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The impact of a STEM-Integrated project-based learning e-module on students' algebra achievement and self-confidence

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Abstract

This study investigated the effectiveness of a STEM-integrated Project-Based Learning (STEM-PjBL) algebra e-module in improving seventh-grade students' algebra learning outcomes and examined students' self-confidence following its implementation. The study was motivated by students' difficulties in understanding algebraic concepts and their limited confidence in solving mathematical problems. A quasi-experimental design employing a nonequivalent control group was used, involving 44 students purposively selected from a population of 184 seventh-grade students at Al-Rifaie Gondanglegi Junior High School. The experimental group (n = 22) learned using the STEM-PjBL algebra e-module, whereas the control group (n = 22) used a conventional algebra e-module. The research instruments included an algebra achievement test, expert validation sheets, and a self-confidence questionnaire. Validation results indicated that the e-module demonstrated satisfactory content validity, with Aiken's V coefficients of 0.78 for material validation and 0.83 for media validation, resulting in an overall coefficient of 0.80. The algebra achievement test showed excellent reliability (Cronbach's $\alpha = 0.917$). Following normality and homogeneity testing, learning outcome data were analyzed using the Mann–Whitney U test because the assumption of normality was not met. The results revealed a statistically significant difference in algebra learning outcomes between the experimental and control groups ($U = 133.5$, $Z = -2.576$, $p = .010$), with a moderate effect size ($r = 0.39$). Descriptive findings further indicated that most students in the experimental group demonstrated high to very high levels of self-confidence. These findings suggest that the STEM-PjBL algebra e-module may enhance students' algebra learning outcomes and support the development of self-confidence in mathematics learning, although the results should be interpreted cautiously given the limited sample and the descriptive assessment of self-confidence.

Keywords: STEM-PjBL; algebra e-module; algebra learning outcomes; self-confidence; junior high school mathematics

Introduction

Algebra constitutes a foundational domain of school mathematics because it provides the conceptual framework underlying advanced mathematical disciplines, including calculus, analytic geometry, and statistics (Hartono, 2025; McGinn & Booth, 2025). Beyond its role in symbolic manipulation, algebra supports the development of logical reasoning, analytical thinking, and problem-solving competencies that enable students to interpret and represent quantitative relationships in both academic and everyday contexts (Adu-Gyamfi et al., 2025; Wahyuni et al., 2025; Yu et al., 2026). Consequently, proficiency in algebra is widely regarded as essential for students' mathematical development and future engagement with increasingly complex mathematical ideas. Nevertheless, students' difficulties in algebra frequently arise not only from challenges in performing symbolic procedures but also from limitations in connecting algebraic representations with meaningful situations and contexts.

Research has consistently demonstrated that many students encounter difficulties when translating real-world situations into mathematical models, thereby limiting their capacity to solve algebraic problems effectively (Patac & Patac, 2025; Riduan et al., 2024). Such difficulties suggest that algebra learning requires instructional approaches that support students in constructing meaningful connections between mathematical symbols, representations, and contextual situations. Concurrently, advances in educational technology have increased interest in the use of digital learning media, particularly interactive e-modules, as tools for supporting mathematical learning (Ulya et al, 2024). Previous studies have reported that digital learning materials can enhance students' engagement and facilitate conceptual understanding in mathematics (Nasution et al., 2025; Winarni et al., 2024). However, much of the existing literature has examined either students' conceptual understanding or their engagement with digital media in isolation. Consequently, limited attention has been devoted to investigating how digital learning resources can be designed to simultaneously promote algebraic modelling, contextual problem solving, and students' confidence in participating actively in mathematical learning.

This issue becomes particularly significant within the context of Islamic boarding schools. As educational institutions, Islamic boarding schools aim not only to foster academic achievement but also to cultivate independence, discipline, social responsibility, and spiritual development through students' daily routines and communal activities (Azizah et al., 2025; Baharun & Solehudin, 2023; Murdianto, 2025). Many of these routine activities including managing memorization targets, organizing schedules, allocating responsibilities, and planning study time contain quantitative relationships that can be represented mathematically through variables, constants, coefficients, and algebraic expressions. From this perspective, the Islamic boarding school environment offers a rich and authentic context through which algebraic concepts can be meaningfully situated in students lived experiences. Such contextualization has

the potential to support students in constructing stronger connections between abstract algebraic ideas and practical situations encountered in everyday life (Donovan & Fyfe, 2022).

