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Environment on students' mathematical representation abilities: A quantitative study in an Indonesian secondary school

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ABSTRACT

This quantitative study aims to examine the influence of the learning environment on students' mathematical representation abilities. The research is motivated by the relatively low levels of mathematical representation skills observed among students, which may be associated with variations in the quality of their learning environments. The study was conducted at a junior high school in Cirebon during the 2024/2025 academic year, involving 30 students selected through purposive sampling. Data were collected using a questionnaire to measure students' perceptions of the learning environment and a test instrument to assess their mathematical representation abilities, including verbal, visual, and symbolic representations. The findings indicate that the learning environment has a significant influence on students' mathematical representation abilities. However, the results also reveal that both the quality of the learning environment and students' mathematical representation abilities are relatively low. Statistical analysis shows that the learning environment accounts for 9.3% of the variance in students' mathematical representation abilities, while the remaining 91.7% is explained by other factors beyond the learning environment. Future studies should explore the influence of additional factors such as learning motivation, instructional methods, and cognitive abilities on students' mathematical representation skills. Moreover, research involving larger and more diverse populations is recommended to enhance the generalizability and applicability of the findings.

KEYWORDS

Learning environment; mathematical representation ability; social interaction; effective learning.

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INTRODUCTION

Mathematical representation plays a crucial role in understanding and solving mathematical problems. It serves as a bridge between abstract concepts and concrete applications, enabling students to interpret, communicate, and manipulate mathematical ideas effectively. One of the essential skills in mathematics learning is the ability to represent mathematical ideas (Sholehah et al., 2023). Riyanto et al. (2024) define mathematical representation ability as a core competency in mathematics learning that involves expressing, presenting, and transforming mathematical concepts into various representational forms, including verbal, visual, and symbolic modes.

According to Novitasari et al. (2021), representation is the process of transforming a problem or idea into a new form, such as converting images or physical models into symbols, words, or sentences. The importance of representation is also emphasized in the NCTM standards, as cited in Miranda et al. (2022), which state that instructional programs from preschool through grade 12 must ensure that students can: (1) create and use representations to organize, record, and communicate mathematical ideas; (2) select, apply, and translate mathematical representations to solve problems; and (3) use representations to model and interpret physical, social, and mathematical phenomena.

Recent studies further highlight that representation connects concrete experiences with abstract reasoning while supporting metacognitive awareness, problem-solving skills, and conceptual understanding (Utomo et al., 2024). Students who can flexibly shift between visual, symbolic, and verbal representations tend to demonstrate better comprehension and memory retention (Khoerunnisa & Maryati, 2022). Therefore, representational ability is vital for helping students internalize abstract mathematical ideas and express them effectively.

Cumarlin et al. (2023) identify three key indicators of mathematical representation ability: (1) visual representations (images, diagrams, graphs) that concretize abstract concepts by illustrating relationships between mathematical objects; (2) symbolic representations, regarded as mathematics' universal language, which employ numbers, letters, and notation to formulate theories, prove theorems, and solve problems with precision; and (3) verbal representations, which use linguistic descriptions to articulate mathematical relationships while developing students' communication skills. Similarly, Villegas, as cited in Saputri & Faiziyah (2023) categorizes mathematical representation into three forms: (1) verbal representation, which involves solving problems through descriptive statements using words; (2) visual representation, which includes constructing graphs, diagrams, or drawings to represent problems; and (3) symbolic representation, which focuses on employing mathematical models and symbols for problem-solving. These indicators emphasize that students' ability to shift among different forms of representation is key to their mathematical understanding.

Supporting this, Astuti et al. (2022) assert that mathematical learning involves coordinating multiple semiotic systems, and meaningful learning occurs when students are able to shift effectively between these representations. Although representations can enhance clarity, communication, and problem-solving efficiency, Nisya et al. (2025) argue that overreliance on a single type or the misapplication of representations may lead to misconceptions or hinder comprehension. Given these challenges, it is essential to consider how the learning environment can support students in developing flexible and meaningful representational abilities.

