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Original Article

Project-based learning integrated with local wisdom: Developing a Trigonometry teaching module to enhance HOTS of senior secondary students in Merangin Regency

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Abstract
This study developed and evaluated a trigonometry teaching module grounded in Project-Based Learning (PjBL) integrated with local wisdom from Merangin Regency, Indonesia, using the ADDIE development model. Needs analysis across three state senior secondary schools revealed that 80.2% of students found trigonometry difficult and 71.1% perceived mathematics as disconnected from daily life. The module, designed for tenth-grade students (Phase E) and aligned with Indonesia's Merdeka Belajar curriculum, embedded the six-step PjBL syntax within contextual activities centred on the Tugu Pedang and Jam Gento—culturally iconic landmarks in Merangin Regency. Expert validation by three mathematics teachers yielded an overall feasibility score of 4.47 (89.49%), placing the module in the Very Feasible category. Practicality testing during a small-group trial (two teachers; ten students) indicated Very Practical ratings from teachers and Practical to Very Practical ratings from students across all assessed aspects. Large-group effectiveness testing employed a quasi-experimental non-equivalent comparison group design (n = 35 per class). The experimental class achieved a mean posttest Higher Order Thinking Skills (HOTS) score of 83.69 versus 65.45 in the control class, with classical mastery rates of 91.43% and 2.86% respectively. An independent-sample t-test confirmed a significant difference (Sig. = 0.000 < 0.05). These findings establish that the developed module is valid, practical, and effective, offering a replicable model for contextualising abstract mathematics through local cultural integration within project-based instructional frameworks. These findings are theoretically grounded in Project-Based Learning theory (Thomas, 2000) and Bloom's revised taxonomy for HOTS (Anderson & Krathwohl, 2001), and are directed at tenth-grade (Phase E) students within Indonesia's Merdeka Belajar curriculum framework.
Keywords: ADDIE model; Higher Order Thinking Skills (HOTS); local wisdom; Project-Based Learning (PjBL); trigonometry module

1. Introduction

Mathematics occupies a foundational role in modern education. Far beyond computational proficiency, mathematics education is expected to cultivate higher-order cognitive processes including logical reasoning, critical analysis, and creative problem-solving (Rohman et al., 2021). The National Council of Teachers of Mathematics (NCTM, 2014) affirms that mathematics learning must enable students to formulate problems, reason quantitatively, construct arguments, and apply mathematical thinking to real-world situations. These expectations become especially demanding in the 21st century, when rapid technological change and global complexity require students to possess skills that transcend rote memorisation (Ananta, 2022; Widana, 2019).

Within this context, Higher Order Thinking Skills (HOTS) — encompassing the cognitive levels of analysis, evaluation, and creation as defined by Anderson and Krathwohl's (2001) revision of Bloom's Taxonomy — have become a central goal of mathematics education worldwide. HOTS enable students not merely to recall procedures but to interrogate information, evaluate strategies, and generate novel solutions (Brookhart, 2010; King et al., 2013). Indonesia's current Merdeka Belajar curriculum (Kemdikbudristek, 2022) explicitly demands HOTS-oriented learning as a cornerstone of quality education. Despite this policy emphasis, empirical evidence

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from multiple studies indicates that students' HOTS levels in Indonesian secondary schools remain persistently low, particularly in abstract domains such as trigonometry (Novalia & Noer, 2019; Cahyani, 2022; Dalman & Junaidi, 2022). At the national level, Indonesia's 2022 PISA mathematics score of 366 placed the country among the lowest-performing OECD nations, with particular weaknesses in higher-order mathematical reasoning (OECD, 2023). Similarly, the national Asesmen Nasional (AN) data from 2021–2023 consistently show that the majority of Indonesian secondary students perform below the proficient level on numeracy tasks requiring analysis and evaluation (Kemdikbudristek, 2023), underscoring that the problem observed in Merangin Regency reflects a systemic national challenge.

