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Original Article

Contextual teaching and learning assisted by E-modules: Enhancing mathematical communication ability and learning motivation on the Pythagorean Theorem

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Abstract
This study examined the effect of Contextual Teaching and Learning (CTL) assisted by an electronic module (e-module) on Grade VIII students' mathematical communication ability and learning motivation in the Pythagorean Theorem. A quantitative quasi-experimental approach with a Nonequivalent Control Group Design involved 64 students at SMP Negeri 08 Tanjung Jabung Barat, Indonesia, divided equally into experimental and control classes ($n = 32$ each). The experimental class received e-module-assisted CTL across eight meetings, while the control class received conventional instruction. Data were collected using a mathematical communication essay test and a 32-item motivation questionnaire, both demonstrating high reliability (Cronbach's alpha = 0.917 and 0.881). Baseline testing indicated no significant differences between groups in communication ability or motivation. After treatment, the experimental class achieved a significantly higher mathematical communication mean (82.42) than the control class (70.31), $t(62) = 6.16$, $p < 0.0001$, with a large effect ($d = 1.54$). A Mann–Whitney U test also showed significantly higher motivation in the experimental class (median = 88.00) than the control class (median = 78.00), $Z = 6.87$, $p < 0.0001$, $r = 0.86$. The experimental class also demonstrated substantially greater gains in both outcomes across the intervention period overall. These findings indicate that e-module-assisted CTL effectively enhances students' mathematical communication ability and learning motivation, providing a practical technology-integrated alternative for junior secondary mathematics instruction.
Keywords: Contextual Teaching and Learning, e-module, learning motivation, mathematical communication ability, Pythagorean Theorem

1. Introduction

Twenty-first-century education demands a fundamental shift in learning paradigms, requiring students to master core competencies widely referred to as 21st-century skills, including critical thinking, creativity, collaboration, and communication (van Laar et al., 2017). This shift repositions teachers from being the sole source of information to facilitators of student-centred learning, a transition strongly supported by the integration of digital technology, which has been shown to enhance learning outcomes and engagement when digital materials are designed to be interactive and communication-rich (Weylin et al., 2023).

Mathematics occupies a strategic position in developing higher-order thinking, underpinning logical, analytical, and systematic reasoning. Process standards articulated in the mathematics education literature identify problem solving, connections, communication, reasoning, and representation as core components of mathematical learning (Hulukati et al., 2023). Among these, mathematical communication ability is critical: it is the capacity to express mathematical ideas through language, notation, or symbols so as to interpret, represent, and solve contextual problems both orally and in writing (Bach et al., 2024; Ingram et al., 2019). Without adequate communication ability, students struggle to develop deep conceptual understanding and to apply mathematics to real-world problems.

Despite its importance, Indonesian students' mathematical communication ability remains concerning. The 2022 Programme for International Student Assessment (PISA) ranked Indonesia 68th of 81 participating countries in mathematics, with a mean score of 366, far below the international average of 472 (OECD, 2023). Nguyen et al. (2025) similarly emphasise that mathematical communication ability remains a persistent global challenge requiring sustained pedagogical innovation.

This pattern was mirrored locally at SMP Negeri 08 Tanjung Jabung Barat, Jambi Province. A mathematical communication test administered to Grade VIII-A students (n = 32) in August 2024 found that only 2 students (6.25%) scored in the 71–80 (good) range, 3 students (9.38%) scored 61–70 (adequate), while 27 students (84.38%) scored 0–60, indicating a need for guided intervention. Students commonly struggled to write systematic solutions, connect visual representations to mathematical equations, and articulate solution steps using coherent mathematical language.

This weakness is closely tied to learning motivation. A motivation questionnaire completed by the same 32 students showed that only 8 students (25%) were highly motivated, while the remaining 24 (75%) fell into the moderately or poorly motivated categories. An interview with the class mathematics teacher (7 August 2024) revealed that instruction remained conventional and lecture-based, without interactive media, leaving students passive and disengaged, and expressing an explicit preference for more attractive digital learning resources.

