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# Realistic mathematics education module integrated with problem-based learning: Fostering learning interest and mathematics achievement

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**Abstract:** Despite growing interest in digital learning modules for mathematics instruction, few studies have examined how integrating realistic mathematics education and problem-based learning within a single e-module shapes students' learning interest and achievement, particularly in data processing. While realistic mathematics education grounds abstract concepts in contextual problems and problem-based learning strengthens engagement through authentic tasks, empirical evidence on their combined effect within a digital format remains scarce. This study examined the effect of learning interest on mathematics achievement among fifth-grade students learning through such an e-module. A quantitative correlational design was employed with 26 fifth-grade participants. Data were collected via a learning interest questionnaire and a mathematics achievement test, then analyzed using the Shapiro-Wilk test, linearity test, Pearson correlation, and simple linear regression. Results showed a positive, statistically significant effect of learning interest on achievement ($p < 0.01$), with learning interest explaining 27.9% of the variance, while other factors likely accounted for the remainder. These findings suggest that integrating realistic mathematics education with problem-based learning in a digital module can foster learning interest and improve mathematics achievement, offering practical implications for designing contextual, problem-oriented digital learning materials.

**Keywords:** Data processing, e-module, Learning interest, Mathematics achievement, Problem-based learning, realistic mathematics education

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## INTRODUCTION

The ability to collect, organize, interpret, and communicate data has become an essential competency in the twenty-first century, as the pervasive digitization of society increasingly requires individuals to make informed decisions based on quantitative information (Friedrich et al., 2024). Within K–12 education, data and statistical literacy are considered foundational skills that should be cultivated as early as elementary school, since early engagement with data concepts lays the groundwork for more advanced statistical reasoning in later years (Filderman et al., 2022; Friedrich et al., 2024). However, data processing remains one of the more cognitively demanding topics in elementary mathematics, as it requires students not merely to memorize procedures but to reason contextually, interpret patterns, and translate abstract numerical information into meaningful conclusions. This dual cognitive demand makes data processing a particularly suitable domain for examining how instructional design and psychological factors such as learning interest jointly shape achievement, yet it remains comparatively underexplored relative to other elementary mathematics topics such as arithmetic or geometry.

Realistic mathematics education (RME) offers a theoretically grounded response to this challenge. As a domain-specific instructional theory originally developed in the Netherlands, RME positions rich, experientially "realistic" situations at the center of the learning process, allowing students to construct mathematical understanding informally before progressing toward more formal and generalized reasoning (Van den Heuvel-Panhuizen & Drijvers, 2020). Because data-processing tasks are inherently tied to real-world phenomena—such as counting, categorizing, and comparing everyday quantities. RME is theoretically well-suited to this content area, as it allows students to anchor abstract statistical concepts in problem situations they can imagine and relate to their own experience. Parallel evidence from digitally mediated mathematics environments suggests that when learning is embedded in meaningful, engaging contexts, both achievement and interest tend to improve simultaneously rather than being mutually exclusive outcomes (Yeh et al., 2019). This reinforces the theoretical plausibility of RME as a vehicle not only for improving mathematical performance but also for cultivating a more positive disposition toward learning mathematics.

Complementing RME, problem-based learning (PBL) has accumulated a substantial and recent evidence base as an instructional model that promotes active, learner-centered engagement with authentic problems. Empirical studies have demonstrated that PBL implementation improves mathematics teaching and learning outcomes among diverse populations, including pre-service teachers (Boye & Agyei, 2023), and that its long-term implementation is associated with sustained improvements in primary students' mathematical problem-solving ability rather than short-lived gains (Alashwal & Barham, 2025). These findings collectively indicate that PBL is pedagogically robust across educational levels. Nevertheless, most existing PBL research in mathematics education has examined the model either in isolation or in combination with conventional, non-digital instructional materials, leaving open the question of how PBL performs when embedded within a structured digital module explicitly designed around RME principles, an integration that, in theory, could combine the contextual grounding of RME with the active problem-solving orientation of PBL within a single coherent learning experience.

