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STEM Literacy Development Among Elementary Students in Central Jakarta: Evidence from the P5 Project Implementation

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ABSTRACT: This study aimed to measure the level of STEM literacy among elementary school students in Central Jakarta and analyze differences across grade levels. Eight literacy indicators were derived from existing frameworks and used to construct the assessment instrument. Data were collected from 90 fourth- and fifth-grade students at SDN Johar Baru 01 Pagi. Descriptive statistics and an independent samples t-test were employed to evaluate literacy levels and group differences. Results indicated that most students scored low in five indicators such as STEM discipline knowledge and critical thinking. However, they performed higher in three indicators, including independent decision-making and risk management. The t-test revealed no statistically significant difference between the two grade levels. These findings highlight the need for early STEM learning interventions and integrated instructional approaches to strengthen weak aspects of students' STEM literacy.

KEYWORDS: STEM Literacy, Elementary Student, Indonesia Education, STEM Education

I. INTRODUCTION

The Fourth Industrial Revolution has brought about significant changes across various aspects of life, including the field of education. These changes demand an increase in students' competencies, particularly in STEM literacy (Science, Technology, Engineering, and Mathematics), to enable them to compete and contribute in a global era marked by the complex challenges of the 21st century (Dito & Pujiastuti, 2021). The definition of STEM literacy has evolved alongside the growing awareness of the importance of integrating science, technology, engineering, and mathematics in education. Initially, literacy in each domain was viewed separately. Scientific literacy referred to the understanding of scientific concepts for everyday life (National Research Council, 1996), technological literacy emphasized the ability to use and evaluate technology (National Assessment Governing Board, 2010), engineering literacy focused on design processes and the application of scientific principles (OECD, 2003), while mathematical literacy encompassed the use of mathematics in various life contexts (OECD, 2006). This historical understanding of literacy, along with efforts to integrate STEM learning, has helped identify the components that form a comprehensive definition of STEM literacy. According to the National Governors Association (2007), STEM literacy is defined as an individual's ability to use their understanding of how the world works through four interconnected domains. Therefore, STEM literacy is understood as an interdisciplinary field that links science, technology, engineering, and mathematics—not merely mastery of each domain in isolation, but also a deep understanding of the interconnections and integration among the four.

This perspective is supported by Bybee (2013), who argues that STEM literacy is not limited to conceptual knowledge within each discipline, but also includes integrative skills that enable the application of science and technology to solve real-world problems. Similarly, Cavalcanti (2017) emphasizes that STEM literacy involves knowledge, skills, and a positive attitude toward STEM fields, as well as the ability to use and relate that information to daily life contexts. STEM literacy is thus defined as encompassing conceptual understanding, procedural skills, and competencies that empower individuals to address personal, social, and global issues related to STEM (Bybee, 2010); the ability to engage in STEM-specific discourse; a positive disposition toward STEM (Wilkins, 2000, 2010), including the willingness to engage and persist in STEM-related fields (Wilkins, 2000, 2010); an understanding of how STEM concepts can be applied to solve real-world problems; and an appreciation for how STEM processes and practices evolve with technological advancements and societal demands (Moore et al., 2020).

Nevertheless, various studies have shown that Indonesian students' STEM literacy levels remain relatively low. According to the 2022 Programme for International Student Assessment (PISA) report, Indonesian students' performance in science and mathematics literacy is still below the OECD average (Center for Educational Assessment, 2023). This indicates that Indonesian students have not yet fully mastered the foundational competencies required for STEM literacy. Although the issues of literacy and STEM education frequently appear in national education discourse, research that specifically explores STEM literacy at the elementary level is still scarce. Most existing studies focus on secondary or higher education, such as those by Harpian et al. (2021), Nurlaely et al. (2017), and Dewi et al. (2024). Literature on elementary students' understanding and application of STEM concepts remains limited (Rochman et al., 2019), even though elementary school is a critical phase for developing scientific thinking and interest in science and technology (Abdullah et al., 2025). Therefore, empirical studies are needed to measure elementary students' STEM literacy comprehensively, to fill this research gap and provide baseline data that can inform policies and STEM-based instructional practices from an early age.