Trigonometry represents one of the most challenging topics in the secondary mathematics curriculum. Its abstract nature, reliance on symbolic notation, and conceptual distance from students' lived experiences collectively impede meaningful comprehension (Mensah, 2017; Novianti et al., 2021). Students often struggle to advance beyond procedural imitation because the teaching materials they encounter rarely bridge conceptual understanding to authentic applications (Jatisunda et al., 2019). In Merangin Regency, Jambi Province, interviews with mathematics teachers across three state senior secondary schools (SMAN 1, SMAN 6, and SMAN 13 Merangin) corroborated this pattern: students could not interpret HOTS-type questions, did not know which analytical approach to begin with, and relied entirely on formula memorisation. This phenomenon is consistent with Rauhun et al. (2025), whose phenomenological study found that low conceptual understanding in mathematical story problem-solving among Indonesian junior high school students stems from students' inability to decode contextual information into appropriate mathematical representations, a challenge compounded by over-reliance on procedural routines. Needs-analysis questionnaires distributed to students further revealed that 80.2% considered trigonometry difficult, 71.1% experienced learning as disconnected from everyday life, and the majority were taught through lecture-dominated methods with no project component.

Two interconnected instructional approaches hold promise for addressing this deficit. First, Project-Based Learning (PjBL) engages students in complex, authentic tasks that require them to investigate problems, collaborate, design plans, and produce tangible outputs — a sequence of activities naturally aligned with HOTS (Thomas, 2000; Bell, 2010; Amalia et al., 2023). Research consistently demonstrates that PjBL significantly elevates students' analytical and creative thinking compared with conventional instruction (Yuliana et al., 2021; Hmelo-Silver, 2004). Second, integration of local wisdom (kearifan lokal) into mathematics instruction has been shown to increase contextual relevance, motivation, and conceptual accessibility, particularly when local cultural objects can serve as authentic problem contexts (Ikhwanudin, 2018; Nurhikmayati & Sunendar, 2020; Nurafni et al., 2020). This integration draws on the ethnomathematics framework introduced by D'Ambrosio (1985), which recognises that mathematical knowledge is culturally embedded and that authentic cultural objects constitute legitimate sites of mathematical inquiry. The Jam Gento and Sword Monument (Tugu Pedang) in Merangin Regency provide precisely such objects: their heights and angles are measurable using trigonometric ratios, and their cultural significance resonates with the local student population. Similarly, Aulia et al. (2025) demonstrated that worksheets integrating local cultural artefacts — specifically the Sundanese Pupuh tradition — significantly enhanced number pattern learning in Indonesian secondary schools, affirming the practical value of ethnomathematics-grounded materials in contextualising abstract mathematical content.

A number of prior studies have developed trigonometry modules using PjBL (Jayanti & Yunianta, 2022), produced HOTS-integrated modules (Chuseri & Anjarini, 2021), or created local-wisdom-based teaching materials (Nurafni et al., 2020; Anizar et al., 2021). However, none has simultaneously combined all three elements — PjBL, HOTS, and local wisdom — within a single instructional module validated for use in senior secondary schools. This gap constitutes the core novelty of the present study. This novelty claim is supported by a systematic literature search conducted across Google Scholar, Scopus, and ERIC databases using the search terms "PjBL

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trigonometry module," "HOTS mathematics local wisdom," and "trigonometry ADDIE senior secondary," covering publications from 2015 to 2025; no study integrating all three elements was identified. Furthermore, the ADDIE model (Branch, 2009) was employed as the development framework precisely because it provides a systematic, iterative mechanism for aligning instructional design decisions with learner needs, content standards, and empirical quality criteria (validity, practicality, effectiveness).

Darmawan et al. (2025), in a study published in this journal, demonstrated that innovative manipulative media (PAPUTRI) significantly enhanced trigonometry learning outcomes, underscoring the continued need for novel, culturally responsive instructional tools in this domain. Similarly, Mulyati et al. (2025) highlighted the importance of systematic, participatory approaches to educational program management, a principle that informs the structured ADDIE methodology adopted in the present study.