The increasing shift toward digital instructional media adds a further layer of relevance to this integration. Digital technologies have been shown to meaningfully support mathematics achievement across K–12 classrooms, although the magnitude of their effect depends heavily on how technology is functionally and pedagogically deployed rather than on its mere presence in the classroom (Ran et al., 2022). This nuance is critical: digitizing instructional content does not by itself guarantee improved outcomes unless the underlying pedagogical design is sound. Supporting this view, digitally delivered problem-

based learning has been found to significantly improve mathematics proficiency and problem-solving ability compared with traditional approaches, particularly when the pedagogical model rather than the medium itself drives the learning process (Yang et al., 2025). Given that digital technologies are increasingly embedded across nearly every domain of education (Haleem et al., 2022), an e-module that deliberately fuses RME's contextual approach with PBL's problem-solving structure represents a timely response to the persistent demand for effective digital mathematics instruction, particularly for a topic that has received comparatively limited attention in the digital learning literature.

A second, equally critical dimension of this study concerns learning interest as a psychological mechanism underlying achievement. Recent research on students' approaches to learning continues to distinguish between deep and surface learning strategies, wherein deep approaches are characterized by genuine interest, intentional understanding, and active engagement with content, whereas surface approaches remain driven by rote memorization and a narrow focus on passing assessments (Dolmans et al., 2016; Khong & Tanner, 2024). Within mathematics and science education specifically, interest has been empirically linked to improved attitudes and achievement outcomes when instructional innovation is present (Savelsbergh et al., 2016), and longitudinal evidence from related STEM domains confirms that increases in learning interest are associated with corresponding gains in academic performance over time (Chang, 2024). Moreover, because data-processing tasks often resemble word-problem structures requiring both comprehension and procedural execution, recent evidence on the effectiveness of word-problem-solving interventions for elementary-aged students is directly relevant, showing that well-designed interventions can produce substantial improvements in this skill area (Vessonen et al., 2025). Taken together, these strands of literature reveal a clear and specific research gap: while the theoretical and empirical merits of RME, PBL, digital learning media, and learning interest have each been substantiated independently in recent studies, no identified study has examined an e-module that simultaneously grounds instruction in RME's contextual principles, structures learning activities according to PBL's problem-solving framework, targets the specific topic of data processing, and empirically tests the relationship between learning interest and achievement as a joint outcome of this integrated digital intervention.

Based on this gap, the present study aims to examine the effect of learning interest on mathematics achievement among fifth-grade elementary students learning through an e-module grounded in realistic mathematics education and integrated with problem-based learning, with a specific focus on the topic of data processing. More specifically, this study seeks to determine the extent to which learning interest predicts students' achievement within this integrated digital learning environment, thereby providing empirical evidence on the psychological mechanism through which an RME–PBL-based e-module may contribute to improved mathematics learning outcomes at the elementary level.

## METHODS

### Research Design

This study employed a quantitative approach using a correlational design. Within this design, learning interest was positioned as the independent variable (X) and mathematics achievement as the dependent variable (Y), both measured after students completed instruction using a Deep Learning-based e-module grounded in Realistic Mathematics Education (RME) and integrated with Problem-Based Learning (PBL). The e-module served as the instructional context in which learning took place, rather than as a variable being compared against another condition. The correlational design was chosen to examine the strength and direction of the relationship between learning interest and mathematics achievement within this single instructional setting, as well as to determine the extent to which learning interest predicts achievement outcomes.

## Participant

The participants in this study were 26 fifth-grade students from a public elementary school serving a semi-rural community. The class consisted of 14 male students and 12 female students, aged between 10 and 11 years (M = 10.4, SD = 0.5). All participants were enrolled in the same classroom and had received prior instruction in foundational mathematics topics preceding the data-processing unit examined in this study. articipants were selected using purposive sampling, based on the following considerations: (1) the class had not previously been exposed to RME- or PBL-based digital learning modules, ensuring that prior experience with similar instructional models would not confound the results; (2) students possessed at least basic familiarity with using digital devices (computers or smartphones) for learning purposes, which was necessary given the e-module's digital delivery format; and (3) the school's facilities. In terms of socioeconomic and educational context, the school was a public institution with a student body predominantly from families working in agriculture and small-scale trade. The classroom was equipped with a projector and shared access to the school's Wi-Fi network, which was taken into account when planning the e-module implementation to ensure all students had equal access to the learning material.