Contextual Teaching and Learning (CTL) is an instructional approach that connects subject matter to students' real-world situations, thereby making learning more meaningful (Mahmuti et al., 2025). Through CTL, students do not merely memorise formulas but come to understand why and how mathematical concepts apply to daily life. CTL comprises seven interrelated components: constructivism, inquiry, questioning, learning community, modelling, reflection, and authentic assessment. To optimise CTL implementation, digital teaching materials are needed; an e-module is a systematically designed, curriculum-aligned digital teaching resource incorporating text, images, animation, video, and interactive elements (Sugianto et al., 2025), offering richer, more accessible, and more interactive content than conventional printed modules.

Prior studies support the combined use of CTL and digital modules. Mahmuti et al. (2025) found that contextual teaching and learning significantly improved students' mathematics achievement compared with conventional instruction. Shang et al. (2026) similarly found that a technology-enhanced, motivationally engaging pedagogical approach significantly improved both mathematics achievement and learning motivation relative to a conventional comparison condition. Purba and Surya (2020) demonstrated that a CTL-based instructional approach improved both mathematical understanding and students' attitudes relative to conventional instruction, while Mahendra (2016) found that a contextual learning approach produced better mathematics learning outcomes than a conventional approach even after controlling for numerical aptitude. These findings collectively suggest that combining CTL with an e-module holds strong potential for improving both mathematical communication ability and learning motivation.

Building on this rationale, the present study developed and tested a CTL-based e-module on the topic of the Pythagorean Theorem — a topic rich in real-world connections and demanding of strong mathematical communication for its understanding and problem-solving (Rahmah et al., 2025; Scott, 1999). This study specifically investigated the extent to which CTL assisted by an e-module influences Grade VIII students' mathematical communication ability and learning motivation at SMP Negeri 08 Tanjung Jabung Barat. Accordingly, this study addressed two research questions: (RQ1) Is Grade VIII students' mathematical communication ability on the Pythagorean Theorem significantly higher among students taught with CTL assisted by an e-module than among students receiving conventional instruction? (RQ2) Is Grade VIII students' learning motivation on the Pythagorean Theorem significantly higher among students taught with CTL assisted by an e-module than among students receiving conventional instruction?

2. Method

2.1 Research Design

This study used a quantitative quasi-experimental design, selected because full randomisation of students into treatment groups was not feasible within the school's existing class structure (Kim & Steiner, 2016). The specific design applied was the Nonequivalent Control Group Design, in which both classes underwent a pretest, a treatment period, and a posttest, but were not formed through random assignment (Koçak et al., 2025; Mohr, 1982). The pretest served to verify baseline equivalence between classes, so that any posttest differences could be attributed more confidently to the treatment rather than pre-existing differences. Table 1 summarises the design.

Table 1

Nonequivalent Control Group Design

Class	Pretest	Treatment	Posttest
Experimental (VIII-A)	O1	X = CTL + E-Module	O2
Control (VIII-B)	O3	C = Conventional Instruction	O4

Note. O1, O3 = pretest measures of mathematical communication ability and learning motivation; O2, O4 = posttest measures; X = CTL assisted by e-module; C = conventional lecture-based instruction.

The research proceeded in three stages. In the pre-treatment stage, both classes simultaneously completed the mathematical communication pretest and the initial motivation questionnaire, followed by prerequisite testing (normality and homogeneity) and an equivalence test. In the treatment stage, spanning eight meetings (2 × 40 minutes each), the experimental class received CTL instruction assisted by the e-module following a designed syntax, while the control class received conventional lecture-based instruction, question-and-answer sessions, and textbook exercises on the same material and time allocation. In the post-treatment stage, both classes completed the posttest and final motivation questionnaire, and the resulting data were analysed to test the research hypotheses.

The study involved three variables: the independent variable was the instructional approach (CTL assisted by e-module versus conventional instruction); the first dependent variable (Y1) was mathematical communication ability, measured with an essay test comprising three items with six scored sub-questions (score range 0–100); and the second dependent variable (Y2) was learning motivation, measured with a 32-item Likert questionnaire (score range 32–128). Both dependent variables were analysed separately, as each reflects a distinct construct with its own measurement instrument.