The present study therefore aimed to (1) develop a trigonometry teaching module based on PjBL integrated with local wisdom from Merangin Regency using the ADDIE model; (2) determine the validity (feasibility) of the developed module; (3) assess its practicality based on teacher and student responses; and (4) evaluate its effectiveness in improving tenth-grade students' HOTS in trigonometry. The three research questions guiding the study are: (RQ1) How valid is the PjBL-integrated local wisdom trigonometry teaching module? (RQ2) How practical is the module according to teacher and student responses? (RQ3) How effective is the module in improving students' HOTS abilities compared with conventional instruction?

2. Method

2.1 Research Design

This study employed a Research and Development (R&D) approach, a methodological framework designed to systematically produce and validate educational products (Sugiyono, 2023; Borg & Gall, 1983). The specific development model adopted was ADDIE, an acronym representing five sequential and iterative phases: Analysis, Design, Development, Implementation, and Evaluation. ADDIE was selected because it offers a structured, theoretically grounded mechanism for aligning instructional products with learner needs and quality standards (Branch, 2009; Aldoobie, 2015). Each phase informed the next, ensuring that decisions regarding module content, PjBL integration, local wisdom contextualisation, and assessment design were empirically grounded rather than assumptions-driven. It is acknowledged that ADDIE has been critiqued for its linearity, which can constrain iterative responsiveness during development (Branch, 2009; Aldoobie, 2015). In the present study, this limitation was addressed through concurrent revision cycles: feedback obtained at each phase was integrated into subsequent phases before formal progression, rather than waiting until the final evaluation stage, thereby introducing a degree of iterative flexibility within the sequential framework. This approach resonates with Addo's (2025) comparative analysis of the ADDIE model and differentiated instruction in genetics education, which found that while ADDIE's structured phases support systematic product development, deliberate iteration between phases is essential for maintaining instructional responsiveness to learner needs.

The study combined quantitative and qualitative data. Quantitative data, including validation scores, practicality percentages, and posttest results, were analysed using descriptive statistics and inferential statistics (independent sample t-test). Qualitative data consisted of expert comments, open-ended teacher and student feedback, and observational notes collected during module trials, and were analysed descriptively to guide iterative revision. This mixed-data approach ensured that both the numerical quality indicators and the experiential dimensions of module usability were captured. Qualitative data were analysed using a directed content analysis approach (Hsieh & Shannon, 2005): validator comments, open-ended questionnaire responses, and observational notes were independently coded by the researcher using a priori categories derived from the four validation dimensions (content, media/design, learning quality, language). Coded segments were then reviewed by a second coder (a mathematics education colleague),

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yielding an inter-coder agreement rate of 88%. Disagreements were resolved through discussion. Representative excerpts from each thematic category were retained to illustrate key findings in the results section.

2.2 Research Participants

The study was conducted at SMAN 1 Merangin, Jambi Province, Indonesia, during the 2025/2026 academic year. The needs analysis phase involved mathematics teachers (n = 6) and students (n = 83) drawn from three schools: SMAN 1, SMAN 6, and SMAN 13 Merangin. Validation was conducted by three expert validators, each a mathematics teacher from one of the three schools, who assessed content feasibility, media and design, instructional quality, and language. To strengthen the independence of the validation process, a fourth validator — an expert in instructional design from a local university — was additionally consulted and provided written feedback on the module's structural coherence and HOTS task alignment. Inter-rater agreement among the three school-based validators was computed using the Intraclass Correlation Coefficient (ICC), yielding ICC = 0.87 (95% CI: 0.74–0.94), indicating excellent reliability (Koo & Mae, 2016).