## Material

*Learning instructional material*. The e-module used in this study was designed by integrating RME principles with the PBL syntax (problem orientation, investigation, and presentation of findings), framed within a Deep Learning approach that emphasizes meaningful understanding and deep reflection. The e-module was developed on a digital platform accessible via computer or mobile devices, and consisted of eight main components: (1) module instructions and information, (2) learning outcomes and objectives, (3) the DL-PBL learning flow syntax, (4) interactive learning content, (5) real-data visualization simulations, (6) learn-through-play games, (7) assessment and self-evaluation, and (8) reference materials and learning resources (see **Figure 1**).

*Measurement instruments*. Two instruments were used, both administered after students completed instruction through the e-module. First, a learning interest questionnaire consisting of 25 statements rated on a 4-point Likert scale, covering the aspects of attention, interest, enjoyment, and engagement in mathematics learning. Content validity was established through expert judgment, while reliability was measured using Cronbach's Alpha coefficient, yielding a value of 0.87, indicating high internal consistency. Second, a mathematics achievement test comprising multiple-choice and short-essay items (25 items in total), covering core competencies in data processing (data collection, presentation in tables and diagrams, and data interpretation). The test was validated by a mathematics education expert holding a senior academic position at a teacher training institution, obtaining a validity score of 88.64% (categorized as highly valid); following minor revisions, the instrument was deemed valid for use. Test reliability was measured using the Cronbach's alpha coefficient, yielding a value of 0.81, indicating adequate reliability for classroom-based achievement testing.

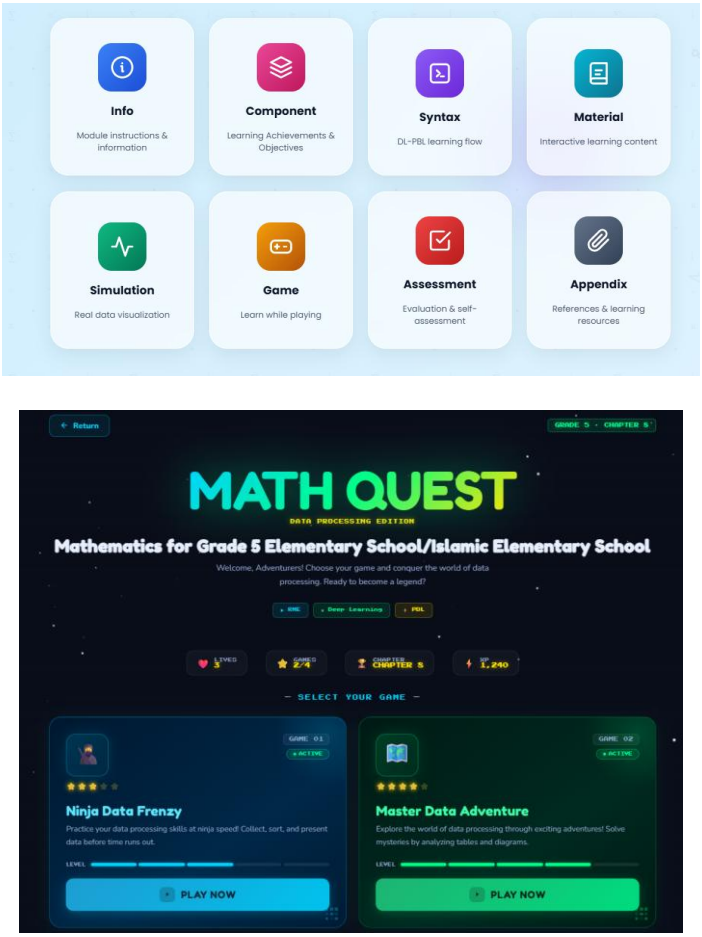



**FIGURE 1**. *Developed Module*

## Procedure

Prior to implementation, the researchers conducted a briefing session with the classroom teacher to explain the structure and learning flow of the RME–PBL-based Deep Learning e-module, ensuring that the teacher understood their role as a facilitator rather than a direct instructor during the learning process. Students were also given a brief orientation session (approximately 15 minutes) introducing them to the e-module platform, including how to navigate its features and access the learning materials via computer or mobile device.

