The Impact of STEM Literacy on Architectural Engineering Education Students' Understanding of Green Architecture

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Abstract – *The construction industry accounts for approximately 39% of total global carbon emissions, making green architecture a conceptual and practical solution rooted in environmental stewardship through energy efficiency and sustainable practices. In this context, Architecture Engineering Education (PTA) students play a crucial role as future vocational high school teachers who will impart an understanding of green architecture to their students in accordance with the requirements of the Merdeka Curriculum, mastering these concepts requires an interdisciplinary knowledge base in the form of STEM literacy, which is indirectly integrated across various courses in the PTA curriculum. This study aims to describe the level of STEM literacy and the level of understanding of green architecture among students, as well as to identify the impact of STEM literacy on PTA students' understanding of green architecture. This study employs a quantitative approach using an associative-causal method, involving 51 active PTA students as the sample, selected through purposive and accidental sampling techniques. Data were collected using a multiple-choice objective test instrument and analyzed using multiple linear regression analysis. The results show that PTA students' STEM literacy levels fall into the high category (78%), with technology literacy as the highest component and engineering literacy as the lowest, while students' understanding of green architecture falls into the very high category (80%). Simultaneously, STEM literacy has a significant impact on students' understanding of green architecture, contributing 66%, however, when analyzed partially, only mathematics literacy had a significant impact, whereas science, technology, and engineering literacy were not significant individually. Based on these findings, it can be concluded that overall STEM literacy has a significant impact on PTA students' understanding of green architecture, with mathematics literacy serving as a cross-dimensional foundation that supports the other STEM components.*

Keywords*: STEM literacy; green architecture; architectural engineering education*

INTRODUCTION

The increase in carbon emissions resulting from human activities also poses a major challenge to maintaining environmental quality (Rahman & Suharyani, 2025). Data from the World Green Building Council shows that the construction sector accounts for approximately 39% of global carbon emissions (Andraini, 2024), making green architecture a design solution that emphasizes energy efficiency and sustainability (Rijasa, 2020). Understanding this concept is important not only for practitioners but also for architecture educators, while students' awareness of the importance of green architecture remains relatively low (Chandra & Purwanto, 2022).

Students in the Architectural Engineering Education (PTA) program are prepared to become teachers at Vocational High Schools (SMK) in the Design, Modeling, and Building Information specialization, which—under Phase E of the Merdeka Curriculum—includes material on green building and sustainable building. Mastery of green architecture concepts requires an interdisciplinary foundation in STEM (Science, Technology, Engineering, and Mathematics) literacy, given that in 2018 the United States Congress designated architecture as part of the STEM field

(Mackie, 2025). In the PTA curriculum, the four components of STEM are indirectly integrated into various design and building science courses.

Previous research on STEM has generally focused on a single component of literacy, for example, science literacy in relation to students' conceptual understanding or on STEM as a learning approach in secondary schools and its impact on students' cognitive abilities. Research on green architecture, on the other hand, is generally still limited to its relationship with environmental literacy or science literacy and green buildings, while research on the relationship between STEM and architecture focuses more on the contribution of architectural education to STEM education. Therefore, no research has been found that specifically examines the extent of the impact of STEM literacy as a whole on the understanding of green architecture, particularly among PTA students.

Given this gap, this study aims to (1) describe the level of STEM literacy among PTA students, (2) describe the level of understanding of green architecture among PTA students, and (3) identify the impact of STEM literacy on PTA students' understanding of green architecture.

RESEARCH METHODS

This study employs a quantitative approach using the associative causality method to measure the impact of STEM literacy on the understanding of green architecture. The study was conducted in the PTA Study Program at the Universitas Pendidikan Indonesia during the even semester of the 2025/2026 academic year.

The study population consisted of active PTA students who had taken courses related to STEM components, specifically students in their 6th semester and above. The sample was determined using purposive and accidental sampling techniques, with the sample size based on Roscoe's recommendation cited in Sugiyono (2019), which requires a minimum of ten times the number of research variables (5 variables = at least 50 respondents). Data were collected from 54 respondents; however, after conducting an outlier analysis on inconsistent response patterns, three respondents were excluded, resulting in a final analysis based on n = 51 respondents.

Data were collected using an objective multiple-choice test, consisting of 30 STEM literacy questions (covering science, technology, engineering, and mathematics literacy, based on Bybee's indicators, 2013) and 25 questions on green architecture understanding developed based on the nine criteria for green architecture according to Karyono (2010). Both instruments underwent content validity testing (expert judgment), empirical validity testing (Point Biserial correlation), reliability testing (KR-20), difficulty index assessment, and discriminant power assessment prior to use.