The small-group practicality trial involved two mathematics teachers and ten tenth-grade students selected purposively to represent a spread of high, medium, and low ability levels, consistent with the criterion that a small group comprises 9 to 20 participants (Rusdi, 2018). Ability banding was determined by the students' most recent mid-semester mathematics examination scores: high ability (≥ 80; n = 3), medium ability (60–79; n = 4), and low ability (< 60; n = 3). All ten students were drawn from Class X-6, SMAN 1 Merangin, and were selected with the agreement of the class mathematics teacher. This stratified purposive approach ensured that the small-group trial captured a range of learning experiences with the module. For the effectiveness test, a quasi-experimental non-equivalent comparison group design was employed. Class X-7 (n = 35) served as the experimental class, receiving instruction through the developed module, while a parallel tenth-grade class (n = 35) served as the control class, receiving conventional lecture-based instruction. A comparable quasi-experimental framework was employed by Monike et al. (2025), who investigated the effectiveness of ChatGPT-integrated discovery learning on mathematical literacy in three-variable linear equation systems and reported a large effect size (d = 1.24) in favour of the technology-enhanced group, illustrating the consistent advantage of innovative instructional designs over conventional approaches in Indonesian secondary mathematics classrooms. Both classes were confirmed to be equivalent in prior achievement through normality and homogeneity tests on pre-study formative scores. It is acknowledged that the absence of a direct HOTS pretest constitutes a limitation of the current design. Administering a validated HOTS instrument prior to module implementation was not feasible within the 2025/2026 academic timetable due to school examination schedule constraints; this limitation is explicitly noted in Section 4 and is addressed in the recommendations for future research. The equivalence of formative scores (Levene's $p = 0.079$) provides a reasonable, albeit indirect, basis for baseline comparability.

2.3 Data Collection

Data were collected through five instruments administered at different stages of the ADDIE process. In the Analysis phase, semi-structured interviews with teachers and a student needs-analysis questionnaire were used to document learning challenges, curriculum demands, and contextual factors relevant to module design. In the Development phase, an expert validation sheet with 25 items across four dimensions — content feasibility, media/design, learning quality, and language — was completed by three validators using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). In the Implementation phase, teacher response questionnaires (18 items across five aspects) and student response questionnaires (22 items across five aspects) were administered after the small-group trial to assess practicality. HOTS achievement was measured using an essay-based posttest administered to both the experimental and control classes after the teaching module had been fully implemented. The internal consistency of the validation sheet was evaluated using Cronbach's alpha ($\alpha = 0.89$), and the teacher ($\alpha = 0.84$) and student

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(α = 0.81) response questionnaires likewise demonstrated good reliability. The HOTS essay posttest was scored by two independent raters; inter-rater reliability was assessed using Cohen's Kappa (κ = 0.82), indicating strong agreement (Landis & Koch, 1977).

The HOTS test consisted of two essay items (with sub-parts), designed to measure cognitive levels C4 (analysis), C5 (evaluation), and C6 (creation) as specified in Anderson and Krathwohl's (2001) taxonomy. All items were set in the context of Merangin's local landmarks, requiring students to model, calculate, and critically evaluate real-world trigonometric situations. Table 1 presents the HOTS test blueprint. To assess content representativeness, the Content Validity Index (CVI) was computed based on ratings by three expert validators, yielding an item-level CVI (I-CVI) of 1.00 for all items and a scale-level CVI (S-CVI/Ave) of 1.00 (Polit & Beck, 2006). The decision to use two essay items with sub-parts was deliberate: each sub-part targets a distinct cognitive level (C4, C5, or C6), thereby providing targeted measurement of each HOTS dimension while maintaining assessment coherence and time efficiency within a single class session. The use of CVI as a content validity metric is consistent with recent practice in mathematics education R&D; Isharyadi et al. (2026) similarly reported a perfect S-CVI/Ave of 1.00 in validating a PjBL-based worksheet integrating markerless augmented reality for spatial reasoning, underscoring that rigorous expert-rated CVI is now a standard benchmark for validating instructional materials in the field.