The learning process was conducted over three sessions, each lasting approximately 70 minutes (2 x 35 minutes), following the DL-PBL learning flow embedded within the e-module. In the first session, students engaged with the problem orientation phase, in which they were presented with contextual, real-world data-processing problems (e.g., organizing classroom survey data) through the e-module's interactive content and real-data visualization simulation features. In the second session, students proceeded to the investigation phase, working both individually and in small groups to collect, categorize, and represent data using tables and diagrams, guided by scaffolded tasks within the e-module and supported by the built-in learn-through-play game feature to reinforce conceptual understanding. In the third session, students completed the presentation of findings phase, in which they interpreted their processed data and shared their conclusions, either through short written responses or brief in-class discussions facilitated by the teacher. Throughout all sessions, students also had access to the assessment and

self-evaluation feature of the e-module, allowing them to monitor their own understanding progressively.

Upon completion of the three-session instructional sequence, students were administered the two research instruments in a single sitting lasting approximately 60 minutes. The learning interest questionnaire (25 statements, 4-point Likert scale) was administered first, followed by the mathematics achievement test (25 items, multiple-choice and short-essay format). Both instruments were administered in paper-based format under the supervision of the researchers and the classroom teacher to ensure standardized testing conditions and to minimize discussion among students during completion. Completed questionnaires and test sheets were collected, checked for completeness, and coded for anonymity prior to data entry. Responses were then tabulated and entered into a digital spreadsheet before being transferred to SPSS for subsequent statistical analysis, including normality testing, linearity testing, correlation analysis, and simple linear regression.

### Data Analysis

All data were analyzed quantitatively using SPSS at a significance level of $\alpha = 0.01$, following four sequential steps. First, the Shapiro-Wilk normality test was conducted to examine the distribution of the learning interest and achievement data, as this test is considered more appropriate than other normality tests for small sample sizes (Razali & Wah, 2011). Second, a linearity test was performed to confirm that the relationship between learning interest and achievement was linear. Third, if the data were normally distributed and linear, Pearson Product-Moment correlation was used to determine the strength and direction of the relationship between the two variables; if the data were not normally distributed, Spearman's Rank correlation was used as a non-parametric alternative. The strength of the relationship was interpreted based on established correlation coefficient guidelines: 0.00–0.19 (very weak), 0.20–0.39 (weak), 0.40–0.59 (moderate), 0.60–0.79 (strong), and 0.80–1.00 (very strong) (Evans, 1996). Fourth, simple linear regression analysis was conducted to test the significance of the effect of learning interest on achievement, examining the coefficient of determination ($R^2$) to determine the magnitude of learning interest's contribution to achievement (Field, 2024). The statistical hypotheses tested were formulated as follows: H0, there is no significant effect of learning interest on mathematics achievement; Ha, there is a significant effect of learning interest on mathematics achievement. H0 was rejected and Ha accepted if the significance value (Sig.) < 0.01.

## RESULTS

### Learning Interest and Mathematics Achievement Among Students

Descriptive analysis was conducted on the two main variables: learning interest and mathematics achievement, based on data from 26 fifth-grade students (see **Table 1**). The mean score for learning interest was 82.31 (SD = 10.53), while the mean score for mathematics achievement was 71.85 (SD = 14.77). The relatively higher standard deviation in mathematics achievement scores compared to learning interest scores suggests greater variability among students in their achievement outcomes than in their reported interest levels, indicating that while most students expressed a fairly consistent level of interest, their resulting achievement varied more widely. Prior to further analysis, the distribution of both variables was examined using the Shapiro-Wilk test, given the sample size of fewer than 30 participants. The results indicated that the learning interest data were normally distributed (Sig. = 0.160 > 0.01), and the mathematics achievement data were also normally distributed (Sig. = 0.959 > 0.01). This suggests that students'

scores on both variables were fairly evenly spread around the mean, without extreme skewness, supporting the use of parametric statistical procedures in subsequent analyses.