In addition to cognitive aspects of learning, affective factors play a crucial role in students' engagement with mathematics. Among these factors, self-confidence has been identified as an important determinant of students' willingness to participate actively in learning activities and persist when encountering challenging tasks. Students with higher levels of self-confidence are generally more willing to express ideas, ask questions, engage in collaborative discussions, and attempt independent problem solving (Ferdianto, 2023; Kusumadewi, 2024). In contrast, students with lower confidence tend to rely heavily on teacher guidance, hesitate to communicate their reasoning, and avoid taking intellectual risks when confronted with unfamiliar problems. Within algebra learning, such tendencies are particularly problematic because successful problem solving requires students not only to manipulate symbols but also to interpret contextual information, formulate mathematical models, and justify their reasoning processes. Consequently, self-confidence is closely associated with students' willingness and capacity to engage productively in algebraic problem-solving activities (Das & Ali, 2023; Nurhadi et al, 2025).

Preliminary observations conducted at Al-Rifaie Gondanglegi Junior High School revealed both cognitive and affective challenges in students' algebra learning. When presented with a problem involving the seating arrangement of a triangular park, only two of twenty-five students obtained the correct solution. Four students successfully translated the situation into mathematical statements, five students identified and recorded relevant information from the problem, and the remaining fourteen students merely reproduced the problem text without developing an appropriate solution strategy. Classroom observations further indicated that many students were reluctant to explore alternative approaches, participated passively in learning activities, and frequently waited for direct guidance from the teacher before attempting solutions. These findings suggest that students' difficulties in algebra extend beyond conceptual understanding and are also associated with affective dimensions, particularly their confidence in constructing, communicating, and defending mathematical ideas.

Addressing these challenges requires learning environments that provide structured opportunities for students to investigate contextual problems, develop mathematical models, collaborate with peers, and reflect on their learning processes. One promising approach is the integration of Science, Technology, Engineering, and Mathematics (STEM) education with Project-Based Learning (PjBL) (Khaerunisa, Serevina, & Wibowo, 2024; Moxie et al, 2025; Supianti et al, 2025). This instructional framework encourages students to engage with authentic problems through processes of investigation, design, implementation, and evaluation while connecting mathematical concepts with real-world applications (Agatolio et al., 2018). Within this framework, STEM contributes interdisciplinary and contextually meaningful problem situations, whereas PjBL promotes inquiry, collaboration, reflection, and the construction of tangible learning products. Furthermore, when such an approach is delivered through an e-module, students are provided with greater flexibility in accessing learning materials, revisiting explanations, following systematic project stages, and receiving

instructional support that may foster greater confidence in learning mathematics (Jaya et al., 2025; Liu et al, 2025).

Accordingly, the STEM-PjBL algebra e-module developed in this study was designed not merely as a technological enhancement of conventional instruction but as an integrated learning environment that combines contextual algebraic modelling, project-based investigation, collaborative problem solving, and reflective learning activities. Such a design is particularly relevant for students in Islamic boarding schools because it situates algebraic concepts within familiar experiences, including scheduling activities, managing memorization targets, allocating responsibilities, and organizing resources. By aligning mathematical learning with students' everyday experiences, the e-module is expected to increase the meaningfulness of algebra learning while encouraging greater student participation and engagement (Naseer et al., 2025).

Against this background, the present study investigates the effectiveness of a STEM-integrated Project-Based Learning algebra e-module in improving seventh-grade students' algebra learning outcomes. In addition, the study examines students' self-confidence following participation in learning activities supported by the e-module. By considering both cognitive and affective dimensions of learning, this study seeks to contribute to the growing body of research on contextualized mathematics instruction and to provide empirical evidence regarding the potential of STEM-PjBL e-modules to support algebra learning within the distinctive educational setting of an Islamic boarding school.