The learning environment therefore plays a critical role in cultivating students' representational competencies. An environment that provides structured learning through meaningful tasks, scaffolded guidance, and collaborative discussion enables students to explore and internalize mathematical ideas from multiple perspectives (Ekawati & Maharani, 2025). Learning mathematics is inherently complex, involving dynamic interactions between students and their educational settings. These interactions are intentionally designed not only to achieve learning objectives but also to foster cognitive development through the coordinated use of multiple representations (Indriyani et al., 2021). However, the ability to flexibly shift between different forms of representation remains a significant challenge for many Indonesian students, highlighting the importance of a rich and supportive instructional environment that explicitly develops representational thinking (Ole & Dipan, 2023).

Recent studies have revealed concerning findings regarding Indonesian students' mathematical representation abilities, particularly in transforming between different representational forms (visual, symbolic, verbal, and numeric). Research by Fajriah et al. (2020) on high school students in Singkawang found a significant disparity in competencies: only 20% of students reached the high category, 27% were in the moderate category, while the majority (53%) fell into the low category, with an average score of just 54.6%. These findings are reinforced by a qualitative study conducted by Miranda et al. (2022), which, through in-depth interviews, revealed that most students continued to struggle with comprehending problems, recalling materials, and determining correct solutions, leading to frequent errors in solving mathematical representation problems. Limited mathematical representation ability is influenced by various factors, among which the learning environment is a significant contributor.

The learning environment, encompassing both physical and psychosocial aspects, plays a vital role in shaping behavioral patterns and personal development, particularly in educational contexts (Makaremi et al., 2024). A well-designed environment fosters a constructive learning atmosphere that enhances students’ motivation, active participation, and creative thinking, all of which are key drivers for achieving learning competencies. Conversely, an unsupportive environment may significantly hinder optimal learning outcomes and limit the realization of students’ potential.

According to Utaminingtyas et al. (2021), the learning environment comprises all elements that interact with students throughout the learning process and can be categorized into two primary dimensions. The first is the non-social environment, which includes physical factors such as the school’s location, architectural design, classroom arrangement, availability

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of instructional materials, and overall cleanliness. The second is the social environment, which consists of family-related factors such as parenting style and parental involvement, as well as school-based interactions including teacher-student relationships and peer associations. As emphasized by Ole & Dipan (2023), the learning environment serves as a facilitative mechanism that promotes students' academic success and supports the achievement of learning objectives. Collectively, these components create an educational ecosystem that fosters student potential, deepens conceptual understanding, and enhances overall learning outcomes.

Previous studies have extensively examined the impact of learning environments on students' general learning outcomes, including cognitive and affective domains, as well as their relationship with learning motivation and participation. However, few studies have specifically investigated the role of physical and social learning environments in developing students' mathematical representation abilities. Most prior research has focused on pedagogical approaches, learning media, or instructional strategies without comprehensively addressing the contribution of the learning environment.

This study aims to examine the influence of the learning environment on students' mathematical representation abilities. Specifically, it seeks to: (1) describe students' perceptions of their learning environment; (2) assess the level of students' mathematical representation abilities; and (3) analyze the influence of the learning environment on students' mathematical representation abilities. The findings of this study are expected to provide valuable insights for educators, schools, and educational stakeholders in developing learning conditions that support students in effectively representing mathematical concepts.

METHODS

This study employs a quantitative approach using a one-shot case study design, which involves administering a treatment and measuring outcomes in a single group without a comparison group (Sofiyana et al., 2022). he quantitative approach was selected because it enables researchers to obtain an objective and measurable overview of the variables through systematic numerical data collection techniques (Sudaryana & Agusiady, 2022). Quantitative research aims to address research problems through precise variable measurement and to produce conclusions that can be generalized beyond specific times and contexts (Sofiyana et al., 2022).

The population of this study comprised all students at a junior high school in Cirebon,

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Indonesia. The sampling technique used was purposive sampling, in which participants were selected based on specific criteria relevant to the research objectives (Sugiyono, 2022). Considerations such as data availability, accessibility, and representation of diverse learning environment conditions led to the selection of one class consisting of 30 students as the research sample.

Two instruments were employed in this study: a questionnaire and a test. The questionnaire was designed to measure students' perceptions of the learning environment and was developed based on ten key aspects: (1) physical environment, (2) learning method, (3) technology use, (4) social interaction, (5) concept visualization, (6) self-confidence, (7) motivation and engagement, (8) assessment and feedback, (9) relevance to real life, and (10) openness in learning (Fauziah & Ratnaningsih, 2021). The questionnaire used a four-point Likert scale ranging from *Strongly Agree* to *Strongly Disagree*. Positive statements were scored from 4 to 1, while negative statements were scored in reverse (1 to 4). The design of the learning environment questionnaire is presented in Table 1.