Prior to hypothesis testing, the data were tested for normality using the Kolmogorov-Smirnov test, for multicollinearity (Tolerance and VIF), and for heteroscedasticity (Glejser test, followed by the Spearman test if necessary). The data analysis techniques used were descriptive analysis using the Respondent Achievement Level (RAL) to address the first and second research questions, and multiple linear regression analysis (t-test, F-test, coefficient of determination, and semi-partial correlation) to address the third research question.

RESULTS AND DISCUSSION

Results

An analysis was conducted on 51 respondents to address the first and second

research questions, while a regression analysis was conducted to address the third research question.

1. STEM Literacy Levels of PTA Students.

The results of the TCR analysis (Table 1) show that the overall STEM literacy of PTA students falls into the "fairly high" category, with a score of 78%. When examined by component, technology literacy had the highest achievement (82%, high), followed by mathematics literacy (81%, high) and science literacy (80%, high), while engineering literacy had the lowest achievement (68%, fairly high).

Table 1. Respondents' Achievement Levels in STEM Literacy Components

Components	Mean	Max	RAL	Category
Science Literacy	5,63	7	80%	High
Technology Literacy	6,53	8	82%	High
Engineering Literacy	5,47	8	68%	Fairly High
Mathematics Literacy	5,67	7	81%	High
STEM Literacy	**23,29**	**30**	**78%**	**Fairly High**

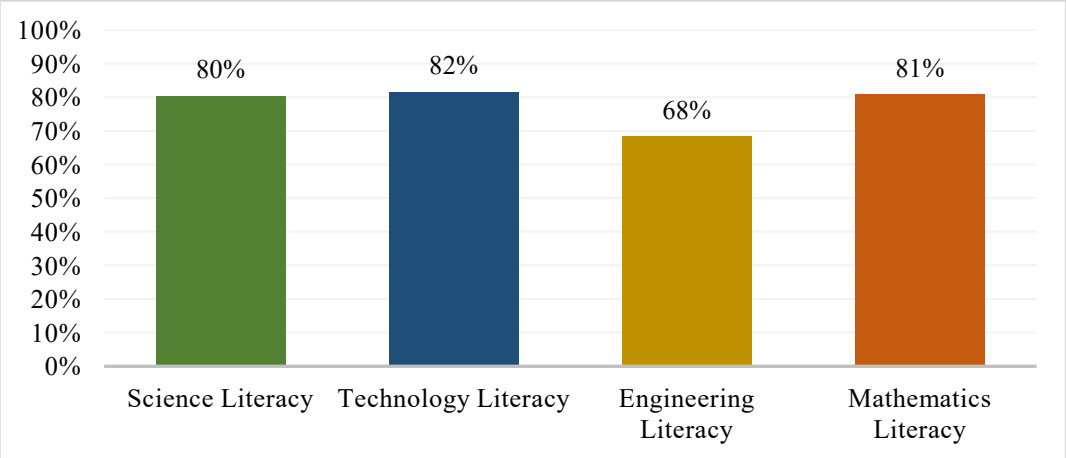

Figure 1. Respondents' Achievement Levels for the STEM Literacy Variable

2. Understanding of Green Architecture Levels of PTA Students.

For the variable of understanding of green architecture, the results of the 25-question test showed an average score of 20.04 (SD=4.50) out of a maximum score of 25, with a TCR of 80%, which falls into the "high" category.

3. The Impact of STEM Literacy on PTA Students' Understanding of Green Architecture

Prior to hypothesis testing, the data were found to satisfy the classical assumptions: the normality test showed a Sig. value of 0.200 (>0.05); the multicollinearity test showed that the Tolerance and VIF values met the criteria for all variables; and the heteroscedasticity test (followed by the Spearman test) showed no signs of heteroscedasticity.

The results of the multiple linear regression analysis yielded the equation Y = 2.74 + 0.16X1 + 0.67X2 + 0.32X3 + 1.80X4, where Y represents understanding of green architecture, X1 represents science literacy, X2 represents technology literacy, X3 represents engineering literacy, and X4 represents mathematics literacy. All regression coefficients are positive,

indicating a positive relationship among the variables.

The F-test yielded an F-value of 25.22 (Sig. = 0.001 < 0.05), indicating that the four components of STEM literacy simultaneously have a significant impact on the understanding of green architecture, with a coefficient of determination (Adjusted R^2) of 0.660, accounting for 66% of the variance. However, the results of the t-test (Table 2) show that, when analyzed partially, only mathematical literacy has a significant effect (t = 5.32; Sig. = 0.001), while science, technology, and engineering literacy are not significant individually (Sig. > 0.05). The results of the semi-partial correlation analysis reinforce these findings, showing that mathematical literacy makes the largest unique contribution (19.34%) compared to the other three components, each of which is below 2.5%.