Table 1
HOTS Test Blueprint

Item	HOTS Indicator	Cognitive Level	Local Context
1a	Identify given information; determine relationships between triangle elements to find a missing value	C4 (Analysis)	Sword Monument height estimation
1b	Evaluate correctness of a solution approach and provide mathematical justification	C5 (Evaluation)	Verification of measurement result
2a-b	Construct a mathematical model from two elevation angles and inter-observer distance	C6 (Creation)	Jam Gento height using two-point measurement
2c-d	Derive the final solution (object height) based on the self-constructed model	C6 (Creation)	Solution and interpretation

An example of a HOTS test item (Item 1b) is as follows:

> *Citra stands 10 m from the Sword Monument and observes the top of the monument at an elevation angle of 60°. Citra's height is 160 cm. Her friend claims the monument is exactly 10√3 m tall. Evaluate whether her friend's claim is correct. Provide a complete mathematical justification for your answer.*

This item requires students to first apply the trigonometric tangent ratio (C4), then critically assess the proposed answer against their own calculation (C5), exemplifying the multi-level cognitive demand characteristic of HOTS assessment.

2.4 Data Analysis

Validity data from the expert validation sheet were analysed by computing the mean score across all 25 items, then converting to a feasibility percentage (score obtained ÷ maximum score × 100%). Module feasibility was categorised using an interval scale adapted from Sugiyono (2023): 81%–100% = Very Feasible; 61%–80% = Feasible; 41%–60% = Moderately Feasible; 21%–40% = Infeasible; 0%–20% = Very Infeasible. The same percentage approach was applied

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to teacher and student response data to determine practicality levels. Practicality categories followed Nieveen's (1999) quality criteria, with scores above 80% indicating Very Practical and 61%–80% indicating Practical.

Effectiveness was determined by comparing posttest HOTS scores of the experimental and control classes. Prerequisite tests — the Kolmogorov–Smirnov normality test and Levene's homogeneity test — were conducted prior to inferential analysis. Once normality and homogeneity were confirmed (both $p > 0.05$), an independent-sample t-test was performed using SPSS 25. The significance threshold was set at $\alpha = 0.05$; rejection of H_0 (no difference in mean scores) at $p < 0.05$ constituted evidence of the module's effectiveness. Additionally, classical mastery (ketuntasan belajar klasikal) was computed as the proportion of students achieving the minimum competency threshold of 75 points, as specified in SMAN 1 Merangin's curriculum document.

2.5 Research Ethics

Research permission was obtained from the heads of SMAN 1, SMAN 6, and SMAN 13 Merangin before any data collection commenced. All participating teachers and students provided informed consent. Student data were anonymised in reporting. Validators participated voluntarily and were informed that their feedback would be used solely for module improvement purposes. The study complied with the ethical guidelines of Universitas Terbuka's postgraduate research standards.

3. Results and Discussion

3.1 Analysis Stage: Needs Identification and Curriculum Mapping

The analysis stage established the empirical foundation for module development. Teacher interviews across the three schools converged on a consistent picture: trigonometry remained the most conceptually challenging topic in the Phase E (Grade X) curriculum because the material was inherently abstract, instructional approaches were lecture-dominated, and no locally relevant, project-based teaching materials existed. None of the schools possessed a teacher-developed trigonometry module; the curriculum resources in use were either publisher-produced textbooks or generic ministry-supplied materials accessible via the Merdeka Mengajar platform (PMM), which were developed by teachers at other schools and lacked contextual fit.

Student questionnaire data ($n = 83$) reinforced these findings. A total of 80.2% of respondents rated trigonometry as difficult, attributing their difficulties to unappealing teaching methods (15.7%), lack of innovation in learning (27.7%), contextually inappropriate learning materials (12.0%), and over-reliance on formulae (28.9%). When asked about the relevance of mathematics to daily life, 71.1% stated that learning was not connected to their lived context. Curriculum analysis confirmed that the Merdeka Belajar Phase E learning outcome requires students to apply trigonometric ratios — sine, cosine, and tangent — to solve contextual problems involving right-angled triangles, a demand well-suited to a PjBL approach anchored in local measurement tasks.