**TABLE 1**. *Descriptive Statistics and Shapiro-Wilk Normality Test Results*

| Variable | N | Mean | SD | *p* |
|---|---|---|---|---|
| Learning Interest | 26 | 82.31 | 10.53 | 0.160 |
| Mathematics Achievement | 26 | 71.85 | 14.77 | 0.959 |

## The Pattern of Relationship Between Learning Interest and Achievement

Before testing the strength of association between learning interest and mathematics achievement, it was first necessary to establish the functional form of their relationship, since both the Pearson correlation and simple linear regression techniques planned for subsequent analysis assume a linear association between variables. If the true relationship were non-linear. For instance, if achievement increased sharply only after interest passed a certain threshold, or if very high interest scores corresponded to a plateau or decline in achievement then a linear model would misrepresent the data and could lead to inaccurate conclusions about the effect of learning interest.

To examine this, a linearity test was conducted through the Test for Linearity procedure in SPSS, which decomposes the relationship between the two variables into a linear component and a deviation-from-linearity component. The linear component reflects the extent to which the relationship can be explained by a straight-line trend, while the deviation-from-linearity component indicates whether there is any additional, non-linear pattern in the data that a straight line fails to capture. A non-significant deviation-from-linearity result ($p > 0.01$) supports the assumption that a linear model adequately represents the relationship, whereas a significant result would suggest that a linear model is inappropriate and that curvilinear or other non-linear modeling approaches should be considered instead. The results of this test showed a Deviation from Linearity significance value of 0.190 ($p > 0.01$), indicating that there was no statistically significant deviation from linearity in the relationship between learning interest and mathematics achievement. In other words, the data did not reveal any meaningful curvilinear pattern beyond what a straight-line relationship could already explain.

Substantively, this finding suggests that the relationship between learning interest and mathematics achievement in this study was consistent and proportional across the observed range of scores. Students with progressively higher interest scores tended to show correspondingly higher achievement scores, without evidence of the relationship weakening, intensifying, or reversing direction at particular points along the interest scale. There was no indication, for example, that only students with very high interest experienced achievement gains while those with low-to-moderate interest saw no benefit, nor was there evidence of a ceiling effect in which additional interest beyond a certain point failed to translate into further achievement gains. This finding carries an important methodological implication: it confirms that the assumption of linearity required for Pearson correlation and simple linear regression was satisfied, thereby justifying the use of these parametric techniques in the subsequent stages of analysis. Had the deviation-from-linearity result been significant, the interpretation of the correlation coefficient and regression model presented in the following sections would need to be approached with considerably more caution, as a linear model would not have adequately captured the true nature of the relationship between the two variables.

## The Pattern of Relationship Between Learning Interest and Achievement

Having established that the relationship between learning interest and mathematics achievement was linear, the next step was to determine how strongly the two variables

were associated and in which direction. This was examined using Pearson Product-Moment correlation analysis, an appropriate technique given that both variables met the assumptions of normality and linearity established in the preceding analyses. The analysis revealed a positive correlation coefficient of r = 0.528 (p = 0.006, N = 26), indicating a statistically significant relationship between learning interest and mathematics achievement. The positive sign of the coefficient indicates that the two variables moved in the same direction: students who reported higher levels of learning interest tended to also obtain higher mathematics achievement scores, whereas students who reported lower learning interest tended to obtain lower achievement scores. No cases were observed in which the pattern ran counter to this trend in a way that would suggest an inverse relationship.

**TABLE 2**. *Pearson correlation between learning interest and mathematics achievement*

| Variable | N | r | p-value | $R^2$ (Shared Variance) | Strength Category |
|---|---|---|---|---|---|
| Learning Interest ↔ Mathematics Achievement | 26 | 0.528 | 0.006 | 0.279 (27.9%) | Moderate |

Note. Correlation is significant at the 0.01 level (2-tailed). Strength category based on Evans's (1996) correlation interpretation guidelines: 0.00–0.19 (very weak), 0.20–0.39 (weak), 0.40–0.59 (moderate), 0.60–0.79 (strong), 0.80–1.00 (very strong).