Table 2. Results of the Regression Test and t-Test on the Effect of STEM Literacy on Understanding of Green Architecture

Variable	b	t	Sig.	Description
Science Literacy	0,16	0,41	0,67	Not Significant
Technology Literacy	0,67	1,90	0,06	Not Significant
Engineering Literacy	0,32	1,36	0,18	Not Significant
Mathematics Literacy	1,80	5,32	0,001	Significant

Constants: a = 2.74; F = 25.22 (Sig. = 0.001); Adjusted R^2 = 0.660.

Discussion

1. STEM Literacy Levels of PTA Students

The fairly high level of STEM literacy among PTA students indicates that, in general, students have been able to integrate knowledge of science, technology, engineering, and mathematics to understand problems in an architectural context, in line with the definition of STEM literacy as the capacity to integrate these four fields into daily life (Bybee, 2010)

This level of achievement is supported by the characteristics of the PTA curriculum, which incorporates STEM elements in an integrated manner into design courses, consistent with the findings of Rusydiyah et al. (2021) that a learning environment supporting STEM integration contributes to strengthening students' interdisciplinary understanding.

Technology literacy emerged as the component with the highest achievement level, which was influenced not only by the intensity of technology-based courses in upper-level semesters but also by the characteristics of students as "digital natives" who have grown up alongside digital technology (Mance, 2025).

Conversely, engineering literacy was the component with the lowest achievement, similar to the findings of Hubinský et al. (2022) among architecture students at other institutions. This situation is believed to be related to the learning culture in the PTA program, which is more oriented toward design exploration and form visualization than the use of analytical simulation tools; consequently, Rizaoglu & Voss (2022) suggest integrating building performance simulation tools directly into the design process in the studio.

2. Understanding of Green Architecture Levels of PTA Students

The PTA students' understanding of green architecture, which falls into the "high" category, indicates that they have a strong conceptual foundation regarding sustainable design approaches (Karyono, 2010). Given that PTA students are being prepared to become vocational high school teachers, this high level of understanding serves as an important foundation, in line with the theory of Pedagogical Content

Knowledge, which emphasizes that mastery of content is a prerequisite for prospective teachers to effectively convey knowledge to their students (Shulman, 1986, 1987). This achievement is also closely linked to several courses in the PTA curriculum that directly or indirectly incorporate elements of green architecture, such as Sustainable Architecture, Site Planning, and Building Physics.

3. The Impact of STEM Literacy on PTA Students' Understanding of Green Architecture

Simultaneously, STEM literacy was found to have a significant impact on the understanding of green architecture, contributing 66%, which confirms that understanding green architecture is not a standalone architectural competency but is shaped by a foundation of STEM literacy, in line with Cole's (2019) finding that understanding green building is built upon a foundation of science and environmental literacy.

However, among these, only mathematical literacy has a significant impact, while science, technology, and engineering literacy are not significant individually. This can be explained by the OECD's (2023) definition of mathematical literacy as the ability to formulate, apply, and interpret mathematics in problem-solving; thus, mathematical literacy serves as a tool that translates conceptual understanding of science, technology, and engineering into measurable design decisions, such as determining the dimensions of openings or the ratio of green open spaces.

This finding aligns with Li's (2025) research, which emphasizes the role of mathematics in sustainable learning as a means of analyzing data and reasoning about interrelated issues, as well as the research by Ghani et al. (2021), which demonstrates a positive relationship between mathematical ability and students' multidisciplinary STEM literacy.

Nevertheless, the partial non-significance of science, technology, and engineering literacy does not mean that these three fields play no role, given that STEM literacy is fundamentally an integration of these four fields that cannot stand alone (Bybee, 2013), as evidenced by the consistently strong and positive zero-order correlations across all components.

These findings suggest that efforts to enhance PTA students' understanding of green architecture should not only focus on reinforcing conceptual sustainability material but should also strengthen students' mathematical skills as analytical tools, while integrating simulation-based engineering practices into design courses so that the four components of STEM literacy can contribute more evenly to the understanding of green architecture.

CONCLUSION

Based on the results and discussion, it can be concluded that the STEM literacy level of PTA students falls into the fairly high category (78%), with technology literacy as the component with the highest achievement and engineering literacy as the component with the lowest achievement. This situation indicates the need to strengthen analytical simulation-based engineering practices in design courses so that they are not solely focused on the exploration of visual forms.