Table 1. Construction of the Learning Environment Questionnaire

Aspect	Indicator	Statement Number
Physical Environment	Classroom conditions that support plane geometry learning	1, 2, 12, 20
Learning Method	Use of various media and instructional methods;	4, 8, 17, 18
	Availability of sufficient time and tasks to understand plane geometry	5, 7, 13
Technology Use	Utilization of technological tools to support plane geometry learning	6
Social Interaction	Student discussion and collaboration in learning plane geometry	10, 12, 23
Concept Visualization	Use of visual representations to understand plane geometry concepts	14, 15, 11
Self-Confidence	Students' ability to express and represent plane geometry ideas	16, 19
Motivation and Engagement	Students' level of motivation and engagement in plane geometry learning	18, 24, 25
Assessment and Feedback	Assessment focus on conceptual understanding and representation	21
Relevance to Real Life	Connection between plane geometry concepts and everyday experiences	9
Openness in Learning	Opportunities for questioning and further exploration	22, 20

Meanwhile, the test was designed to assess students' mathematical representation

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abilities. This instrument was developed based on three main indicators of mathematical representation: (1) verbal representation, (2) visual representation, and (3) symbolic representation (Cumarlin et al., 2023). The blueprint of the mathematical representation test instrument is presented in Table 2.

Table 2. The Blueprint of The Mathematical Representation Test

Indicator	Description	Statement Number	Cognitive Level
Verbal Representation	Answering questions using written or spoken explanations.	1, 4, 5, 7, 8, 9; 2, 6, 10; 3	C1 C2 C3
Visual Representation	Creating graphs, diagrams, or drawings to solve problems.	11, 13, 14, 16, 17, 18, 19, 20; 15; 12	C3 C4 C5
Symbolic Representation	Solving problems using mathematical models, equations, or symbols.	21, 22, 23, 24, 25, 27, 28, 29, 30; 26	C3 C4

Before implementation, the learning environment questionnaire was tested for validity and reliability. Item validity was examined using Pearson's correlation and compared against the r-table; items with correlation coefficients above the critical value were deemed valid. Reliability was evaluated using Cronbach's alpha, with values of $\alpha \geq 0.7$ indicating acceptable internal consistency (Sofiyana et al., 2022). The results confirmed that the questionnaire was both valid and reliable for data collection.

Similarly, the mathematical representation ability test underwent pretesting to assess validity, reliability, discrimination power, and difficulty level. Following successful validation, both instruments were administered to the study sample (Sugiyono, 2022).

The collected data were analyzed using descriptive statistics to identify general trends in students' perceptions of the learning environment and their mathematical representation abilities. A subsequent simple linear regression analysis was conducted to examine the influence of the learning environment on students' mathematical representation abilities (Syafriani et al., 2023).

RESULT AND DISCUSSION

After processing the data from the mathematical representation ability test and the learning environment questionnaire, the following results were obtained:

Learning Environment

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Data on the learning environment were collected using a questionnaire consisting of 25 statements administered to 30 students. The responses were analyzed using SPSS 21. A description of students' perceptions of the learning environment is presented in Table 3.

Table 3. Statistical Description of Learning Environment Questionnaire Results

The Learning Environment	
N	30
Min	35
Max	72
Sum	1606
Mean	53.53
Std. dev	10.569

Based on Table 3, the questionnaire results from 30 students show an average score of 53.53 with a standard deviation of 10.569, indicating a moderate perception of the learning environment and fairly high variability among responses. The scores ranged from 35 to 72, suggesting that while some students perceive the learning environment as highly supportive, others experience it as less conducive. This variation may reflect differences in classroom conditions, teaching methods, or peer interactions, highlighting the need for more consistent and inclusive learning experiences for all students.

Students' Mathematical Representation Ability Data Description

The test results from 30 students in Cirebon for the 2024/2025 academic year provide an overview of their mathematical representation abilities. Table 4 presents a detailed statistical description of students' mathematical representation ability based on the administered test results.