Based on the interpretation guidelines applied in this study, a correlation coefficient of 0.528 as shown as **Table 2** falls within the moderate category, positioned roughly midway between a weak and a strong association. This categorization carries a specific substantive meaning: learning interest was neither a trivial nor a dominant factor in explaining students' mathematics achievement, but rather one of several factors that meaningfully contributed to it. Squaring the correlation coefficient ($r^2$ = 0.279) indicates that approximately 27.9% of the variance in mathematics achievement scores could be statistically accounted for by learning interest, while the remaining 72.1% of the variance was attributable to other, unmeasured factors such as students' prior mathematical ability, the quality of teacher facilitation during the DL-PBL learning process, family support, or individual cognitive differences.

Practically, this moderate correlation suggests that fostering learning interest through the RME–PBL-based e-module is a worthwhile and empirically justified instructional strategy for improving mathematics achievement, but it should not be treated as a sufficient condition on its own. A student with high learning interest was likely, though not guaranteed, to achieve a correspondingly high mathematics score; conversely, low interest was associated with a higher likelihood of lower achievement, but did not deterministically preclude satisfactory performance. This nuance is consistent with the broader literature suggesting that learning interest functions as one of several interacting psychological and contextual mechanisms that jointly shape learning outcomes, rather than as an isolated causal determinant.

Finally, the statistical significance of the correlation (p = 0.006), which fell below the stringent threshold of α = 0.01 set for this study, provides strong evidence that the observed relationship was unlikely to have occurred by chance, thereby lending confidence to the subsequent regression analysis used to further quantify and test the predictive effect of learning interest on mathematics achievement.

## The Effect of Learning Interest on Mathematics Achievement

Following the correlation analysis, which established that learning interest and mathematics achievement were significantly and moderately associated, a simple linear regression analysis was conducted to move beyond association and test whether learning interest could meaningfully predict students' mathematics achievement scores. While

correlation quantifies the strength and direction of a relationship, regression analysis allows for an estimate of the magnitude of change in achievement that can be expected for a given change in learning interest, as well as a formal significance test of that predictive relationship. The overall regression model was tested using an F-test to determine whether learning interest, as a predictor, explained a statistically significant proportion of the variance in mathematics achievement. The results showed that the model was statistically significant, $F(1, 24) = 9.270$, $p = 0.006$ (see **Table 3**). This result indicates that the variance in mathematics achievement explained by learning interest was unlikely to have occurred by chance, and that learning interest functioned as a genuine, meaningful predictor of achievement rather than an incidental statistical association.

**TABLE 3**. *Summary of simple linear regression analysis predicting mathematics achievement from learning interest*

| Source | Sum of Squares (SS) | df | Mean Square (MS) | F | Sig. |
|---|---|---|---|---|---|
| Regression | 1,584.72 | 1 | 1,584.72 | 9.270 | 0.006 |
| Residual | 4,103.28 | 24 | 170.97 | | |
| Total | 5,688.00 | 25 | | | |

The coefficient of determination ($R^2$) of 0.279 indicates that learning interest accounted for 27.9% of the variance in students' mathematics achievement scores. The Adjusted $R^2$ value of 0.249, which corrects for the small sample size ($N = 26$) and the number of predictors in the model, remains reasonably close to the unadjusted $R^2$, suggesting that the model's explanatory power was not substantially inflated by sample-specific characteristics. The remaining 72.1% of the variance in achievement was attributable to factors outside the scope of this model most plausibly students' prior mathematical ability, the quality and consistency of teacher facilitation during the DL-PBL learning process, parental or home academic support, individual cognitive differences, and possibly variation in students' familiarity with digital learning tools.

The t-test for the learning interest coefficient was statistically significant ($t = 3.045$, $p = 0.006$), providing further confirmation that learning interest was a reliable predictor of mathematics achievement rather than a coefficient that emerged by chance. The statistical hypotheses tested in this study were as follows: H0, positing no significant effect of learning interest on mathematics achievement, and Ha, positing a significant effect. Given that the significance value associated with the regression coefficient ($p = 0.006$) fell below the predetermined threshold of $\alpha = 0.01$, H0 was rejected, and Ha was accepted. This confirms that learning interest exerted a statistically significant, positive effect on mathematics achievement among fifth-grade students learning through the RME–PBL-based Deep Learning e-module on the topic of data processing. Taken together, these regression results extend the correlational findings by demonstrating not merely that learning interest and achievement are related, but that learning interest can be used to meaningfully predict achievement outcomes within this instructional context. The magnitude of the effect ($b = 0.740$) suggests a practically meaningful, though moderate, impact: interventions or instructional designs that succeed in raising students' learning interest could reasonably be expected to yield corresponding gains in mathematics achievement, even though interest alone does not account for the majority of variation in achievement outcomes. This underscores the value of designing digital mathematics instruction that deliberately cultivates interest, while also pointing to the need for complementary instructional strategies that address the substantial remaining variance attributable to other cognitive, instructional, and contextual factors.