2.2 Research Participants

The population comprised all Grade VIII students at SMP Negeri 08 Tanjung Jabung Barat in the 2025/2026 academic year, totalling 125 students across four parallel classes (VIII-A, VIII-B, VIII-C, and VIII-D), all taught by the same mathematics teacher with equivalent weekly instructional hours. Using purposive sampling (Memon et al., 2025), Class VIII-A (n = 32) was designated the experimental class and Class VIII-B (n = 32) the control class, based on: (1) comparable prior achievement, verified through Grade VII mathematics final examination scores (mean difference < 5 points); (2) adequate access to digital devices for accessing the e-module; (3) teacher willingness to collaborate; and (4) both classes being taught by the same teacher, controlling for teacher-competency differences. The total sample was 64 students.

2.3 Instruments and Data Collection

Mathematical communication ability was measured using an essay test comprising three contextual items with six scored sub-questions, covering six indicators: stating a situation mathematically, drawing a visual representation, using correct mathematical notation, explaining a solution procedure in writing, interpreting a result in context, and evaluating and justifying a mathematical claim, following established approaches to designing written mathematical communication assessments (Hidayat & Aripin, 2023). The test was administered as both pretest and posttest. Learning motivation was measured using a 32-item four-point Likert questionnaire covering eight dimensions: desire and drive to succeed, need and urge to learn, hopes and aspirations for the future, appreciation in learning, engaging learning activities, a conducive learning environment, persistence, and learning independence, consistent with a self-determination perspective on the sources of student motivation (Ryan & Deci, 2020), summarised in Table 2 below.

Table 2
Structure of the Learning Motivation Questionnaire

No.	Dimension	Items	Maximum Score
1	Desire and drive to succeed	4	16
2	Need and urge to learn	4	16
3	Hopes and future aspirations	4	16
4	Appreciation in learning	4	16
5	Engaging learning activities	4	16
6	Conducive learning environment	4	16
7	Persistence	4	16
8	Learning independence	4	16

Note. Total = 32 items; maximum total score = 128.

Both instruments were tried out on 30 students in Class VIII-C prior to use. Item validity was assessed using Pearson product-moment correlation, and reliability using Cronbach's alpha. Table 3 presents the results.

Table 3

Instrument Validity and Reliability Testing (n = 30, Class VIII-C)

Instrument	Items	r range	r table	Cronbach's alpha	Conclusion
Mathematical communication test	6	0.822–0.882	0.361	0.917	Valid & reliable
Learning motivation questionnaire	32	0.364–0.791	0.361	0.881	Valid & reliable

Source: Instrument try-out data, Class VIII-C (2026).

Supplementary data were also gathered through observation of CTL syntax implementation in the experimental class and documentation of the research process, as reported in Section 3.1.

2.4 Data Analysis

Descriptive statistics (mean, median, standard deviation, minimum, and maximum) were computed for pretest and posttest scores on both variables. Prerequisite testing comprised the Shapiro–Wilk normality test (Shapiro & Wilk, 1965) and either the F-test or Levene's test for homogeneity of variance (Brown & Forsythe, 1974). Where both assumptions were satisfied, hypotheses were tested using an independent-samples t-test (Kim & Steiner, 2016), with effect size computed using Cohen's d (Lakens, 2013; Sullivan & Feinn, 2012). Where the normality assumption was violated, the non-parametric Mann–Whitney U test (Mann & Whitney, 1947) was applied instead, with effect size computed as the rank-biserial correlation ($r = |Z|/\sqrt{N}$). The significance threshold was set at $\alpha = 0.05$.

2.5 Research Ethics

Research permission was obtained from the school principal prior to data collection. Participating teachers and students provided informed consent, and student data were anonymised in reporting. The study complied with the ethical research guidelines of Universitas Terbuka's Postgraduate School.

3. Results and Discussion

3.1 Implementation of the CTL–E-Module Intervention

Before examining the inferential results, this section reports how the intervention was actually delivered in the classroom, consistent with recommendations that reports of educational interventions document implementation fidelity alongside outcome data so that null or positive findings can be properly interpreted (Booth et al., 2007; O'Donnell, 2008). Both classes completed the pretest and initial motivation questionnaire simultaneously, under the same conditions, before treatment began. Figure 1 shows the experimental class (VIII-A) and Figure 2 shows the control class (VIII-B) during this pre-treatment session.

Figure 1

Pretest and Initial Motivation Questionnaire Administration, Experimental Class (VIII-A)

Source: Researcher's documentation (2026).

