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Exploring STEM Attitudes in Indonesian Elementary Students: A Comparative Analysis of Gender and Grade Level

Fitria Wulandari[1,*], & Lilik Binti Mirnawati[2]

[1]Department of Teacher Professional Education, Universitas Muhammadiyah Sidoarjo, Indonesia

[2]Department of Elementary Teacher Education, Universitas Muhammadiyah Surabaya, Indonesia

Abstract: Amidst the rapid development of science and technology, STEM learning has become an essential approach to preparing the younger generation with 21st-century skills. However, in Indonesia, interest and positive attitudes toward STEM subjects at the elementary level remain limited. **Objective:** This study aims to examine students' attitudes toward STEM and identify possible differences by gender and grade level among fourth and fifth-grade students in an elementary school in Sidoarjo, Indonesia. **Methods:** A quantitative cross-sectional comparative design was employed, involving 314 students with 167 males (53.18%) and 147 females (46.81%). Data were collected using the STEM Attitude Scale for upper elementary students, developed by Unfried, with internal reliability coefficients ranging from $\alpha = 0.83$ to $\alpha = 0.87$. The data were analysed using normality and homogeneity tests, independent-samples t-tests, and effect size calculations (Cohen's d). Focus group interviews were also conducted to complement the quantitative data. **Findings:** The results showed students' attitudes toward STEM are positive. Moreover, it was found that there are no significant differences in overall STEM attitudes by gender or grade level. Although no statistically significant difference was observed, a small-to-medium effect ($d = 0.30$) in the science aspect suggested that younger students tended to express slightly higher enthusiasm for science-related learning. Furthermore, findings from the interviews indicate that students' attitudes toward STEM influence their perceptions of their desired future careers or professions. Overall, the findings of this study are largely consistent with those of previous studies. **Conclusion:** The findings suggest that gender and grade-level differences in STEM attitudes among elementary students are minimal, indicating that early, inclusive, and hands-on STEM education may effectively promote equal engagement and interest across these groups. This study is limited by the small sample size, limited variables, and quantitative approach; therefore, future research should involve more schools and explore how STEM attitudes relate to students' interest in STEM careers.

Keywords: STEM education, attitude, gender, grade level.

▪ INTRODUCTION

The rapid development of technology demands that humans possess 21st-century skills to meet the criteria of competent professionals in science and technology. For example, studies show that mastery of skills such as critical thinking, collaboration, communication, creativity, and digital literacy is increasingly important in the modern workforce (Reza et al., 2025). Science and technology play a vital role in scientific development, contributing to the creation of a global civilization. However, in education nowadays, there are two gaps in real-world skills: the first is between the subjects taught in school and the skills needed in a professional environment. For example, research on employability shows a misalignment between curriculum content and industry-required competencies (Alwi & Karim, 2024). The second gap is in Science, Technology, Engineering, and Mathematics (STEM), while demand for STEM-trained professionals continues to grow globally, student interest and engagement in STEM fields remain

Fitria Wulandari
*Email: fitriawulandari1@umsida.ac.id

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relatively low (Chen et al., 2024). One approach considered effective in addressing this discrepancy is the STEM approach (Bybee, 2013). With STEM education, learners are expected to develop not only domain-specific knowledge but also soft skills such as communication, collaboration, problem-solving, and creativity (Ejiwale, 2014). STEM education in Indonesia was introduced by the SEAMEO Center for QITEP in 2013 through teacher training activities, principal training, and other policy forums (SEAMEO SEAMOLEC, 2019; Triyanta, 2018). In 2019, the research theme aligned with the STEM Integration Program outlined in the 2013 Curriculum Implementation. The research was conducted by teachers to gain meaningful experience in implementing STEM in schools, through the provision of research grants based on the selection of proposals submitted by MGMP (SEAMEO SEAMOLEC, 2019). Despite these national efforts to promote STEM education, improvements in students' scientific understanding and attitudes have not been strongly reflected in international assessments.