In response to this challenge, several studies have aimed to identify indicators of STEM literacy as a basis for designing effective assessment tools. A STEM-literate individual, according to Bybee (2010), has a strong understanding of the foundational concepts in science, technology, engineering, and mathematics—summarized by Jackson (2021) under the indicator "STEM Discipline Knowledge." This knowledge forms a critical foundation for explaining scientific phenomena and understanding interdisciplinary connections in real life (Rizki & Suprapto, 2024). STEM literacy is also closely related to critical, creative, and analytical thinking abilities. In facing complex global challenges, students are expected to evaluate information, construct logical arguments, and produce original solutions (Shanta & Wells, 2022; Sie & Lin, 2025).

Moreover, problem-solving skills are a key trait of students who can apply STEM concepts to systematically and innovatively address authentic problems (Solihah et al., 2024). These students are accustomed to making independent decisions based on evidence, data, and logical reasoning—crucial abilities in technology-driven workplaces (Han et al., 2021). Students with strong STEM literacy also develop an awareness of how innovation can drive positive social change, improve quality of life, and expand access to technology (Babenko, 2025; Oschepkov et al., 2022).

The ability to consider environmental impacts and sustainability in every technological decision is also an integral part of STEM literacy. This reinforces the importance of ethics and ecological responsibility in solution development (Purwaningsih & Wulandari, 2024). In addition to cognitive and social dimensions, STEM literacy requires high intrinsic motivation and active engagement in the learning process. Fully engaged students demonstrate their readiness to pursue careers in STEM fields (Meylani, 2024). The dynamic nature of STEM demands adaptability to technological developments and effective risk management. Flexibility and resilience become key indicators to ensure students remain robust and relevant in the face of change (Abina et al., 2024; Funa et al., 2024).

STEM literacy indicators, according to experts, reflect a holistic approach that not only emphasizes mastery of concepts in science, technology, engineering, and mathematics, but also students' ability to apply this knowledge contextually in real-life situations. Falloon (2020) argues that STEM literacy should be developed through interdisciplinary integration, where learning is not fragmented by subject areas but is instead cohesive and mutually reinforcing. He also emphasizes the importance of contextual problem-solving—students' ability to solve problems relevant to their own lives—and the development of a STEM identity, referring to how students perceive themselves as part of the STEM community.

Meanwhile, Bybee (2010) expands the concept of STEM literacy by stressing its role in shaping scientific thinking and increasing awareness of the role of STEM in social and cultural development. According to him, STEM literacy includes the capacity to actively participate in a knowledge-based society, make science-informed decisions, and understand the social implications of technology.

From a more equity-driven perspective, Jackson and Mohr-Schroeder (2018) developed the Equity-Oriented STEM Literacy Framework, which highlights the importance of equitable access to high-quality STEM learning, particularly for historically underrepresented student groups. They emphasize the significance of dispositions (attitudes and interests toward STEM), the development of a positive STEM identity, critical thinking and problem-solving skills, and the empowerment of students as agents of social change.

On the other hand, Cavalcanti (2017), through the *See Blue See STEM Camp* framework, underscores the value of informal learning approaches that prioritize hands-on experiences, project-based learning, engagement in communities of practice, and innovative assessments that include reflection, interviews, and observation. He highlights the importance of students' active participation in authentic STEM activities, suggesting that STEM literacy should not only serve as an academic goal but also contribute to character development and the cultivation of 21st-century skills.

In line with this framework, Jackson (2021) developed eight STEM literacy indicators that are integrated across cognitive, affective, social, and contextual dimensions. According to him, a STEM-literate student should be able to: understand fundamental STEM concepts (*STEM Discipline Knowledge*), engage in critical, creative, divergent, and analytical thinking (*Critical, Creative, Divergent, and Analytical Thinking*), solve complex problems (*Problem-Solving Skills*), make independent decisions (*Independent*

Decision-Making Skills), appreciate the positive impact of innovation (*Positive Impact of Innovation*), consider the environmental and resource implications of actions (*Environmental and Resource Consideration*), demonstrate motivation and engagement in STEM learning and careers (*Motivated Participation in STEM*), and adapt to new situations while managing associated risks (*Adaptability and Risk Management Skills*).