Figure 2

Pretest and Initial Motivation Questionnaire Administration, Control Class (VIII-B)

Source: Researcher's documentation (2026)

During the eight-meeting treatment period, a trained observer monitored the extent to which the seven CTL components (constructivism, inquiry, questioning, learning community, modelling, reflection, and authentic assessment) were enacted in the experimental class, using a structured observation checklist, a practice consistent with guidance on measuring treatment fidelity in classroom-based intervention research (Dane & Schneider, 1998; de Leeuw et al., 2020). Table 4 summarises the results.

Table 4

CTL Syntax Implementation Fidelity Across the Eight Treatment Meetings

Meeting	Components Implemented (of 7)	Fidelity (%)	Observer Note
1	5	71.4	Students still adjusting to the e-module format
2	6	85.7	Growing enthusiasm during the inquiry phase
3	6	85.7	Group discussion reasonably active
4	7	100.0	All components implemented optimally
5	7	100.0	Students increasingly familiar with the CTL flow
6	7	100.0	High engagement during the constructivism phase

Meeting	Components Implemented (of 7)	Fidelity (%)	Observer Note
7	6	85.7	Claim-evaluation discussion ran slightly over time
8	7	100.0	Reflection and authentic assessment implemented optimally

Source: Structured classroom observation checklist, completed by a trained observer (2026). Mean fidelity across the eight meetings = 91.1%.

Fidelity was lowest at the first meeting (71.4%), when students were still becoming familiar with the e-module format, and rose to a sustained 100% by the fourth meeting, averaging 91.1% overall. This pattern, together with the absence of any meeting falling below 71%, supports the inference that the treatment was implemented largely as designed and that posttest differences reported in Sections 3.2 and 3.3 can be attributed with reasonable confidence to the CTL–e-module intervention itself rather than to inconsistent delivery. Figure 3 shows students engaged in the group-based problem-solving activities characteristic of the CTL learning-community component, while Figure 4 shows students accessing the e-module through personal digital devices, consistent with the device-access sampling criterion described in Section 2.2.

Figure 3

Experimental Class (VIII-A) Students During Group-Based Problem-Solving Activity

Source: Researcher’s documentation (2026)

Figure 4

Students Accessing the CTL-Based E-Module via Personal Digital Devices

Source: Researcher’s documentation (2026)

Minor implementation challenges were noted and resolved during the treatment period: uneven familiarity with e-module navigation in the first meeting was addressed with a brief orientation session and peer support; intermittent internet connectivity was addressed by providing a downloadable offline version of the e-module; and time slightly exceeding the allocated 2 × 40 minutes at the seventh meeting, due to lively small-group debate, was managed by condensing the closing reflection without omitting it. None of these issues is judged to have materially compromised treatment fidelity, consistent with the sustained high-fidelity scores reported in Table 4.

3.2 Mathematical Communication Ability

Prior to treatment, descriptive statistics showed comparable pretest means for the experimental class ($M = 54.69$, $SD = 9.51$) and the control class ($M = 57.94$, $SD = 12.04$). An independent-samples t-test confirmed no significant baseline difference, $t(62) = -1.20$, $p = 0.235$, indicating that both classes began from an equivalent level of mathematical communication ability. Following treatment, the experimental class achieved a substantially higher posttest mean than the control class. Table 5 presents the posttest descriptive statistics and hypothesis test results.

Table 5

Posttest Descriptive Statistics and Hypothesis Test — Mathematical Communication Ability

Parameter	Experimental (VIII-A)	Control (VIII-B)
n	32	32
Mean	82.42	70.31
Median	83.33	70.83
Standard deviation	6.84	8.77
Minimum	66.67	54.17
Maximum	95.83	87.50
Gain from pretest	+27.73 (+50.71%)	+12.37 (+21.35%)

Both posttest distributions satisfied the normality assumption (Shapiro–Wilk $W = 0.936$, $p = 0.058$ for the experimental class; $W = 0.954$, $p = 0.185$ for the control class) and the homogeneity assumption ($F = 1.65 < F$ table), permitting use of a parametric independent-samples t-test. The test yielded $t(62) = 6.16$, $p < 0.0001$, leading to rejection of H0: students' mathematical communication ability following CTL instruction assisted by an e-module was statistically significantly higher than that of students receiving conventional instruction. The effect size, Cohen's $d = (82.42 - 70.31)/7.87 = 1.54$, falls in the large category ($d \geq 0.80$; Lakens, 2013), indicating that the difference is not only statistically significant but also practically substantial. The experimental class's gain of 27.73 points (50.71%) considerably exceeded the control class's gain of 12.37 points (21.35%), reinforcing the descriptive pattern underlying the inferential result.