In the Programme for International Student Assessment (PISA), Indonesia's ranking in science has remained relatively low, placing 70th out of 78 participating countries in 2018 and maintaining the same position out of 81 countries in 2022 (OECD, 2023). This issue highlights long-term challenges in developing students' scientific literacy and motivation toward science learning. Several studies have shown that low achievement in large-scale assessments such as PISA is not only influenced by cognitive factors but also by students' affective domains, particularly their attitudes toward science and learning motivation (Bybee, 2013; Ogegbo & Aina, 2024; Osborne et al., 2003). Therefore, efforts to improve national science performance must begin by fostering positive attitudes toward STEM from an early age.

At the elementary school level, students' attitudes toward science and technology serve as a foundation for later interest in STEM-related careers (Archer et al., 2013; Nugent et al., 2015). A lack of early engagement can lead to declining motivation and participation in STEM subjects as students progress through schooling, which ultimately contributes to the shortage of qualified STEM professionals observed in many developing countries (Marginson et al., 2013). Thus, examining the STEM attitudes of elementary students, particularly in the domains of science and 21st-century skills, is an essential step in understanding how interest and confidence in science develop. This study responds to that need by analysing how differences in STEM attitudes manifest across grade levels in Indonesian elementary schools.

According to the expectancy value theory, students' attitudes toward learning are shaped by two primary psychological factors: expectancy beliefs, which refer to the degree to which they believe they can succeed in a task, and task values. The perceived importance and enjoyment of the task (Eccles & Wigfield, 2020). These factors jointly influence the affective, cognitive, and behavioural components of attitude formation, which in turn predict students' engagement, achievement, and long-term career choices. In STEM education, a positive attitude can increase students' persistence and achievement, while a negative attitude can discourage participation in STEM-related pathways (Archer et al., 2013).

Building on this theoretical framework, numerous empirical studies have investigated the relationship between students' attitudes toward specific STEM domains and their academic performance. Previous STEM research has shown that mathematics and science achievement are significantly and positively correlated with students'

mathematics and science attitudes, as female students often outperform male students in both areas, whereas male students tend to express stronger interest in the fields related to engineering (Karalar et al., 2021; Yerdelen et al., 2016). There is a significant reciprocal relationship between the dimensions of attitudes towards STEM (Suprapto, 2016). In addition, a positive relationship exists between attitudes towards STEM fields and interest in STEM careers (Ciftci et al., 2020), suggesting that approximately 43% of the total variance in interest in STEM careers is attributed to attitudes towards the STEM field. They reported that attitude toward STEM was an essential factor in determining interest in a STEM career. These findings underscore that students' attitudes toward STEM are a key determinant of their academic motivation and future career orientation.

In Indonesia, a study has shown that STEM learning can influence the development of student motivation, an active lifestyle, and self-confidence (Byoka & Budiana, 2021; Ginanjar et al., 2021). Other research suggests that students' interest in STEM does not directly lead them to choose careers in STEM fields, and that other factors, such as attitudes, abilities, personal characteristics, and job opportunities, may also have a mediating effect. Attitudes towards STEM education can also be seen as one of these factors (Demir et al., 2021). In Indonesia, research has been conducted on student attitudes in STEM at the junior high school level (Suprapto, 2016). However, at the elementary school level, especially grades 4 and 5, there has been no research examining this.

Attitudes towards STEM education are defined as the behaviours that an individual is expected to show in the field of science, technology, engineering, and mathematics (Yıldırım, 2021). Students' attitudes are the most important factor in determining satisfaction and acceptance of STEM-based learning, which also affects learning outcomes (Zhao et al., 2022). Students' attitudes toward STEM self-efficacy and expectancy value beliefs influence STEM achievement, either directly or indirectly (Han et al., 2021). In addition, by determining attitudes towards STEM education, especially at a young age, it is possible to shape the education that directs students to a STEM-based workforce (Demir et al., 2021).

Despite the growing body of research on STEM attitudes, the conceptual understanding of how such attitudes develop and differ across STEM domains during early schooling remains limited. Most previous studies have focused on secondary or tertiary students, leaving unanswered questions about how children's affective and cognitive beliefs about science, technology, engineering, and mathematics begin to diverge or stabilize during late elementary years. Therefore, this study aims to compare elementary students' attitudes toward STEM across gender and grade levels, particularly among students in grades 4 and 5, and also to analyse variations in students' attitudes across the four subdomains of STEM. The findings are expected to provide empirical insights for educators, curriculum developers, and policymakers seeking to enhance early STEM engagement.

