes toward stem: The development of upper elementary school and middle/high school student surveys. *ASEE Annual Conference and Exposition, Conference Proceedings*, *June*.

Farwati, R., Metafisika, K., Sari, I., Sitinjak, D. S., Solikha, D. F., & Solfarina, S. (2021). STEM Education Implementation in Indonesia: A Scoping Review. *International Journal of STEM Education for Sustainability*, *1*(1), 11–32. https://doi.org/10.53889/ijses.v1i1.2

Firda, R.-, Kaniwati, I., & Sriyati, S. (2021). STEM Learning in Sustainability Issues to Improve Sustainability Consciousness of Junior High School Students. *Paedagogia*, *24*(1), 53. https://doi.org/10.20961/paedagogia.v24i1.54212

Fritz, A., Haase, Victor, G., & Räsänen, P. (2019). *International Handbook of Mathematical Learning Difficulties: Foreword by* Springer.

García-González, E., Jiménez-Fontana, R., & Azcárate, P. (2020). Education for sustainability and the sustainable development goals: Pre-service teachers' perceptions and knowledge. *Sustainability*, *12*(7741). https://doi.org/10.3390/su12187741

Hall, B. J. M., Ponton, M. K., & Hall, J. M. (2005). Mathematics self-efficacy of college freshman. *Journal of Developmental Education*, *28*, 26–32.

Honey, M., Pearson, G., & Schweingruber, H. (2014). STEM integration in K-12 education status, prospects, and an agenda for research. In T. N. A. Press (Ed.), *70th Annual International Technology Education Association Conference*. https://www.nap.edu/catalog/18612/stem-integration-in-k-12-education-status-prospects-and-an

Juliangkary, E. (2025). *Realistic Mathematics Education as a Contextual Approach in Overcoming Learning Difficulties Circle*. *10*(2), 569–576.

Kijima, R., & Sun, K. L. (2020). 'Females Do not Need to be Reluctant': Employing Design Thinking to Harness Creative Confidence and Interest in STEAM. *International Journal of Art and Design Education*, *40*(1), 66–81. https://doi.org/10.1111/jade.12307

Lane, C., Kaya-Capocci, S., Kelly, R., O'Connell, T., & Goos, M. (2022). Fascinating or dull? Female students' attitudes towards STEM subjects and careers. *Frontiers in Psychology*, *13*(September), 1–16. https://doi.org/10.3389/fpsyg.2022.959972

Le, L. T. B., Tran, T. T., & Tran, N. H. (2021). Challenges to STEM education in Vietnamese high school contexts. *Heliyon*, *7*(12), e08649. https://doi.org/10.1016/j.heliyon.2021.e08649

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-018-0151-2

Mau, W. C., Chen, S. J., & Lin, C. C. (2019). Assessing high school student's stem career interests using a social cognitive framework. *Education Sciences*, *9*(2). https://doi.org/10.3390/educsci9020151

Muneer, S., Santhosh, M., Parangusan, H., & Bhadra, J. (2025). A meta-analysis to explore the role of design thinking in enhancing creativity as learning outcomes in STEM education. In *International Journal of Technology and Design Education* (Issue 0123456789). Springer Netherlands. https://doi.org/10.1007/s10798-025-10005-2

Nadelson, L. S., & Seifert, A. L. (2017). Integrated STEM defined: Contexts, challenges, and the future. *Journal of Educational Research*, *110*(3), 221–223. https://doi.org/10.1080/00220671.2017.1289775

National Center for Science and Engineering Statistics. (2023). Women, Minorities, and Persons with Disabilities in Science and Engineering: 2021. *Special Report NSF 21-321*, 1–62. https://ncses.nsf.gov/pubs/nsf21321/report/introduction

Nugraha, M. G., Kidman, G., & Tan, H. (2023). Pre-service teacher in STEM education: An integrative review and mapping of the Indonesian research literature. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(5). https://doi.org/10.29333/ejmste/13155

OECD. (2016). *Innovating Education and Educating for Innovation*. OECD Publishing. https://doi.org/10.1787/9789264265097-en

OECD. (2025). Gender Differences in Education, Skills and STEM Careers in Latin America and the Caribbean: Insights from PISA and PIAAC. In *Gender Differences in Education, Skills and STEM*

Careers in Latin America and the Caribbean. OECD Publishing. https://doi.org/10.1787/4ea07281-en

Özcan, B., & Kültür, Y. Z. (2021). The Relationship Between Sources of Mathematics Self-Efficacy and Mathematics Test and Course Achievement in High School Seniors. *SAGE Open*, *11*(3). https://doi.org/10.1177/21582440211040124

Perdana, R., Apriani, A. N., Richardo, R., Rochaendi, E., & Kusuma, C. (2021). Elementary students' attitudes towards STEM and 21st-century skills. *International Journal of Evaluation and Research in Education*, *10*(3), 1080–1088. https://doi.org/10.11591/IJERE.V10I3.21389

Permanasari, A., Rubini, B., & Nugroho, O. F. (2021). STEM education in Indonesia: Science teachers' and students' perspectives. *Journal of Innovation in Educational and Cultural Research*, *2*(1), 7–16. https://doi.org/10.46843/jiecr.v2i1.24