3.3 Learning Motivation

Prior to treatment, motivation scores were also comparable between classes (experimental: $M = 73.88$, 57.7% of the maximum score; control: $M = 75.22$, 58.8%), with an independent-samples t-test confirming no significant baseline difference, $t(62) = -1.45$, $p = 0.151$. Following treatment, the experimental class showed a markedly larger improvement in motivation than the control class, as shown in Table 6.

Table 6

Posttest Descriptive Statistics and Hypothesis Test — Learning Motivation

Parameter	Experimental (VIII-A)	Control (VIII-B)
n	32	32
Mean total score	89.88 (70.2%)	77.94 (60.9%)
Median	88.00	78.00

Parameter	Experimental (VIII-A)	Control (VIII-B)
Standard deviation	4.44	2.71
Minimum	88	73
Maximum	112	86
Gain from pretest	+16.00 (+21.66%)	+2.72 (+3.61%)

The experimental class's final motivation data violated the normality assumption (Shapiro–Wilk $W = 0.457$, $p < 0.0001$). This departure is attributable primarily to a sharp clustering of 20 of the 32 students at an identical total score of 88, together with one markedly higher score (112), rather than to a single outlier alone; researchers using similarly derived classroom scores should routinely re-check raw data for such clustering before concluding that it reflects a genuine ceiling effect rather than a data-recording artefact. Because the normality assumption was violated, the non-parametric Mann–Whitney U test was applied. The test returned U = 1,024.0, converted to a normal approximation of $Z = 6.87$ (Z table = 1.645 at $\alpha = 0.05$, one-tailed, consistent with the directional hypothesis tested), with the experimental class's median (88.00) exceeding the control class's median (78.00). Both decision criteria being satisfied, H0 was rejected: learning motivation among students receiving CTL instruction assisted by an e-module was statistically significantly higher than among students receiving conventional instruction. The rank-biserial effect size, $r = |Z|/\sqrt{N} = 6.87/8 = 0.86$, falls in the large category ($r \geq 0.50$), indicating a substantial practical impact consistent with the effect observed for mathematical communication ability. The improvement in motivation on the experimental class was observed consistently across all eight questionnaire dimensions, with the largest gains in the desire-and-drive-to-succeed and need-and-urge-to-learn dimensions.

4. Discussion

The findings demonstrate that CTL assisted by an e-module produced a large, statistically significant improvement in both students' mathematical communication ability and their learning motivation on the Pythagorean Theorem. These results are consistent with, and extend, prior findings on the effectiveness of contextual learning approaches. Mahmuti et al. (2025) found that contextual teaching and learning significantly improved students' mathematics achievement relative to conventional instruction, a pattern closely mirrored by the present study's large effect size ($d = 1.54$); Mahendra (2016) and Purba and Surya (2020) similarly reported that contextual approaches outperformed conventional instruction on mathematics learning outcomes. Shang et al. (2026) reported significant motivation and achievement gains under a technology-enhanced, motivationally engaging pedagogical approach, consistent with the present study's finding of a large rank-biserial effect ($r = 0.86$) for motivation.

The improvement in mathematical communication ability can be explained through the seven components of CTL. By grounding the Pythagorean Theorem in authentic, real-life contexts, rather than abstract symbolic manipulation alone, the constructivism and modelling components enabled students to build their own understanding and then express it using appropriate mathematical language. The inquiry and questioning components encouraged students to investigate relationships between triangle elements independently, which likely strengthened their ability to explain solution steps systematically, addressing the specific weaknesses identified in the initial diagnosis (difficulty writing systematic answers and connecting visual representations to equations), a pattern also reported by Ingram et al. (2019) in their analysis of how students construct explanations in mathematics classrooms.