1. What are students' attitudes toward STEM?
2. How significant are the differences in students' attitudes toward STEM in terms of gender?
3. What are the differences in fourth and fifth graders' attitudes toward STEM?

▪ METHOD

The participants in this study were students from SD Muhammadiyah 1 Sidoarjo, a private Islamic elementary school located in an urban area of East Java, Indonesia. The school serves students from diverse socioeconomic backgrounds and has previously implemented STEM-based learning programs as part of its science curriculum. The population in this study consisted of fourth- and fifth-grade students. A convenience sampling technique was employed, selecting participants based on their accessibility and willingness to participate, rather than through random assignment. Consequently, two naturally existing classroom clusters (grades 4 and 5) were selected as the research sample, comprising a total of 314 students, with 167 male students (53.18%) and 147 female students (46.81%).

The sampling approach did limit the generalizability of findings, but it provided valuable exploratory insights into students' attitudes toward STEM in a school context that actively promotes STEM instruction. An a priori power analysis was conducted using G*Power 3.1, which indicated that with $\alpha = 0.05$ and power $(1–\beta) = 0.80$, a minimum of 210 participants was required to detect a medium effect size ($d = 0.50$). Thus, the sample size of 314 was sufficient to detect moderate to large effects (Cohen, 1992). This research employed a quantitative cross-sectional comparative survey design. The design was appropriate for identifying group differences and describing relationships between variables without manipulation or intervention (Fraenkel et al., 2023). The survey method followed Creswell's framework, which defines a survey as a quantitative procedure for collecting data to describe trends, attitudes, or opinions in a population. In addition, focus group interviews were conducted at the end of the survey session to complement the quantitative findings (Creswell, 2010). These interviews asked students to describe their perceptions of STEM learning, their future career aspirations, and the reasons behind their choices, providing contextual insights into the attitudes captured by the STEM Attitude Scale.

Data were collected using the STEM Attitude Scale, developed by the Friday Institute (2012), for upper-elementary students. The instrument measures four subdomains: attitudes toward science, mathematics, engineering, and technology, as well as 21st-century learning skills. The original English version reports internal consistency reliability coefficients for upper elementary students as follows: $\alpha = 0.85$ for mathematics, $\alpha = 0.83$ for science, $\alpha = 0.84$ for engineering & technology, and $\alpha = 0.87$ for 21st-century learning attitudes (Friday Institute for Educational Innovation, 2014; Unfried et al., 2015). For this study, the instrument was translated into Bahasa Indonesia by the researchers. However, due to resource constraints, the authors did not conduct a formal pilot test, and reliability estimates for the Indonesian version are assumed to be comparable based on previous use in Indonesian primary school contexts (Manalu & Chang, 2025).

The data was gained in classroom settings during school hours under the supervision of the researcher and class teachers. Before distribution, students received standardized oral instructions that explained the purpose of the study and the confidentiality of their responses. Participation was voluntary, and they were instructed to complete the questionnaire individually within approximately 30 minutes. Questionnaires were collected immediately after completion. This study focused on gender and grade level as the primary independent variables, because both factors have been widely identified in previous STEM education research as key determinants influencing students' attitudes toward STEM learning. Gender differences often relate to

variations in interest, confidence, and self-efficacy in science and technology fields. At the same time, grade level reflects developmental and experiential differences in students' exposure to STEM content. Focusing on these two variables enables a clearer and more controlled examination of how demographic and educational factors influence students' STEM attitudes, without introducing additional confounding variables that could obscure the analysis.

Prior to analysis, assumptions for the independent-samples t-test were examined. Normality was tested using the Shapiro–Wilk test, and homogeneity of variance was verified using Levene's test. Both assumptions were met ($p > 0.05$). Data analysis was conducted using IBM SPSS Statistics version 26 at a significance level of 0.05. The independent-samples t-test was used to compare the mean differences across the two groups (gender and grade level). Effect sizes were calculated using Cohen's d, with benchmarks of small (0.20), medium (0.50), and large (0.80) (Cohen, 1992).