Pilotti, M. A. E., El Alaoui, K., & Al-Zohbi, G. (2022). What Are Male and Female Students' Views of Science in a Society in Transition? A Self-Study of an Institution of Higher Education. *Education Sciences*, *12*(12). https://doi.org/10.3390/educsci12120920

Potvin, P., & Hasni, A. (2014). Interest, motivation and attitude towards science and technology at K-12 levels: a systematic review of 12 years of educational research. *Studies in Science Education*, *50*(1), 85–129. https://doi.org/10.1080/03057267.2014.881626

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics*, *117*(1–2), 1–12. https://doi.org/10.1111/ssm.12201

Rahman, A. A., Kaniawati, I., Riandi, R., & Hendayana, S. (2023). Secondary Science Teachers Perception on STEM Learning for Sustainable Development. *Jurnal Penelitian Pendidikan IPA*, *9*(3), 1297–1303. https://doi.org/10.29303/jppipa.v9i3.2776

Septiyanto, A., Widodo, A., & Prima, E. C. (2024). Elementary Teachers ' Science Background and Its Impact on Their Science Teaching. *Acta Scientiae*, *26*(1), 205–232. https://doi.org/10.17648/acta.scientiae.7889

Shin, S., Rachmatullah, A., Roshayanti, F., Ha, M., & Lee, J. K. (2018). Career motivation of secondary students in STEM: a cross-cultural study between Korea and Indonesia. *International Journal for Educational and Vocational Guidance*, *18*(2), 203–231. https://doi.org/10.1007/s10775-017-9355-0

Stohlmann, M., Moore, T., & Roehrig, G. (2012). Considerations for Teaching Integrated STEM Education. *Journal of Pre-College Engineering Education Research*, *2*(1), 28–34. https://doi.org/10.5703/1288284314653

Tamba, R. M., & Chiang, C. L. (2021). Gender Disparity in Higher Education in North Sumatra and the Challenges Young Indonesian Women Face in STEM Education. *Advances in Engineering Research*, *209*(Ijcse), 635–641.

Tan, A. L., Ong, Y. S., Ng, Y. S., & Tan, J. H. J. (2023). STEM Problem Solving: Inquiry, Concepts, and Reasoning. *Science and Education*, *32*(2), 381–397. https://doi.org/10.1007/s11191-021-00310-2

To Khuyen, N. T., Van Bien, N., Lin, P. L., Lin, J., & Chang, C. Y. (2020). Measuring teachers' perceptions to sustain STEM education development. *Sustainability*, *12*(4), 1–15. https://doi.org/10.3390/su12041531

Toma, R. B., & Greca, I. M. (2018). The effect of integrative STEM instruction on elementary students' attitudes toward science. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(4), 1383–1395. https://doi.org/10.29333/ejmste/83676

Tunc, C., & Bagceci, B. (2020). Teachers' Views of the Implementation of STEM Approach in Secondary Schools and The Effects on Students. *Pedagogical Research*, *6*(1), em0085. https://doi.org/10.29333/pr/9295

UNESCO. (2019). Sub-Education policy review report: Education for sustainable development. *UNESCO, Paris France*, *290*.

Ünlü, Z. K., Dököe, İ., & Ünlü, V. (2016). Adaptation of the Science, Technology, Engineering, and Mathematics Career Interest Survey (STEM-CIS) into Turkish. *Eurasian Journal of Educational Research*, *16*(63), 21–36. https://doi.org/10.14689/ejer.2016.63.2

Wahono, B., & Chang, C. Y. (2019). Assessing Teacher's Attitude, Knowledge, and Application (AKA) on STEM: An Effort to Foster the Sustainable Development of STEM Education. *Sustainability (Switzerland)*, *11*(4). https://doi.org/10.3390/su11040950

Wang, H., Moore, T. J., Roehrig, G. H., & Park, M. S. (2011). STEM Integration : Teacher Perceptions and Practice STEM Integration : Teacher Perceptions and Practice. *Journal of Pre-College Engineering Education Research (J-PEER)*, *1*(2), 1–13. https://doi.org/10.5703/1288284314636

Wang, N., Tan, A. L., Zhou, X., Liu, K., Zeng, F., & Xiang, J. (2023). Gender differences in high school students' interest in STEM careers: a multi-group comparison based on structural equation model. *International Journal of STEM Education*, *10*(1). https://doi.org/10.1186/s40594-023-00443-6

WEF. (2022). The Global Risks Report 2022. In *World Economic Forum*. wef.ch/risks22

Weinstein, C. S. (1988). Preservice teachers' expectations about the first year of teaching. *Teaching and Teacher Education*, *4*(1), 31–40. https://doi.org/https://doi.org/10.1016/0742-051X(88)90022-4

Yamtinah, S., Utami, B., Masykuri, M., Mulyani, B., Ulfa, M., & Shidiq, A. S. (2022). Secondary School Science Teacher Response to Minimum Competency Assessment: Challenges and Opportunities. *Jurnal Penelitian Pendidikan IPA*, *8*(1), 124–131. https://doi.org/10.29303/jppipa.v8i1.1075

Zhou, S. N., Zeng, H., Xu, S. R., Chen, L. C., & Xiao, H. (2019). Exploring changes in primary students' attitudes towards science, technology, engineering and mathematics (STEM) across genders and grade levels. *Journal of Baltic Science Education*, *18*(3), 466–480. https://doi.org/10.33225/jbse/19.18.46