Methods

This study employed a quasi-experimental design using a nonequivalent control group structure. This design was considered appropriate because the participants were drawn from pre-existing classroom groups, making random assignment of individual students impractical within the school setting (Tymms et al., 2016). Consequently, a randomized controlled design was not feasible. Instead, two intact classes with relatively comparable academic characteristics were purposively selected to serve as the experimental and control groups.

The study population comprised 184 seventh-grade students enrolled at Al-Rifaie Gondanglegi Junior High School. The sample consisted of 44 students distributed across two classes. Class VIIB, comprising 22 students, was assigned as the experimental group, whereas Class VIIC, also comprising 22 students, served as the control group. Participant selection was based on teacher recommendations, classroom accessibility, and similarities in academic characteristics. Given that the study involved a relatively small sample drawn from a single Islamic boarding school, the findings should be interpreted within this specific educational context and should not be generalized indiscriminately to broader populations of junior high school students.

Research Procedure

The study was conducted in three stages: preparation, implementation, and evaluation. During the preparation stage, the STEM-PjBL algebra e-module, the algebra achievement test, and the self-confidence questionnaire were developed and validated. The e-module was structured around six learning phases: planning, investigation, implementation, application, reflection, and evaluation. These phases were intended to guide students through a systematic learning process, beginning with the identification of contextual problems and progressing toward the construction of algebraic models, application of mathematical procedures, reflection on reasoning processes, and evaluation of learning outcomes.

During the implementation stage, both groups studied the same algebra topic over six instructional meetings, each lasting 2 × 40 minutes. The experimental group received instruction through the STEM-PjBL algebra e-module, whereas the control group learned using a conventional algebra e-module. Finally, during the evaluation stage, students' algebra learning outcomes were assessed using a posttest. Students' self-confidence was measured through a questionnaire administered exclusively to the experimental group following the intervention.

Research Instruments

Three instruments were employed in this study: (a) an algebra achievement test, (b) expert validation sheets, and (c) a self-confidence questionnaire. The algebra achievement test was designed to assess students' learning outcomes following the instructional intervention. The self-confidence questionnaire was used to describe students' affective responses after engaging with the STEM-PjBL algebra e-module. Because the questionnaire was administered only to students in the experimental group, the resulting self-confidence data were analyzed descriptively and were not used to draw comparative conclusions between the experimental and control groups.

Instrument Validity

The e-module and supporting research instruments were evaluated by material and media experts using a four-point rating scale. Content validity was determined using Aiken's V coefficient, calculated as follows:

$$V = \frac{\Sigma_s}{[n(c-1)]} \quad (1)$$

$$s = r - l_o \quad (2)$$

In this formula, V is Aiken's validity coefficient, r is the score given by each validator, l_o is the lowest score in the rating scale, n is the number of validators, and c is the highest score in the rating scale. The material expert evaluation yielded an Aiken's V coefficient of 0.78, while the media expert evaluation yielded a coefficient of 0.83. The overall validity coefficient was

0.80, indicating that the e-module and supporting instruments possessed adequate content validity and were suitable for implementation as summarized in Table 1.

Table 1. Results of Expert Validation

Component	Number of Items	Aiken's V	Interpretation
Material expert validation	18	0.78	Adequate
Media expert validation	11	0.83	Good
Overall validation	29	0.80	Adequate

Instrument Reliability

The algebra achievement test consisted of ten constructed-response items scored using item-based scoring criteria. Because the items were not scored dichotomously, reliability was examined using Cronbach's alpha coefficient:

$$\alpha = \frac{k}{(k-1)}\left(1 - \frac{\Sigma\sigma_i^2}{\sigma_t^2}\right) \quad (3)$$

In this formula, α is the reliability coefficient, k is the number of items, $\Sigma\sigma_i^2$ is the total variance of each item, and σ_t^2 is the total score variance. The reliability analysis produced a Cronbach's alpha coefficient of 0.917, indicating excellent internal consistency presented in Table 2.