For the qualitative stage, focused group interviews were conducted with four participants selected purposively, including one male and one female student from grade IV, as well as one male and one female student from grade V. The selection of a limited number of participants was intended to provide in-depth, qualitative insights to explain the quantitative findings, rather than for generalization. This approach aligns with the principle of embedded design, where qualitative data serve as supporting evidence to enhance the interpretation of survey results (Creswell & Clark, 2018).

▪ RESULT AND DISSCUSSION

This study was designed to examine students' attitudes towards STEM. The survey results showed the demographics of students in grades 4 and 5. Demographic information and the STEM Attitude Scale were used as data collection tools in this study.

Table 1. Participants demographic information

Dimension	Category	Frequency	Percentage
Gender	Man	167	53.18%
	Woman	147	46.81%
Class Level	4th grade	121	38.53%
	Grade 5	193	61.46%

Table 1 above shows that, based on gender, there are 167 males (53.18%) and 147 females (46.81%). Thus, the subjects in the study were mostly male than female. Meanwhile, from grade level, there are 121 students from fourth grade (38.53%) and 193 students from fifth grade (61.46%). Therefore, in this study, the fifth graders outnumbered the fourth graders.

Student Attitude towards STEM

Table 2 below presents the statistics obtained from the STEM Attitude Scale and its aspects, including Mathematics, Science, Technology, Engineering, 21st-century skills, and total STEM attitudes, based on data from 314 research subjects.

Table 2. Student attitude towards STEM

Aspect	*N*	*M*	*SD*	S^2	*Min*	*Max*
Mathematics	314	23.03	5.19	6.32	16	32

Science	314	27.52	5.56	16.87	15	45
Engineering-technology	314	30.85	5.56	27.24	14	45
21st-century skills	314	38.53	6.48	17.53	23	55
Total	314	119.95	11.44	120.68	42	160

Based on the data, the average score on the STEM attitude scale of the Mathematics aspect is M=23.03 and SD=5.19 out of 32, the Science aspect is M=27.52 & SD=5.56 out of 45, the Technological-engineering aspect is M=30.85 & SD=5.56 out of 45, and the 21st-century skills aspect is M = M=38.53 & SD=6.48 out of 55. The total STEM attitude is M = 119.95 and SD = 11.44 out of 160. All numbers of each aspect are high, indicating that students have a positive learning attitude towards STEM. Additionally, interview data revealed that most students enjoyed the STEM learning approach, as it made learning both fun and interactive. Similar results can be found in interviews, which show that students have a positive attitude towards STEM learning. Students stated that "they like STEM lessons because they can immediately try to make their own tools." They also mentioned that "STEM is fun because they work in groups and make projects." They further mentioned their interest in STEM fields in the future: "When they grow up, they want to work in one of the STEM fields."

This study examined the attitudes of elementary students toward STEM, with a focus on gender and grade-level differences. Overall, the findings indicated that both male and female students showed positive attitudes toward STEM learning. These results are consistent with previous research, which has shown that elementary students generally hold positive perceptions toward STEM and 21st-century learning skills (Karalar et al., 2021; Perdana et al., 2021). High mean scores across all sub-scales suggest that early exposure to integrated and active STEM experiences can nurture curiosity and enjoyment in learning, which are critical elements in sustaining engagement in science and technology fields from an early age (Yıldırım, 2021).

Students' Attitudes toward STEM in Terms of Gender

Table 3 below shows statistical data on student attitudes toward STEM in terms of gender. The STEM attitude scale scores for male and female students, assessed across the same aspects (Mathematics, Science, Technology, Engineering, and 21st-century skills), and total STEM attitudes, by gender, are as follows.

Table 3. T-Test results of attitude scale against STEM by gender

Aspect	Category	*N*	*M*	*SD*	*S2*	*Min*	*Max*	*t*	*p*	*Cohens*
Mathematics	Male	167	23.64	2.81	7.91	18	32	0.23	0.89	0.00
	Female	147	23.63	2.76	7.67	16	30			
Science	Male	167	28.94	4.48	20.09	16	45	-1.13	0.44	-0.13
	Female	147	29.53	4.73	22.40	15	39			
Engineering-Technology	Male	167	32.71	5.46	29.89	14	45	0.84	0.43	0.09
	Female	147	32.22	4.79	22.98	14	44			
21st-Century Skills	Male	167	41.60	5.37	28.87	29	55	-1.13	0.80	-0.12
	Female	147	42.23	4.71	22.23	23	53			
STEM-Gender	Male	167	126.90	13.33	177.78	42	156	0.49	0.95	0.05