Table 4. Statistical Description of Students' Mathematical Representation Ability Test Results

Mathematical Representation Ability	
N	30
Min	40
Max	63
Sum	1602
Mean	53.40
Std. dev	5.042

Based on Table 4, the results of the mathematical representation ability test administered to 30 students in Cirebon show an average score of 53.40, with a standard deviation of 5.042, indicating a moderate level of ability with relatively low variability among students. The scores ranged from 40 to 63, suggesting that most students performed within a similar range without extreme outliers. This reflects a generally average and consistent level of mathematical representation abilities, emphasizing the need for strategies to enhance students' verbal, visual, and symbolic representations.

Before testing the research hypotheses, a normality test was conducted to determine whether the data were drawn from a normally distributed population. This test is important because many statistical analyses assume normality; if the data are not normally distributed, the accuracy of the results may be affected, potentially requiring alternative analysis methods. The Kolmogorov-Smirnov test was used with a significance level (α) of 0.05, with the following statistical hypotheses:

H_0: The population data are normally distributed

H_1: The population data are not normally distributed

The testing criteria are as follows: H_0 is accepted if the significance value ≥ 0.05, and H_0 is rejected if the significance value < 0.05.

Table 5. Normality Test

Group	The Learning Environment	Mathematical Representation Ability
N	30	30
Kolmogorov-Smirnov	0.93	0.200
Shapiro-Wilk	0.100	0.758
Conclusion	Normal	Normal

From Table 5, the significance values for both the learning environment data and students' mathematical representation abilities are greater than 0.05, indicating that the data are normally distributed at a 5% significance level. This suggests that there is insufficient evidence to reject the null hypothesis of normality, and the data can be assumed to come from a normally distributed population. Consequently, parametric statistical tests that require the normality assumption can be appropriately applied in the subsequent analysis.

Following the confirmation of normal distribution, a test of variance homogeneity was conducted using Levene's test (α = 0.05). The statistical hypotheses were formulated as follows:

H_0: The datasets demonstrate variance homogeneity

H_1: The datasets do not demonstrate variance homogeneity

The testing criteria were: H_0 is accepted if the significance value ≥ 0.05, and H_0 is rejected if the significance value < 0.05.

Table 6. Homogeneity Test

Levene Statistic	df1	df2	Sig.	Conclusion
0.971	6	12	0.484	Homogenic

Based on Table 6, the results of the homogeneity test show a significance value of

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0.484, which is greater than 0.05, so H_0 is accepted. Therefore, it can be concluded that the data for the learning environment and students' mathematical representation abilities are homogeneous.

The final test conducted was the linearity test, which was used to determine whether the regression model demonstrates a linear relationship. Using a significance level (α) of 0.05, the statistical hypotheses were formulated as follows:

H_0: The regression model is linear.

H_1: The regression model is nonlinear.

The testing criteria were: H_0 is accepted if the significance value ≥ 0.05, and H_0 is rejected if the significance value < 0.05.

Table 7. Linearity Test

			F	Sig.
The Learning Environment*Mathematical Representation Ability	Between Groups	Combined	1.041	0.501
		Linearity	2.758	0.131

Based on Table 7, the significance value in the linearity test is 0.131. Since this value is greater than the significance level of 0.05, it can be concluded that there is no significant deviation from linearity. Therefore, the relationship between the learning environment and students' mathematical representation abilities can be appropriately modeled using a linear regression approach.

After confirming that the data met the prerequisite assumptions of normality, homogeneity, and linearity, the study proceeded with hypothesis testing. Because the data were valid, reliable, normally distributed, and demonstrated a linear pattern, simple linear regression analysis was employed to examine the influence of the independent variable (learning environment) on the dependent variable (students' mathematical representation abilities). The hypotheses for the regression analysis were as follows:

H_0: There is no significant positive influence of the learning environment on students' mathematical representation abilities.

H_1: There is a significant positive influence of the learning environment on students' mathematical representation abilities.

The null hypothesis (H_0) is accepted if the significance value exceeds 0.05, indicating insufficient evidence to support a significant effect. Conversely, H_0 is rejected if the significance value is less than 0.05, indicating statistically significant evidence in favor of the alternative hypothesis (H_1).