Table 2. Reliability of the Algebra Achievement Test

Instrument	Number of Items	Reliability Coefficient	Interpretation
Algebra achievement test	10	Cronbach's alpha = 0.917	Very good

Data Analysis

Data analysis was conducted in accordance with the research objectives. To evaluate the effectiveness of the STEM-PjBL algebra e-module on students' learning outcomes, posttest scores from the experimental and control groups were compared. Prior to hypothesis testing, normality and homogeneity analyses were performed to determine the suitability of parametric statistical procedures. Because the posttest scores did not satisfy the assumption of normality, differences between groups were analyzed using the Mann–Whitney U test at a significance level of 0.05. The Mann–Whitney U statistics were calculated using the following formulas:

$$U_1 = n_1 n_2 + \frac{n_1(n_1+1)}{2} - R_1 \quad (4)$$

$$U_2 = n_1 n_2 + \frac{n_2(n_2+1)}{2} - R_2 \quad (5)$$

In these formulas, n_1 is the number of students in the experimental group, n_2 is the number of students in the control group, R_1 is the sum of ranks for the experimental group, and R_1 is the sum of ranks for the control group. The smaller value between U_1 and U_2 was used as the final Mann-Whitney U value.

To determine the practical significance of group differences, an effect size was calculated using:

$$r = \frac{|Z|}{\sqrt{N}} \quad (6)$$

In this formula, r is the effect size, Z is the standardized value obtained from the Mann-Whitney U test, and N is the total number of students in both groups.

Students' self-confidence data were analyzed descriptively because the questionnaire was administered only to the experimental group. Percentage scores were calculated using:

$$P = \left(\frac{S}{S_{max}}\right) \times 100\% \quad (6)$$

where P is the percentage score, S is the student's obtained score, and S_max is the maximum possible score. The resulting scores were subsequently categorized into very high, high, moderate, and low levels based on the classification criteria proposed by Erayani et al. (2022).

Results

This study examined two interrelated dimensions of students' learning: algebra learning outcomes and self-confidence following participation in learning activities supported by the STEM-PjBL algebra e-module. The analysis of learning outcomes was conducted to evaluate the effectiveness of the e-module in supporting students' algebra achievement, whereas the self-confidence analysis served as descriptive evidence of students' affective responses to the learning experience.

Students' Algebra Learning Outcomes

The distribution of posttest scores revealed notable differences between the experimental and control groups. In the control group, students' scores were predominantly distributed within the low-to-moderate achievement ranges. Five students (22.7%) obtained scores within the ≤61 interval, six students (27.3%) scored within the 62–71 interval, six students (27.3%) fell within the 72–81 interval, and five students (22.7%) achieved scores within the 82–91 interval. No student in the control group reached the highest score interval (92–100).

In contrast, the score distribution of the experimental group was concentrated within the higher achievement ranges. Four students (18.2%) were categorized within the ≤61 interval, three students (13.6%) achieved scores within the 72–81 interval, fourteen students (63.6%) were distributed within the 82–91 interval, and one student (4.5%) attained a score within the 92–100 interval. Notably, no student in the experimental group was represented within the 62–71 interval. This pattern suggests that students who learned using the STEM-PjBL algebra e-

module tended to achieve higher levels of algebra performance than those who learned through the conventional algebra e-module.

Prior to hypothesis testing, assumption tests were conducted to determine the appropriate statistical procedure. The results of the Kolmogorov–Smirnov and Shapiro–Wilk tests indicated that the posttest scores in both groups were not normally distributed, as reflected by significance values below the .05 threshold. However, Levene's test produced a significance value of 0.854, indicating homogeneity of variance across groups presented in Table 3. Because the assumption of normality was violated, a nonparametric Mann–Whitney U test was employed to compare students' algebra learning outcomes.

Table 3. Assumption Test Results

Test	Group	Sig.Value	Interpretation
Kolmogorov–Smirnov/Shapiro–Wilk	Experimental group	< 0.05	Not normally distributed
Kolmogorov–Smirnov/Shapiro–Wilk	Control group	< 0.05	Not normally distributed
Levene's test	Experimental and control groups	0.854	Homogeneous variance

The Mann–Whitney U analysis revealed a statistically significant difference in algebra learning outcomes between the experimental and control groups. The analysis yielded U = 133.5, Z = −2.576, and p = .010 as summarized in Table 4. Because the probability value was lower than the established significance level of .05, the null hypothesis was rejected. These findings indicate that students who learned using the STEM-PjBL algebra e-module achieved significantly higher algebra learning outcomes than students who learned using the conventional algebra e-module.