Female	147	127.62	12.43	154.56	77	160

Table 3 reports the results of independent-samples t-tests comparing male and female students on the STEM attitude subscales. With degrees of freedom equal to 312 ($N_1 = 167$, $N_2 = 147$), no statistically significant gender differences were observed on any subscale, for Mathematics (M male = 23.64, SD = 2.81; M female = 23.63, SD = 2.76), t = 0.23, p = 0.89, Cohen's d = 0.00; for Science (M male = 28.94, SD = 4.48; M female = 29.53, SD = 4.73), t = -1.13, p = 0.44, Cohen's d = -0.13; for Engineering–Technology (M male = 32.71, SD = 5.46; M female = 32.22, SD = 4.79), t = 0.84, p = 0.43, Cohen's d = 0.09; and for 21st-century skills (M male = 41.60, SD = 5.37; M female = 42.23, SD = 4.71), t = -1.13, p = 0.80, Cohen's d = -0.12. Overall STEM scores were also similar between genders (t = 0.49, p = 0.95, Cohen's d = 0.05), meaning there is no significant difference in the results of STEM-Gender. All p-values exceed 0.05, and effect sizes are near zero or small, indicating negligible gender differences in STEM attitudes in this sample.

To provide a more precise visual representation of the gender-based comparison in STEM attitude subscales, a bar chart illustrating the mean scores of male and female students across each domain is presented in Figure 1.

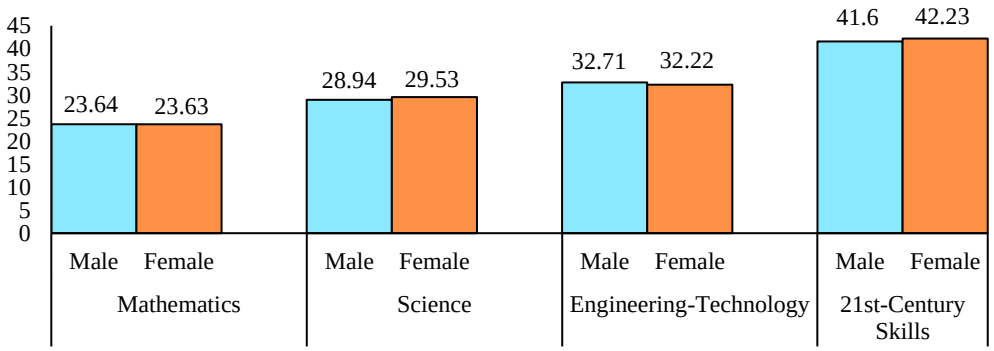

Figure 1. Comparison of the STEM attitude scale by gender

The figure shows that the average difference between male and female students in all aspects of STEM (Mathematics, Science, Technology & Engineering, and 21st Century Skills) is very small and insignificant (p > 0.05). The blue bars represent the average scores of male students and the yellow bars represent female students, while the vertical lines indicate the 95% confidence interval. The overlap of all confidence intervals confirms that there are no significant differences between the two groups. The interview results support these findings. Analysis of the interview results shows that both male and female students have an attitude towards STEM. Male and female students show that "they are interested in Science, Technology & Engineering, Mathematics for their future." From the interviews, similar results were obtained from male and female students who said "they are doing very well in mathematics and science classes this year." Furthermore, the interview results from both male and female students mentioned that "they know adults who work as scientists, engineers, mathematicians, and adults who work as technologists." Thus, both male and female students showed relatively similar attitudes towards STEM in all aspects measured.