## DISCUSSION

This study examined the effect of learning interest on mathematics achievement among fifth-grade students learning through a Deep Learning e-module integrating realistic mathematics education (RME) and problem-based learning (PBL) on the topic of data processing. The results demonstrated a positive, moderate, and statistically significant relationship between learning interest and mathematics achievement ($r = .528$, $p = .006$), with learning interest accounting for 27.9% of the variance in achievement scores. This section situates these findings within recent international literature, examines plausible explanatory mechanisms, and discusses theoretical and practical implications.

The finding that learning interest significantly predicted mathematics achievement is consistent with recent evidence on the mechanisms linking engagement-related constructs to performance in mathematics. A systematic review of student engagement in undergraduate mathematics found that the way engagement is conceptualized and measured moderates its observed relationship with achievement, suggesting that instruments capturing attention, enjoyment, and involvement tend to detect a meaningful but not overwhelming association with performance (Wong et al., 2025). This pattern parallels the moderate correlation coefficient obtained here and cautions against overstating learning interest as a dominant determinant of achievement. Complementing this, large-scale research tracking interest, enjoyment, and confidence in mathematics has shown that these affective variables are shaped by context and vary systematically across student subgroups (Zhao et al., 2025). Although the present study did not disaggregate by gender, this body of work suggests that instructional designs capable of broadly raising interest may hold particular value for narrowing such affective disparities.

The theoretical premise of combining RME and PBL rests on the idea that grounding mathematics in authentic contexts can raise comprehension and motivation simultaneously. This premise is supported by recent RME research: a quasi-experimental study of flipped RME instruction reported measurable gains in students' achievement, self-efficacy, and critical thinking tendency when mathematics tasks were framed within a flipped, realistic-education structure (Yohannes & Chen, 2024). Similarly, a comparative evaluation study found that realistic mathematics education produced improvements in secondary students' problem-solving skills relative to conventional instruction (Ventista et al., 2024). Retrospective analyses describe RME as deliberately structured to let learners progress from informal, context-bound reasoning toward formal mathematical understanding rather than beginning with abstract symbolic manipulation (Smid, 2023). Complementing this, accounts of RME's adoption across educational systems describe contextual problem situations as a bridge between everyday experience and formal mathematical structures (Zulkardi et al., 2020), a bridge plausibly responsible for the co-occurrence of improved performance and heightened interest observed in RME-based interventions.

The present findings also resonate with research examining how teaching practices shape the pathway from motivational constructs to achievement. Structural equation modeling of preservice elementary teachers found that teaching style significantly predicted perceived mathematics achievement, with attitude toward mathematics and math self-concept found to partially mediate this relationship (Awado et al., 2024). Although that study examined preservice teachers rather than elementary pupils, its central insight is transferable: motivational variables such as learning interest do not act as isolated determinants of achievement but are embedded within, and shaped by, the surrounding instructional environment. In the present study, the DL-PBL e-module's structured problem-orientation, investigation, and presentation phases likely functioned analogously to a structured teaching style, providing scaffolding through which interest could translate into achievement gains. This interpretation is reinforced by longitudinal research on teacher autonomy support, which found that perceived autonomy support was positively associated with students' mathematics achievement over time using latent

growth curve modelling (Wei et al., 2020). It is plausible that the e-module's built-in self-assessment and reflection features served as a digital analogue of autonomy support, reinforcing the interest–achievement pathway identified in this study.