The e-module appears to have played a complementary rather than incidental role. Consistent with Sugianto et al.'s (2025) finding that electronic, problem-based teaching materials measurably improve students' mathematical communication skills, and with Sudirman et al.'s (2020) finding that augmented-reality-based digital media significantly improved pre-service mathematics teachers' attitudes, motivation, and conceptual understanding of geometry, the digital format allowed the learning community and reflection components of CTL to be scaffolded through interactive content and immediate feedback, supporting Weylin et al.'s (2023) finding that interactive e-modules substantially improve students' digital mathematical communication relative to non-interactive teaching materials.

The gains in learning motivation are similarly explicable through CTL's authentic-assessment and community-of-learning components, which foster a more engaging and socially supported classroom environment than conventional lecture-based instruction, and are consistent with self-determination theory's account of how supporting students' needs for competence, autonomy, and relatedness sustains intrinsic motivation for learning (Ryan & Deci, 2020). The improvement was observed consistently across all eight motivation dimensions, suggesting a broad-based rather than narrowly targeted effect.

The high average implementation fidelity documented in Section 3.1 (91.1%) strengthens confidence that the observed effects can be attributed to the CTL–e-module intervention itself rather than to inconsistent or partial delivery, in line with methodological guidance that treatment effects in classroom-based intervention research are only interpretable once fidelity of implementation has been established (Booth et al., 2007; O'Donnell, 2008).

Several limitations should be acknowledged. First, the quasi-experimental design used intact, purposively sampled classes rather than full individual randomisation; although pretest equivalence was statistically confirmed for both variables, uncontrolled extraneous factors, such as differing classroom social dynamics, cannot be entirely ruled out, a limitation inherent to nonequivalent control group designs more generally (Kim & Steiner, 2016; Mohr, 1982). Second, the sample was limited to two classes at a single school ($n = 64$), constraining the generalisability of findings to schools with different demographic, infrastructural, or cultural characteristics. Third, the pronounced clustering of scores in the experimental class's final motivation data required the use of a non-parametric test; the individual and instructional factors underlying this clustering could not be examined in depth within the present quantitative design. Fourth, the eight-meeting treatment period captures only a short-term effect; the durability of communication-ability gains and motivational improvement beyond the intervention period remains unknown without longitudinal follow-up.

5. Conclusion

This study provides empirical evidence that Contextual Teaching and Learning assisted by an e-module, implemented with a mean fidelity of 91.1% across eight meetings, significantly improves both Grade VIII students' mathematical communication ability and their learning motivation on the Pythagorean Theorem. Students in the experimental class achieved a significantly higher posttest mathematical communication mean (82.42) than the control class (70.31), $t(62) = 6.16$, $p < 0.0001$, with a large effect size ($d = 1.54$). Learning motivation also improved significantly more in the experimental class (median = 88.00) than the control class (median = 78.00), $Z = 6.87$, $p < 0.0001$, $r = 0.86$. Both classes began from statistically equivalent baselines, strengthening the attribution of these gains to the CTL–e-module intervention rather than to pre-existing differences.

Theoretically, these findings support constructivist and self-determination accounts of motivation underlying CTL (Ryan & Deci, 2020), showing that mathematical knowledge becomes more meaningful and durable when constructed through experiences connected to students' real-life contexts. Practically, the findings suggest that mathematics teachers can adopt digitally delivered, contextually grounded teaching materials to improve both cognitive and affective learning outcomes simultaneously, without requiring additional instructional time. School leaders may consider these findings when formulating policies to encourage the development of contextual digital teaching materials more broadly, and local education authorities may use this evidence to support teacher-training initiatives on digital, contextual instructional design.

Limitations of the study include its single-site, two-class quasi-experimental design; a short, eight-meeting treatment period without longitudinal follow-up; and a single topic of focus (the Pythagorean Theorem). Future research should extend this work through multi-site replication with larger and more diverse samples, application of CTL-assisted e-modules to other mathematical topics and educational levels, longitudinal designs to assess the retention of communication-ability and motivational gains, and mixed-methods designs, for example, in-depth interviews with students showing extreme motivational responses, to better understand individual variation in intervention impact.