Interestingly, there were no significant differences in overall STEM attitudes between male and female students. This finding aligns with other studies that reported negligible gender differences among primary students, suggesting that stereotypes related to the "masculine" and "feminine" STEM domains may not yet be fully formed at this age (Karalar et al., 2021). Another study by Manalu & Chang (2025) presented the results of a chi-square analysis on the gender variable, with a p-value of 0.697, indicating no significant relationship between gender and students' interest in STEM. The distribution of interest was almost the same between the two groups, male and female. The result is also in line with some research that found no significant difference in the attitudes of elementary school students toward STEM and gender (Bakırcı & Karışan, 2017; Brown et al., 2016; Ciftci et al., 2020; Yerdelen et al., 2016). Furthermore, Luo et al. (2021) explain that gender-based stereotypes regarding STEM typically begin to influence self-efficacy and outcome expectations when students enter adolescence, when social identity and societal expectations become more influential. Therefore, the absence of significant differences in this study can be interpreted as indicating that the participants' school environment has been quite successful in creating a gender-neutral STEM learning environment.

The qualitative data from student interviews further support the interpretation of quantitative data. Both boys and girls reported enjoying science experiments and group projects because these activities were fun and collaborative. These experiences likely help minimize the reinforcement of gendered stereotypes in classroom settings. Similar observation found that engaging, interactive coding and problem-solving tasks fostered equal enthusiasm among male and female students, increasing their confidence and perceived relevance of STEM activities to daily life (Ogegbo & Aina, 2024).

Although the gender differences in this study were not statistically significant, other studies have found minor variations that require further attention. Female students showed slightly higher attitudes toward science and 21st-century skills, while male students had marginally higher scores in mathematics and technology, and engineering. This subtle pattern aligns with the expectancy-value theory and findings from other studies, which suggest that while intrinsic interest in learning may be similar across genders, differences in self-efficacy (confidence in performing STEM-related tasks) can emerge even in early education (Eccles & Wigfield, 2020; Ketenci et al., 2021). Such variations, though small, may evolve into larger disparities later if not addressed through supportive classroom practices. However, these variations do not reflect ability gaps, but rather different motivational orientations shaped by social experiences and learning contexts. Positive self-efficacy beliefs develop through mastery experiences and social reinforcement; thus, designing balanced STEM learning environments where both genders can experience competence and collaboration is crucial (Bandura, 1997).

Students' Attitudes towards STEM in Terms of Grade Level

There is statistical data on student attitudes towards STEM, specifically regarding grade levels (grades 4 and 5), from the aspects of Mathematics, Science, Technology, Engineering, and 21st-century skills, as well as total STEM attitudes in terms of grade levels.

Table 4. T-Test results of attitude scale against STEM by grade level

Aspect	*Class*	*N*	*M*	*SD*	*S2*	*Min*	*max*	*t*	*p*	*Cohens*
Mathematics	4	121	23.85	3.06	9.40	16	32	1.09	0.45	0.11
	5	193	23.50	2.59	6.75	17	31			
Science	4	121	30.05	4.50	20.27	20	45	2.58	0.01	0.30
	5	193	28.68	4.59	21.15	15	39			
Engineering-technology	4	121	32.22	5.77	33.37	0	44	-0.70	0.28	-0.07
	5	193	32.64	4.74	22.48	14	45			
21st-century skills	4	121	41.39	5.80	33.70	0	53	-1.39	0.75	-0.14
	5	193	42.21	4.55	20.70	29	55			
STEM- Class	4	121	127.54	14.84	220.23	42	156	0.32	0.26	0.03
	5	193	127.05	11.56	133.72	93	160			

Table 4 presents the results of independent-samples t-tests comparing STEM attitude scores between students in grade 4 and those in grade 5. The analysis revealed no statistically significant differences for Mathematics, Engineering–Technology, 21st-century skills, or total STEM attitude scores ($p > 0.05$). However, a significant difference emerged in the Science aspect, where grade 4 students ($M = 30.05$, $SD = 4.50$) scored higher than grade 5 students ($M = 28.68$, $SD = 4.59$), $t = 2.58$, $p = 0.01$, Cohen's $d = 0.30$, indicating a small-to-moderate effect size. In this study, values around 0.30 were interpreted as small to moderate effects, rather than strictly moderate, to maintain alignment with conventional interpretation standards. Although some analyses yielded non-significant results, these should not be interpreted as evidence of no difference; instead, they suggest that any actual differences are likely small and below the study's statistical power threshold.