Because the intervention was delivered entirely through a digital e-module, the findings should also be situated within research on technology-mediated mathematics instruction. A meta-analysis of mobile learning's impact on mathematics achievement reported a medium-sized positive effect of mobile learning on achievement outcomes (Talan et al., 2021), lending plausibility to the achievement gains observed in the present digitally delivered intervention. However, other research cautions that digital tools do not uniformly improve every motivational and performance indicator: a study of mobile-assisted seamless learning in secondary algebra found significant gains in achievement and motivation scores but no corresponding change in intrinsic goal orientation or test anxiety (Poçan et al., 2023). This nuance helps explain why learning interest in the present study accounted for just under 28% of the variance in achievement digital, interest-oriented design features appear to reliably shift some outcomes while leaving a substantial share of variance attributable to factors outside the model, such as prior mathematical knowledge or classroom-level instructional quality.

These findings extend the literature by providing domain-specific evidence, focused on an underexamined elementary mathematics topic, for the claim that RME and PBL combined within a digital format can foster achievement and interest concurrently rather than as competing outcomes. Practically, the results suggest that instructional designers should treat learning interest as a measurable instructional lever rather than a peripheral affective by-product. At the same time, because interest explained just over a quarter of the achievement variance, interest-building strategies should be paired with complementary attention to instructional scaffolding and teacher facilitation quality, consistent with the mediating roles that teaching style and attitude have been shown to play in related research (Awado et al., 2024).

## CONCLUSION

This study examined the effect of learning interest on mathematics achievement among 26 fifth-grade students learning through a Deep Learning-based e-module that integrated realistic mathematics education (RME) with problem-based learning (PBL) on the topic of data processing. The results demonstrated that learning interest was positively and significantly correlated with mathematics achievement ($r = .528$, $p = .006$), and that a simple linear regression model confirmed learning interest as a significant predictor of achievement, $F(1, 24) = 9.270$, $p = .006$, accounting for 27.9% of the variance in students' mathematics achievement scores. These findings provide empirical support for the hypothesis that learning interest exerts a significant effect on mathematics achievement, and they affirm the theoretical premise that integrating RME's contextual grounding with PBL's problem-solving structure within a single digital instructional format can foster both engagement and achievement concurrently, rather than treating these as competing instructional outcomes. Taken together, the study contributes empirical evidence, specific to the underexamined domain of elementary data-processing instruction, that digitally delivered, contextually grounded, and problem-oriented learning materials can serve as a viable pathway toward improving both students' interest in and achievement in mathematics.

Several limitations should be considered when interpreting these findings. First, the relatively small sample size ($N = 26$), drawn from a single classroom, limits the statistical power available for more complex analyses and constrains the generalizability of the results to other elementary populations with different demographic, geographic, or socioeconomic characteristics. Second, the correlational design of this study, while appropriate for examining the strength and direction of the relationship between learning interest and achievement, does not permit causal inference; because both instruments

were administered only after instruction, it remains unclear whether learning interest changed as a result of the e-module intervention or whether the observed relationship would hold under a pretest–posttest or experimental comparison design. Third, the study relied exclusively on self-reported questionnaire data to measure learning interest, which may be subject to social desirability bias or limited self-awareness among fifth-grade respondents. Finally, because the study focused on a single content area (data processing) within a single instructional format (the RME–PBL Deep Learning e-module), the extent to which these findings generalize to other mathematical topics or alternative digital instructional designs remains untested.

Building on these limitations, future research should consider replicating this study with a larger and more demographically diverse sample across multiple classrooms or schools to strengthen the generalizability of the findings. An experimental or quasi-experimental design would allow researchers to draw firmer causal conclusions about the effect of the RME–PBL e-module itself, independent of other maturational or contextual factors. Future studies would also benefit from incorporating additional psychological and instructional variables, such as self-efficacy, attitude toward mathematics, or teacher facilitation quality, as potential mediating or moderating variables, given that learning interest alone accounted for only 27.9% of the variance in achievement in this study. Furthermore, extending this line of research to other mathematical topics beyond data processing, as well as to other grade levels, would help determine whether the interest–achievement relationship observed here is specific to this content domain or reflects a broader pattern applicable across the elementary mathematics curriculum. Finally, future research could explore qualitative approaches, such as classroom observations or student interviews, to better understand the specific features of the RME–PBL e-module that students perceive as most engaging, thereby providing more actionable guidance for the design of future digital mathematics learning materials.

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