PTA students' understanding of green architecture falls into the "high" category (80%), indicating that they have acquired a strong conceptual foundation as prospective vocational high school teachers who will convey an understanding of green architecture to their students in accordance

with the requirements of the Merdeka Curriculum.

Simultaneously, STEM literacy has a significant impact on the understanding of green architecture, contributing 66%; whereas, when analyzed partially, only mathematical literacy has a significant impact, with the largest unique contribution compared to other components of STEM literacy. These findings confirm that mathematical literacy serves as a cross-dimensional foundation that underpins PTA students' understanding of green architecture; therefore, strengthening mathematical skills and ensuring the equitable integration of all STEM components into the PTA curriculum are important considerations for future study programs.

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REFERENCES

Andraini, E. J. (2024, November 9). *Penerapan Material Daur Ulang Dalam Konstruksi Bangunan Hijau*. Centre for Development of Smart and Green Building. https://cedsgreeb.org/kompetisi-esai/material-daur/

Bybee, R. W. (2010). Advancing STEM education: A 2020 vision. *Technology and Engineering Teacher*, 30–35.

Bybee, R. W. (2013). *The Case for STEM Education: Challenges and Opportunities*. NSTA Press. www.nsta.org/permissions.

Chandra, B., & Purwanto, L. (2022). Korelasi Pemahaman Green Building (Bangunan Gedung Hijau/Arsitektur Hijau) Terhadap Penerapan Desain Arsitektur Di Era Digital. *JoDA Journal of Digital Architecture*, *1*(2), 72–78. https://doi.org/10.24167/joda.v1i2.4186

Cole, L. B. (2019). Green building literacy: a framework for advancing green building education. *International Journal of STEM Education*, *6*(1). https://doi.org/10.1186/s40594-019-0171-6

Ghani, U., Zhai, X., & Ahmad, R. (2021). Mathematics skills and STEM multidisciplinary literacy: Role of learning capacity. *STEM Education*, *1*(2), 104–113. https://doi.org/10.3934/steme.2021008

Hubinský, T., Legény, J., & Špaček, R. (2022). STEM and HASS Disciplines in Architectural Education: Readiness of FAD-STU Bachelor Students for Practice. *Education Sciences*, *12*(5). https://doi.org/10.3390/educsci12050294

Karyono, T. H. (2010). *Green Architecture: Pengantar Pemahaman Arsitektur Hijau di Indonesia*. Rajawali Pers.

Li, H. C. (2025). STEM education and sustainability: what role can mathematics education play in the era of climate change? *Research in Mathematics Education*, *27*(2), 291–313. https://doi.org/10.1080/14794802.2025.2499813

Mackie, A. (2025, April 9). *Is Architecture STEM?* Vera Iconica Architecture. https://veraiconica.com/is-architecture-stem/

Mance, D. (2025). Architectural practice in the Digital Age: Balancing Adoption and Adaptation. In *Springer Series in Design and Innovation* (Vol. 47, pp. 349–361). Springer Nature.

https://doi.org/10.1007/978-3-031-71959-2_38

OECD. (2023). *PISA 2022 Assessment and Analytical Framework* (PISA). OECD Publishing. https://doi.org/10.1787/dfe0bf9c-en

Rahman, A. A., & Suharyani. (2025). *Optimalisasi Material Lokal sebagai Strategi Pengurangan Emisi Karbon: Studi Kasus Co-housing Samadya*. (2025: Prosiding (SIAR) Seminar Ilmiah Arsitektur), 754.

Rijasa, M. M. (2020). Nilai Arsiteltur Hijau pada Pola Massa Rumah Tradisional Desa Penglipuran. *Jurnal Teknik Gradien*, *12*, 50–59.

Rizaoglu, I. K., & Voss, K. (2022). *Building Performance Simulation in Design Education: Design-Integrated Versus Additive Use*.

Rusydiyah, E. F., Indrawati, D., Jazil, S., Susilawati, & Gusniwati. (2021). STEM learning environment: Perceptions and implementation skills in prospective science teachers. *Jurnal Pendidikan IPA Indonesia*, *10*(1), 138–148. https://doi.org/10.15294/jpii.v10i1.28303

Shulman, L. S. (1986). Those who understand: Knowledge Growth in Teaching. *Educational Researcher*.

Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*.

Sugiyono. (2019). *Metode Penelitian Kuantitatif, Kualitatif, dan R&D* (Sutopo, Ed.; 2nd ed.). Penerbit Alfabeta.