The findings indicate that while students in both grades generally showed positive attitudes toward STEM, their enthusiasm for science tended to be slightly higher in grade 4 than in grade 5. This pattern was also reflected in brief focus group interviews, where grade 4 students more frequently mentioned enjoying hands-on experiments and outdoor projects. In contrast, grade 5 students described science lessons as increasingly theoretical and test-oriented.

Another noteworthy result was that fourth graders showed significantly higher attitudes toward science than fifth graders. Younger students tend to exhibit greater enthusiasm for STEM subjects before the curriculum becomes more abstract and test-oriented (Karalar et al., 2021; Perdana et al., 2021). Interviews with students in this study confirmed this tendency: fourth graders enjoyed outdoor experiments and group projects, while fifth graders described science lessons as increasingly theoretical and exam-focused. Such shifts may dampen curiosity and engagement if not counterbalanced with continued hands-on inquiry-based learning opportunities (Yıldırım, 2021).

The findings of this study reinforce the argument that early STEM education should prioritize experiential, inclusive, and collaborative learning approaches. STEM self-efficacy and outcome expectations mediate students' future career interests; thus, maintaining high self-efficacy through enjoyable, gender-neutral learning experiences in primary school is vital for sustaining long-term interest (Luo et al., 2021). Encouragingly, the relatively equal attitudes between genders in this study may signal that the

participating schools have succeeded in creating equitable learning environments. However, teachers must remain vigilant to ensure that subtle patterns, such as boys' higher confidence in technology or girls' preference for science communication, do not crystallize into stereotypes over time. Pedagogical strategies, such as role-model integration (Cheryan et al., 2017), problem-based learning, and gender-inclusive classroom interactions, can help sustain both interest and self-efficacy for all students. Additionally, educators can incorporate project-based assessment methods that value creativity, collaboration, alongside accuracy and technical skills.

This study relied primarily on self-report survey data, which may not capture deeper cognitive and emotional dimensions of students' STEM attitudes. Future research should integrate item-level analyses, distinguishing between interest/value and self-efficacy/expectancy components. Moreover, qualitative methods such as focus groups or classroom observations could further elucidate how students' everyday experiences shape their developing identities in STEM. Longitudinal designs tracking students from elementary to middle school would also be valuable in identifying when and how gender-related differences begin to emerge. Ultimately, replication of this study in various regional contexts across Indonesia could reveal the cultural and institutional factors that influence STEM engagement.

▪ CONCLUSION

This study reveals that elementary school students generally have a positive attitude toward STEM learning. No significant differences were found between male and female students in their attitudes toward STEM, indicating that gender stereotypes in science and technology have not yet developed strongly at the elementary school age. A small difference was found only in science, where fourth graders showed slightly higher enthusiasm than fifth graders. This finding suggests that interest in science tends to decline as students progress to higher grades, when learning becomes more theoretical and exam-oriented. The interview results support the quantitative findings, which indicate that both male and female students enjoy collaborative and fun experiments and group projects. This highlights the importance of implementing STEM learning that is grounded in direct, collaborative, and gender-neutral experiences to sustain students' interest from an early age.

The findings have important implications for primary education. Fun, interactive, and inclusive STEM learning from an early age has the potential to prevent gender-based interest gaps from emerging in the future. From a theoretical perspective, these findings suggest that the models of STEM attitude development commonly applied to adolescents may not be entirely relevant to elementary school children. At this stage, attitudes toward STEM appear to be more influenced by direct learning experiences than by gender identity. Therefore, maintaining inquiry-based learning, real-world practice, and an equitable environment will be key to fostering self-efficacy and long-term interest in STEM.

This study has several limitations. First, the number of fourth- and fifth-grade elementary school students involved is still limited, resulting in a relatively low level of generalization for the findings. This means that the findings cannot be generalized to reflect all fourth- and fifth-grade elementary school students in Indonesia. However, the research findings are useful in understanding the attitudes of fourth and fifth-grade

elementary school students toward STEM. The second limitation of this study is that when examining students' attitudes toward STEM, the variables were gender and grade level. Thus, different variables could be used in future studies. The third limitation of this study is that it is a quantitative study, and students' attitudes toward STEM could be investigated in greater depth with a qualitative study. Therefore, it is recommended that future studies involve more schools and grade levels, as well as explore the relationship between STEM attitudes and students' interest in future careers in the STEM field.

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