In Indonesia, efforts to enhance STEM education, including STEM literacy, have begun to be integrated into educational policy through the implementation of the *Kurikulum Merdeka* and the *Projek Penguatan Profil Pelajar Pancasila* (P5), which is based on a STEM education (Ministry of Education and Culture, 2022). However, studies specifically measuring and mapping the level of STEM literacy among elementary students in this region remain very limited. As the capital city with a strategic role in the national education system, Central Jakarta should ideally have valid and up-to-date data on students' STEM literacy capabilities. Such data are crucial not only for education policy formulation but also for serving as a model for other regions to align educational directions with future needs.

Therefore, this study focuses on measuring the level of STEM literacy among elementary students in Central Jakarta and determining whether there are significant differences in STEM literacy levels based on educational unit characteristics. The research questions addressed in this study are: (1) What is the level of STEM literacy among elementary students in Central Jakarta? (2) Are there significant differences in STEM literacy levels based on educational level within elementary schools?

II. METHOD

The initial step in measuring students' STEM literacy is to operationally define what is meant by STEM literacy and to determine relevant indicators that align with the context of elementary school learners. As outlined in the introduction, one of the key challenges in assessing STEM literacy is the limited availability of comprehensive studies—particularly at the elementary level—that clearly describe indicators capable of representing students' STEM competencies in a holistic manner. Therefore, the researcher began by conducting a literature review of previous studies on STEM literacy, as well as examining conceptual frameworks developed by experts such as Jackson (2021), Falloon (2020), and Bybee (2010).

Based on the results of this review, eight primary indicators were established as the foundation for constructing the STEM literacy assessment instrument in this study: (1) understanding fundamental STEM concepts (STEM Discipline Knowledge), (2) demonstrating critical, creative, and analytical thinking (Critical, Creative, Divergent, and Analytical Thinking), (3) solving complex problems (Problem-Solving Skills), (4) making independent decisions (Independent Decision-Making Skills), (5) appreciating the positive impact of STEM innovation (Positive Impact of Innovation), (6) considering environmental aspects (Consideration of Impact on Environment and Resources), (7) showing motivation to engage in STEM learning (Motivated, Engaged Participation in STEM Learning and Careers), and (8) adapting to technological change (Adaptability and Risk Management Skills). Each indicator was measured using several statements rated on a simple Likert scale.

The instrument was then empirically tested with actual respondents—elementary school students who implement the National Curriculum, which includes the Pancasila Student Profile Strengthening Project (Projek Penguatan Profil Pelajar Pancasila, or P5) as a learning context for STEM. From the participating schools, those whose P5 projects emphasized a specific STEM discipline as the main approach to learning were selected. The instrument was administered using a questionnaire sheet. The P5 themes implemented in these schools were *Sustainable Lifestyle* (*Gaya Hidup Berkelanjutan*) and *Engineering and Technology* (*Rekayasa dan Teknologi*), which provided authentic, real-world contexts for assessing students' STEM literacy.

Tabel 1. The Aspect of STEM Literacy

No	Aspek Literasi STEM yang Diukur	Item
1	STEM Discipline Knowledge	5
2	Critical, Creative, Divergent, and Analytical Thinking	5
3	Problem-Solving Skills	5
4	Independent Decision-Making Skills	5
5	Positive Impact of Innovation	5
6	Consideration of Impact on Environment and Resources	5
7	Motivated, Engaged Participation in STEM Learning and Careers	5
8	Adaptability and Risk Management Skills	5
	Total	**40**

Data collection was conducted at SDN Johar Baru 01 Pagi, Central Jakarta, involving fourth-grade students (N = 28) and fifth-grade students (N = 62), resulting in a total of 90 participants. The selection of participants employed a total sampling method, as the number of students in both classes was manageable for statistical analysis.