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Declarations

Author Contribution	:	Meri Meri: Conceptualisation, Writing, Original Draft, Methodology, Data Collection, Formal Analysis, and Investigation. Thesis supervisors: Supervision, Writing Endang Wahyuningrum: Review and Editing Sudirman Sudirman: Review and Editing Ebenzer Bonyah: Review and Editing
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AI Declaration	:	Artificial intelligence tools were used solely for grammar checking and language polishing during manuscript preparation. All intellectual content, data collection, analysis, and interpretation were performed by the author.
Data Availability	:	The data supporting the findings of this study are available from the corresponding author upon reasonable request.

6. References

Bach, C. C., Bergqvist, E., & Jankvist, U. T. (2024). Students' dynamic communication while transforming mathematical representations in a dynamic geometry environment. *ZDM – Mathematics Education*, *56*(4), 543–557. https://doi.org/10.1007/s11858-024-01575-x

Booth, A., Wood, S., Patterson, M., Carroll, C., Rick, J., & Balain, S. (2007). A conceptual framework for implementation fidelity. *Implementation Science, 2*(1), 40. https://doi.org/10.1186/1748-5908-2-40

Brown, M. B., & Forsythe, A. B. (1974). Robust tests for the equality of variances. *Journal of the American Statistical Association, 69*(346), 364–367. https://doi.org/10.1080/01621459.1974.10482955

Dane, A. V., & Schneider, B. H. (1998). Program integrity in primary and early secondary prevention: Are implementation effects out of control? *Clinical Psychology Review, 18*(1), 23–45. https://doi.org/10.1016/S0272-7358(97)00043-3

de Leeuw, R. R., de Boer, A. A., & Minnaert, A. E. M. G. (2020). The proof of the intervention is in the implementation: A systematic review about implementation fidelity of classroom-based interventions facilitating social participation of students with social-emotional problems or behavioural difficulties. *International Journal of Educational Research Open, 1*, 100002. https://doi.org/10.1016/j.ijedro.2020.100002

Hidayat, W., & Aripin, U. (2023). How to develop an E-LKPD with a scientific approach to achieving students' mathematical communication abilities. *Infinity Journal, 12*(1), 85–100. https://doi.org/10.22460/infinity.v12i1.p85-100

Hulukati, E., Pomalato, S. W. D., Hulukati, W., & Zakiyah, S. (2023). Developing students' mathematical communication skills in junior high school with varying levels of mathematics achievement through a generative learning model. *British Journal of Teacher Education and Pedagogy, 2*(1), 31–37. https://doi.org/10.32996/bjtep.2023.2.1.5

Ingram, J., Andrews, N., & Pitt, A. (2019). When students offer explanations without the teacher explicitly asking them to. *Educational Studies in Mathematics, 101*(1), 51–66. https://doi.org/10.1007/s10649-018-9873-9

Kim, Y., & Steiner, P. (2016). Quasi-experimental designs for causal inference. *Educational Psychologist, 51*(3–4), 395–405. https://doi.org/10.1080/00461520.2016.1207177

Koçak, G. N., Çetin, M. Ç., Kara, M., Genç, M., Lekesiz, G., Açıkbaş, F. C., & Kara, N. Ş. (2025). A quasi-experimental research on developing students' life skills through purposeful leisure time activities. *Frontiers in Psychology, 16*, Article 1634943. https://doi.org/10.3389/fpsyg.2025.1634943

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: A practical primer for t-tests and ANOVAs. *Frontiers in Psychology, 4*, Article 863. https://doi.org/10.3389/fpsyg.2013.00863

Mahendra, I. W. E. (2016). Contextual learning approach and performance assessment in mathematics learning. *International Research Journal of Management, IT & Social Sciences, 3*(3), 7–15. https://doi.org/10.21744/irjmis.v3i3.88

Mahmuti, A., Hamzić, D. K., & Thaqi, X. (2025). The impact of contextual teaching and learning on improving student achievement in economics mathematics. *International Electronic Journal of Mathematics Education, 20*(3), em0833. https://doi.org/10.29333/iejme/16233

Mann, H. B., & Whitney, D. R. (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics, 18*(1), 50–60. https://doi.org/10.1214/aoms/1177730491

Memon, M. A., Thurasamy, R., Ting, H., & Cheah, J.-H. (2025). Purposive sampling: A review and guidelines for quantitative research. *Journal of Applied Structural Equation Modeling, 9*(1), 1–23. https://doi.org/10.47263/JASEM.9(1)01