Table 4. Mann-Whitney U Test and Effect Size

Statistical Component	Value
Mann-Whitney U	133.5
Wilcoxon W	386.5
Z	-2.576
Asymp. Sig. (2-tailed)	0.010
Effect size *r*	0.39
Interpretation	Moderate Effect

To evaluate the practical significance of the observed difference, an effect size analysis was conducted using the formula $r = \frac{|Z|}{\sqrt{N}}$. With $Z = -2.576$ and $N = 44$, the effect size was calculated as follows:

$$r = \frac{|-2.576|}{\sqrt{44}} \quad (7)$$

$$r = \frac{2.576}{6.633} \quad (8)$$

$$r = 0.39 \quad (9)$$

The resulting effect size (r = 0.39) indicates a moderate effect, suggesting that the observed difference between groups was not only statistically significant but also educationally meaningful within the context of this study.

One possible explanation for this finding lies in the instructional structure of the STEM-PjBL algebra e-module. Rather than presenting algebra as a collection of abstract procedures, the e-module situated algebraic concepts within contextual problems derived from students' daily experiences in the Islamic boarding school environment. Through project-based activities, students were encouraged to identify problems, discuss alternative solution strategies, construct algebraic representations, and reflect on their reasoning processes. Such learning experiences may have facilitated students' transition from procedural engagement toward deeper conceptual understanding and application.

Furthermore, the six learning phases embedded within the STEM-PjBL framework appeared to provide a coherent pathway for engaging students in algebraic problem solving. During the planning and investigation phases, students explored familiar situations involving scheduling activities, managing memorization targets, and organizing daily responsibilities. The implementation and application phases required students to formulate mathematical models and apply algebraic reasoning to solve contextualized problems. Finally, the reflection and evaluation phases provided opportunities for students to communicate their mathematical thinking, examine alternative approaches, and evaluate their own understanding. Collectively, these phases created a learning environment that was more active, contextualized, and student-centered than that provided by the conventional e-module.

The present findings are consistent with previous studies demonstrating that STEM-PjBL approaches can enhance students' learning motivation, critical thinking, mathematical communication, and academic achievement (Noviyani et al., 2022; Sari et al., 2021; Papaneophytou & Nicolaou, 2025). Likewise, the results corroborate earlier research indicating that interactive e-modules can facilitate independent learning, enable students to revisit instructional materials, and support conceptual understanding in mathematics (Aini et al., 2022; Mawaddah, 2024; Susanto & Susanta, 2022). However, the current study extends this body of literature by demonstrating the potential of a STEM-PjBL algebra e-module within the distinctive context of an Islamic boarding school, where students' everyday routines provide authentic opportunities for algebraic modelling and contextual reasoning.

Nevertheless, the findings should not be interpreted as evidence that the observed differences were caused exclusively by the e-module itself. Alternative factors may also have influenced students' learning outcomes, including prior academic characteristics, variations in classroom interaction, teacher facilitation practices, and the novelty associated with the use of contextualized digital learning materials. Although the two groups were selected based on relatively comparable academic characteristics, individual students were not randomly assigned to conditions. Consequently, the results should be interpreted as evidence of effectiveness within a quasi-experimental framework rather than as definitive causal evidence.

Students' Self-Confidence

In addition to cognitive learning outcomes, this study examined students' self-confidence following participation in learning activities supported by the STEM-PjBL algebra e-module. The descriptive results revealed that none of the students were classified within the low self-confidence category. Instead, 36% of students demonstrated very high self-confidence, 50% were categorized as having high self-confidence, and 14% were classified within the moderate category. These findings indicate that the majority of students exhibited positive levels of confidence after engaging with the STEM-PjBL learning experience.

This positive affective profile may be associated with the opportunities for participation embedded within the STEM-PjBL learning process. Students were encouraged not only to solve algebraic tasks individually but also to engage in collaborative discussions, construct mathematical models, present their ideas, and reflect upon their learning. Such activities may have fostered students' willingness to communicate mathematical reasoning and participate actively in learning. This interpretation aligns with previous research suggesting that active, collaborative, and contextually meaningful learning environments can support students' confidence and engagement in mathematics (Fidiastuti et al., 2021; Saputri et al., 2025).