Prior to the administration of the test, students were briefed on the purpose and procedures for completing the instrument. The test was conducted in person in the classroom under controlled conditions. All students were instructed to complete the test earnestly without a strict time limit, although an estimated completion time of 15 minutes was provided. Approximately 90% of the students completed the test within 12 minutes, while the remaining students finished within the maximum allotted time of 15 minutes. To ensure the validity of the data, the test sheets were collected immediately upon completion and were not allowed to be taken home.

Data analysis was performed using SPSS version 25. To describe the students' STEM literacy profiles, descriptive statistics—namely frequency, percentage, mean, and standard deviation—were used. Additionally, an independent samples t-test was conducted to determine whether there was a significant difference in STEM literacy levels between fourth- and fifth-grade students.

III. RESULT

Based on the administered test, students responded to a series of questions developed in accordance with the eight aspects of STEM literacy. The results are presented in Table 2. The table shows the students' average scores and the level of achievement for each measured aspect of STEM literacy.

Tabel 2. The Level of STEM Literacy of The Student

Aspek Literasi STEM	Grade IV and V		Interpretasi
	Mean	Standar Deviasi	
STEM Discipline Knowledge	10,88	3,133	Low
Critical, Creative, Divergent, and Analytical Thinking	11,97	2,633	Low
Problem-Solving Skills	11,63	2,778	Low
Independent Decision-Making Skills	13,71	2,084	High
Positive Impact of Innovation	13,60	1,865	High
Consideration of Impact on Environment and Resources	10,40	2,855	Low
Motivated, Engaged Participation in STEM Learning & Careers	11,83	3,109	Low
Adaptability and Risk Management Skills	13,14	2,996	High

Based on the results of descriptive statistical analysis of the STEM literacy questionnaire data, which encompassed eight dimensions, it was found that the students' average scores for each dimension ranged from 10.40 to 13.71 out of a maximum score of 25. In this study, the level of STEM literacy was classified into four categories: Very Low (0.00–6.25), Low (6.26–12.50), High (12.51–18.75), and Very High (18.76–25.00). The majority of the students' STEM literacy aspects—five out of eight dimensions—fell into the "Low" category. This indicates limited conceptual understanding of STEM fundamentals as well as a lack of active student participation in STEM learning.

For instance, the *STEM Discipline Knowledge* dimension (mean = 10.88; SD = 3.133) reveals that students' comprehension of basic concepts in science, technology, engineering, and mathematics remains relatively weak. The relatively high standard deviation also suggests considerable variation in conceptual understanding among students. Similarly, the *Critical, Creative, Divergent, and Analytical Thinking* dimension (mean = 11.97; SD = 2.633) reflects underdeveloped higher-order thinking skills, such as critical and creative thinking. Low scores in the *Problem-Solving Skills* dimension (mean = 11.63; SD = 2.778) suggest that students are still struggling to apply STEM concepts in practical problem-solving contexts. Likewise, the *Consideration of Impact on Environment and Resources* dimension (mean = 10.40; SD = 2.855) indicates limited awareness of the environmental and resource-related consequences of innovation, underscoring the need to integrate ecological aspects more meaningfully into STEM education. Additionally, the *Motivated, Engaged Participation in STEM Learning and Careers* dimension (mean = 11.83; SD = 3.109) was also categorized as low. The highest standard deviation recorded in this dimension suggests a wide range of student motivation and engagement levels, likely influenced by both internal and external factors such as individual interest, teaching methods, or the surrounding learning environment.

Meanwhile, the other three dimensions were classified as "High," indicating that students possessed some strengths in certain 21st-century competencies. In the *Independent Decision-Making Skills* dimension (mean = 13.71; SD = 2.084), students appeared to make independent decisions reasonably well, although not yet at an exceptional level. The *Positive Impact of Innovation* dimension (mean = 13.60; SD = 1.865) suggested that students understood the importance and benefits of innovation in improving human life. Furthermore, the *Adaptability and Risk Management Skills* dimension (mean = 13.14; SD = 2.996) reflected students' capacity to adapt to change and manage risks effectively, though there remains room for improvement to reach a higher level.