Mohr, L. B. (1982). On rescuing the nonequivalent-control-group design. *Evaluation Review, 6*(2), 213–238. https://doi.org/10.1177/0049124182011001003

Nguyen, H. T. M., Nguyen, G. T. C., Nguyen, B. N., Truong, D. T., & Thai, L. T. H. (2025). Mathematical communication skills for high school students: A comprehensive review of present practices, challenges, and prospective advancements. *TEM Journal, 14*(3), 2349–2360. https://doi.org/10.18421/TEM143-40

O'Donnell, C. L. (2008). Defining, conceptualizing, and measuring fidelity of implementation and its relationship to outcomes in K–12 curriculum intervention research. *Review of Educational Research, 78*(1), 33–84. https://doi.org/10.3102/0034654307313793

OECD. (2023). *PISA 2022 results (Volume I): The state of learning and equity in education*. OECD Publishing. https://doi.org/10.1787/53f23881-en

Purba, G. I. D., & Surya, E. (2020). The improving of mathematical understanding ability and positive attitudes of Unimed FMIPA students by using the Contextual Teaching Learning (CTL) approach. *Journal of Physics: Conference Series, 1462*(1), 012019. https://doi.org/10.1088/1742-6596/1462/1/012019

Rahmah, N. T. I., Putri, A., Ikram, M., & Sosa-Moguel, L. (2025). Profiling junior high school students' conceptual understanding of the Pythagorean theorem across ability levels. *Al-Jabar: Jurnal Pendidikan Matematika, 17*(1), 249–268. https://doi.org/10.24042/ajpm.v17i1.30110

Ryan, R. M., & Deci, E. L. (2020). Intrinsic and extrinsic motivation from a self-determination theory perspective: Definitions, theory, practices, and future directions. *Contemporary Educational Psychology, 61*, Article 101860. https://doi.org/10.1016/j.cedpsych.2020.101860

Scott, M. B. (1999). Pythagorean theorem revisited. *Teaching Mathematics and Its Applications: An International Journal of the IMA, 18*(1), 10–11. https://doi.org/10.1093/teamat/18.1.10

Shang, J., Huang, W., & Li, X. (2026). Effects of gamified project-based learning on mathematics achievement and motivation: A comparative study in elementary education. *International Journal of Science and Mathematics Education, 24*, Article 4. https://doi.org/10.1007/s10763-025-10644-w

Shapiro, S. S., & Wilk, M. B. (1965). An analysis of variance test for normality (complete samples). *Biometrika, 52*(3–4), 591–611. https://doi.org/10.1093/biomet/52.3-4.591

Sudirman, S., Mellawaty, M., Yaniawati, P., & Indrawan, R. (2020). Integrating local wisdom forms in augmented reality application: Impact attitudes, motivations and understanding of geometry of pre-service mathematics teachers'. *International Journal of Interactive Mobile Technologies, 14*(11), 91–106. https://doi.org/10.3991/ijim.v14i11.12183

Sugianto, S., Waluya, St. B., Sukestiyarno, Y. L., & Wardono. (2025). Problem-based learning based on electronic module: Students' mathematical communication process in terms of cognitive style. *Educational Process: International Journal, 16*, Article e2025222. https://doi.org/10.22521/edupij.2025.16.222

Sullivan, G. M., & Feinn, R. (2012). Using effect size—or why the P value is not enough. *Journal of Graduate Medical Education, 4*(3), 279–282. https://doi.org/10.4300/JGME-D-12-00156.1

van Laar, E., van Deursen, A. J. A. M., van Dijk, J. A. G. M., & de Haan, J. (2017). The relation between 21st-century skills and digital skills: A systematic literature review. *Computers in Human Behavior*, *72*, 577–588. https://doi.org/10.1016/j.chb.2017.03.010

Weylin, W., Raharjo, H., Haqq, A. A., & Larsari, V. N. (2023). Empowering students in the digital era: An analysis of interactive e-modules' effect on digital mathematical communication. *International Journal of Mathematics and Mathematics Education*, *1*(2), 132–149. https://doi.org/10.56855/ijmme.v1i02.401