Table 8. Simple Linear Regression Test

Regression Equation		Unstandardized Coefficients		t	Sig.
		B	Std. Error		
1	(Constant)	60.934	4.548	1.689	0.102
	Learning Environment	0.135	0.080	13.399	0.000

Based on Table 8, the resulting regression equation is Y = 60.934 + 0.135X, with a regression coefficient of 0.135. This indicates that every one-unit increase in the learning environment score is associated with an increase of 0.135 units in students' mathematical representation abilities. The positive coefficient reflects a positive relationship, meaning that improvements in the learning environment are associated with higher levels of students' representational abilities. Furthermore, the results show a significance value of 0.00, which is less than 0.05, leading to the rejection of H_0. Therefore, it can be concluded that the learning environment has a statistically significant positive effect on students' mathematical representation abilities.

To determine the extent to which the learning environment influences students' mathematical representation abilities, a coefficient of determination test was conducted, with the following results:

Table 9. Coefficient of Determination Test

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	0.304	0.093	0.600	4.888

As shown in Table 9, the correlation coefficient (R) is 0.304, and the coefficient of determination (R^2) is 0.093, indicating that 9.3% of the variance in the dependent variable (mathematical representation ability) is explained by the independent variable (learning environment). In other words, the learning environment accounts for 9.3% of the variation in students' mathematical representation ability, while the remaining 91.7% is attributed to other factors beyond the learning environment.

The findings indicate that the quality of the learning environment remains suboptimal, with an average score of 53.53. These results align with Wulandari & Nurjaman (2023) who identified key challenges in creating a conducive learning environment, including student behavioral issues such as frequent drowsiness and lack of focus, as well as suboptimal classroom management. Additionally, poor classroom layout and limited teacher-student interactions contributed to the low quality of the learning environment. Based on these findings, comprehensive improvements addressing both physical and psychosocial aspects are necessary. For the physical aspect, enhancements could include ergonomic classroom arrangements and the integration of interactive learning media. Regarding the psychosocial aspect, improving teaching quality through professional development on effective classroom management and participatory learning strategies is crucial. These efforts are expected to create a more conducive environment that supports effective learning processes.

Similar to the learning environment, this study reveals that students' mathematical representation abilities remain relatively low, with an average score of 53.4. Most students struggle to express mathematical ideas through visual, symbolic, or verbal representations. This contrasts sharply with Astuti et al. (2022) ho reported a significantly higher average score of 76.49, classified as good for students' mathematical representation abilities. The discrepancy is supported by the questionnaire results, which indicate variations in students' perceptions of the learning environment, particularly regarding classroom facilities, teacher support, and opportunities for collaboration. These differences likely contributed to the variation in students' mathematical representation abilities.

Furthermore, the regression analysis indicates that every one-unit improvement in the quality of the learning environment increases students' mathematical representation abilities by 0.135 units. This positive relationship suggests that both the physical environment (e.g., learning facilities and resources) and the social environment (e.g., teacher support and peer interaction) play crucial roles in enhancing mathematical representation abilities. The learning environment significantly influences mathematical representation, contributing 9.3% to its variance. This finding aligns with Utaminingtyas et al. (2021) who reported that the learning environment significantly affected mathematics learning outcomes for fifth-grade students in Cluster II Elementary Schools, Temon District, contributing 16%. Both studies highlight that a well-structured and conducive learning environment is a key factor in improving students' mathematical abilities.

Practically, these findings underscore the importance of collaboration among teachers, schools, and educational policymakers in creating an optimal learning environment. Teacher training should not only address classroom management but also prioritize pedagogical strategies that actively foster mathematical representation through visualization, symbolization, and verbal reasoning to deepen conceptual understanding. Schools should redesign classrooms to promote interactivity, leveraging tools such as digital modeling aids or manipulatives to bridge abstract and concrete mathematical thinking. Additionally, curriculum designers should align these environmental and instructional improvements with standardized learning objectives to ensure measurable impact.

CONCLUSION

This study indicates that the learning environment has a significant influence on students' mathematical representation abilities. The results reveal that the quality of the learning environment is relatively low, and students' mathematical representation abilities are also relatively low. Statistical analysis shows that the learning environment contributes 9.3% to students' mathematical representation abilities, while the remaining 91.7% is influenced by other factors beyond the learning environment. Future research is recommended to investigate additional factors, such as learning motivation, instructional methods, and cognitive abilities, which may have a stronger impact on students' mathematical representation skills. Moreover, studies involving larger and more diverse samples are encouraged to improve the generalizability of the findings.

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