Overall, no dimension was classified in either the "Very High" or "Very Low" categories, suggesting that the students' overall STEM literacy level tended to fall in the moderate range. This finding also indicates that there are no dimensions demonstrating either exceptional strength or critical deficiency. However, the large variation in scores—especially in the dimension of participation and motivation—suggests that students' learning experiences were highly diverse. This disparity is likely attributable to differences in instructional approaches, socioeconomic backgrounds, and students' intrinsic motivation.

The following results present the STEM literacy levels of fourth-grade students based on the eight established aspects. The data are presented in terms of mean scores and achievement interpretations:

Tabel 2. The Level of STEM Literacy of The Grade IV Student

Aspek Literasi STEM	Grade IV		Interpretasi
	Mean	Standar Deviasi	
STEM Discipline Knowledge	12.11	4.315	Low
Critical, Creative, Divergent, and Analytical Thinking	12.21	3.224	Low
Problem-Solving Skills	12.29	3.230	Low
Independent Decision-Making Skills	13.89	1.988	High
Positive Impact of Innovation	13.93	2.017	High
Consideration of Impact on Environment and Resources	11.21	3.765	Low
Motivated, Engaged Participation in STEM Learning & Careers	11.32	3.422	Low
Adaptability and Risk Management Skills	13.75	3.513	High

The measurement results indicate that most aspects of fourth-grade students' STEM literacy fall into the "Low" category, particularly in areas such as STEM disciplinary knowledge, critical and creative thinking, problem-solving, environmental awareness, and motivation in STEM learning. On the other hand, aspects such as independent decision-making, understanding the positive impact of innovation, and the ability to adapt and manage risks were categorized as "High." These findings suggest that students demonstrate potential in social and reflective skills but still require substantial reinforcement in the cognitive and affective domains related to STEM.

Tabel 3. Frequency of Students' STEM Literacy Skill on Grade IV

Level	Frequency	%
Very Low	6	21,43
Low	9	32,14
High	6	21,43
Very High	7	25
Overall	Mean = 2,61	

The distribution of STEM literacy levels among fourth-grade students shows that the majority fall into the "Low" category, accounting for 32.14% of the total. Meanwhile, the proportions of students in the "Very Low," "High," and "Very High" categories are relatively balanced, each ranging between 21.43% and 25%. The overall mean score of 2.61 indicates that, in general, students' STEM literacy level falls within the moderate-to-low category.

Tabel 4. The Level of STEM Literacy of The Grade V Student

Aspek Literasi STEM	Grade V		Interpretasi
	Mean	Standar Deviasi	
STEM Discipline Knowledge	10.32	2.253	Low
Critical, Creative, Divergent, and Analytical Thinking	11.85	2.339	Low
Problem-Solving Skills	11.34	2.522	Low
Independent Decision-Making Skills	13.63	2.137	High
Positive Impact of Innovation	13.45	1.790	High
Consideration of Impact on Environment and Resources	10.03	2.276	Low
Motivated, Engaged Participation in STEM Learning & Careers	12.06	2.958	Low
Adaptability and Risk Management Skills	12.87	2.719	High

The results of the STEM literacy assessment for fifth-grade students indicate that most aspects remain in the "Low" category, particularly in STEM disciplinary knowledge, critical and analytical thinking, problem-solving, environmental awareness, and participation in STEM learning. On the other hand, students demonstrated higher proficiency in independent decision-making, understanding the positive impact of innovation, as well as adaptability and risk management skills.

Tabel 5. Frequency of Students' STEM Literacy Skill on Grade V

Level	Frequency	%
Very Low	14	22,58
Low	22	335,48
High	17	27,42
Very High	9	14,52
Overall	Mean = 2,39	

Based on Table 5, the majority of fifth-grade students fall into the "Low" category of STEM literacy, with the highest proportion recorded at 33.48%. The remaining students were distributed across the "Very Low" (22.58%), "High" (27.42%), and only a small percentage in the "Very High" category (14.52%). The overall average score of 2.39 indicates that, in general, students' STEM literacy remains relatively low, highlighting the need for targeted interventions to enhance their understanding and skills across the various dimensions of STEM literacy.

Data analysis of the students' answers from the STEM literacy test was conducted. Using the average scores of students in Grades IV and V, the significance of the difference in their STEM literacy levels was examined through an independent samples t-test. The result is presented in Table 6.