Despite these encouraging findings, the results concerning self-confidence should be interpreted cautiously. The questionnaire was administered exclusively to students in the experimental group and was analyzed descriptively rather than inferentially. Consequently, the study does not provide sufficient evidence to conclude that the STEM-PjBL algebra e-module was statistically more effective than the conventional e-module in enhancing students' self-confidence. Rather, the findings indicate that students who participated in STEM-PjBL e-module learning demonstrated a generally positive affective profile following the intervention.

Overall, the findings suggest that the STEM-PjBL algebra e-module provided meaningful support for students' algebra learning outcomes while also being associated with positive descriptive indicators of self-confidence. The primary contribution of this study lies in demonstrating how a contextualized STEM-PjBL learning environment can support algebra achievement within the unique educational context of an Islamic boarding school. At the same time, the findings remain bounded by several limitations, including the relatively small sample size, the use of intact classroom groups in a quasi-experimental design, and the descriptive nature of the self-confidence data. These limitations should be considered when interpreting the results and when designing future studies that seek to examine the relationships among contextualized algebra learning, STEM-PjBL instruction, and students' affective development.

Conclusion

The findings of this study indicate that the STEM-PjBL algebra e-module provided more effective support for students' algebra learning outcomes than the conventional algebra e-module within the context of the participating classes. The statistically significant difference between the experimental and control groups, accompanied by a moderate effect size, suggests that the observed improvement was not only statistically meaningful but also educationally relevant for students' learning. These findings provide empirical support for the potential of

contextualized STEM-PjBL learning environments to facilitate students' engagement with algebraic concepts and problem-solving processes. Nevertheless, the results should be interpreted within the methodological boundaries of the study. Because the research employed a quasi-experimental design with purposive sampling and involved students from a single Islamic boarding school, the findings cannot be generalized beyond similar educational contexts without further empirical verification.

The descriptive findings concerning students' self-confidence also revealed a generally positive affective profile among students who learned through the STEM-PjBL algebra e-module. Most students demonstrated high or very high levels of self-confidence following the learning intervention. However, because self-confidence was assessed only in the experimental group and was not subjected to comparative statistical analysis, the study does not provide evidence of a causal or comparative effect of the e-module on students' confidence. Rather, these findings should be understood as descriptive indications that students responded positively to the learning experience and felt sufficiently confident to engage in algebra-related learning activities. From a theoretical perspective, this study contributes to ongoing discussions concerning contextualized, project-based, and technology-supported mathematics learning by illustrating how algebraic ideas can be meaningfully connected to students' everyday experiences within an Islamic boarding school environment. The findings suggest that learning environments that integrate contextual problem situations, project-based inquiry, collaborative learning, and digital instructional resources may support students' opportunities to construct mathematical meaning and apply algebraic reasoning in authentic situations. In particular, the study extends the existing STEM-PjBL literature by demonstrating the educational potential of embedding algebraic modelling tasks within the sociocultural realities of boarding school life.

From a practical perspective, the study provides an example of how mathematics teachers may design algebra instruction through STEM-PjBL activities that encourage students to identify contextual problems, formulate algebraic representations, construct and evaluate mathematical models, and reflect on their reasoning processes. These findings imply that mathematics instruction, particularly in boarding school settings, should move beyond an exclusive emphasis on procedural competence and create meaningful opportunities for students to engage with algebra as a tool for interpreting and solving problems encountered in their daily lives.

Future research should involve larger and more diverse samples, incorporate multiple educational settings, and employ more rigorous experimental designs to strengthen the generalizability of the findings. Further studies may also examine the long-term effects of STEM-PjBL e-modules on students' algebraic reasoning, mathematical modelling competencies, and affective development, including self-confidence, motivation, and engagement in mathematics learning.

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Conflicts of Interest

The authors affirm that this manuscript was prepared devoid of any conflict of interest. All ethical aspects of the research and publication process have been carefully observed, comprising safeguards against plagiarism, research misconduct, data falsification or fabrication, duplicate submission, and redundant publication.

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