Tabel 6. Independent Sample T-Test

Group	N	Mean	SD	t	dF	P	Description
Grade IV	28	12.59	1.12	1.042	14	0.315	*Not Significant
Grade V	62	11.94	1.34				

Based on the results of the Independent Samples T-Test analysis, the average STEM literacy score of Grade IV students was 12.59, while that of Grade V students was 11.94. The Levene's Test for Equality of Variances yielded a significance value of 0.730, indicating that there is no significant difference in variances between the two groups, and therefore the assumption of homogeneity is met. Furthermore, the t-test result showed a significance value (2-tailed) of 0.315 ($p > 0.05$), which suggests that there is no statistically significant difference in STEM literacy levels between Grade IV and Grade V students. Thus, it can be concluded that the STEM literacy levels of both student groups are relatively comparable.

IV. DISCUSSION

The findings of this study reveal that while students demonstrated relatively strong abilities in social-reflective aspects—such as decision-making, understanding the impact of innovation, and risk management—they showed significant weaknesses in both cognitive and affective dimensions. These weaknesses were evident in their limited understanding of fundamental STEM concepts, lack of critical thinking skills, low problem-solving abilities, poor environmental awareness, and limited motivation to engage in STEM exploration. These findings reinforce the view that STEM literacy is a multidimensional construct, encompassing cognitive, affective, and applicative domains that must be developed in a balanced manner (Bybee, 2013).

Consistent with the studies of Falloon (2020) and Jackson (2021), this research affirms that STEM learning approaches which are not systematically integrated tend to produce emotional engagement without fostering deep conceptual understanding. This calls for instructional strategies that go beyond mere content delivery, aiming instead to cultivate curiosity and establish real-world relevance (Johns & Mentzer, 2016).

Previous studies have also highlighted that successful STEM integration at the elementary level requires interdisciplinary, project-based approaches centered around contextual problem-solving (Jackson & Mohr-Schroeder, 2018). Such holistic approaches enable students to connect STEM learning with their surrounding environment, thereby strengthening 21st-century skills such as creativity, collaboration, and critical thinking (Honey et al., 2014). Consequently, models of STEM literacy at the elementary level must be designed to integrate conceptual understanding with emotional engagement and active participation in real-life contexts (Herro & Quigley, 2017). Teachers play a central role in designing meaningful learning experiences, and they must be equipped with flexible and transformative pedagogical strategies to foster inclusive and sustainable STEM education (Boesdorfer & Greenhalgh, 2014).

V. CONCLUSIONS

Based on the findings of this study on elementary school students' STEM literacy levels, it can be concluded that, in general, the STEM literacy abilities of fourth- and fifth-grade students fall within the low to moderate category. Among the eight measured dimensions, five were categorized as low, particularly those related to conceptual STEM knowledge, critical thinking and problem-solving skills, environmental awareness, and motivation for learning and pursuing STEM-related careers. On the other hand, three aspects scored high: independent decision-making skills, understanding the positive impact of innovation, and the ability to adapt and manage risks—indicating students' potential in social and reflective competencies.

The frequency distribution revealed that the majority of both fourth- and fifth-grade students were classified in the low category, although a small proportion of students demonstrated high levels of STEM literacy. Furthermore, the results of the Independent Samples T-Test indicated no statistically significant differences in STEM literacy levels between the two grade levels, suggesting that the students possess relatively similar competencies. These findings underscore the need to strengthen STEM education in elementary schools, particularly in the dimensions that remain underdeveloped.

Based on these findings, future research is recommended to involve a larger and more diverse sample, covering various school contexts and student characteristics, to yield more representative results. Moreover, it is essential to evaluate the effectiveness of different STEM-based learning models, such as project-based learning and contextual approaches, to enhance the aspects of STEM literacy that remain low. Qualitative methods such as interviews, observations, or case studies are also recommended to explore in greater depth the factors influencing students' STEM literacy, including the role of teachers, family support, and the learning environment. Lastly, the development and validation of STEM literacy assessment instruments that align with local contexts should be prioritized to ensure that the results accurately reflect students' competencies.

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