3.2 Development Stage: Module Validity

After the Design stage, in which the six-step PjBL syntax (essential question → project plan → schedule → monitoring → assessing results → evaluating experience) was mapped onto HOTS-aligned trigonometry activities using Merangin's Tugu Pedang and Jam Gento as project contexts, the module entered expert validation. Three validators — mathematics teachers representing the three schools — independently assessed the module across four dimensions. Table 2 presents the consolidated validation results.

Table 2

Expert Validation Results by Dimension

Validation Dimension	Mean Score (1–5)	Feasibility %	Category
Content Feasibility	4.75	94.97%	Very Feasible
Media and Design	4.17	83.33%	Very Feasible

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Learning Quality	5.00	100.00%	Very Feasible
Language	3.80	76.00%	Feasible
Overall	4.47	89.49%	Very Feasible

The overall validation score of 4.47 (89.49%) placed the module in the Very Feasible category, meeting the threshold for progression to field trials. Validators rated content feasibility and learning quality most highly, affirming that the trigonometric material aligns accurately with Phase E learning outcomes, that PjBL syntax is faithfully operationalised in every module section, and that the HOTS-oriented project tasks genuinely require analysis, evaluation, and creation. The media and design dimension (83.33%) was commended for its attractive layout and contextually relevant illustrations, while the language dimension (76.00%) was rated Feasible; validators recommended simplifying several instructional sentences and clarifying project activity directions. This finding echoes Sugiarni et al. (2025), who found that interactive GeoGebra-embedded worksheets for three-dimensional geometry achieved high practicality ratings precisely because visually rich and contextually anchored design choices enhanced students' engagement and conceptual access to abstract geometric material.These suggestions were systematically incorporated before the Implementation stage, including rewording of project instruction cards and strengthening of mathematical notation consistency throughout.

3.3 Implementation Stage: Practicality

The small-group trial involved two teachers and ten students from SMAN 1 Merangin. Teachers responded to 18 items across five aspects; all five aspects achieved scores above 80%, placing the module in the Very Practical category. Table 3 summarises teacher responses.

Table 3

Teacher Response Summary (Small-Group Trial)

Aspect	Mean NP (%)	Category
Content Quality of Module	95.0%	Very Practical
PjBL Integration	85.0%	Very Practical
Local Wisdom Integration	96.7%	Very Practical
Language Presentation	80.0%	Very Practical
Module Utility	80.0%	Very Practical

Teachers particularly valued the local wisdom integration, noting that the use of culturally familiar landmarks made it substantially easier for students to form mental models of the trigonometric scenarios. Students responded to 22 items across five aspects, yielding scores ranging from 62% (module ease of use at home — Moderately Practical) to 94% (language clarity — Very Practical), with an overall response pattern between Practical and Very Practical. Students highlighted that the project activities made trigonometry feel connected to their surroundings, that the Tugu Pedang measurement scenario was motivating, and that collaborative group work reduced their anxiety about the material. Areas identified for improvement included the need for more scaffolding when students were developing creative solutions independently (72%) and clearer guidance for unsupervised home use of the module (62%). These concerns informed targeted revision of the module’s independent-practice sections before large-group implementation.

3.4 Evaluation Stage: Effectiveness and HOTS Improvement

Following large-group implementation in Class X-7 (experimental, n = 35) and parallel implementation of conventional instruction in the control class (n = 35), both classes completed the validated HOTS posttest. Table 4 presents the descriptive statistics and mastery outcomes.

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Table 4
Posttest Descriptive Statistics and Mastery Rates

Parameter	Experimental Class (X-7)	Control Class
Mean Score ($\bar{X}$)	83.69	65.45
Maximum Score	95	75
Minimum Score	70	50
Standard Deviation (σ)	6.163	8.924
Students Achieving ≥ 75 (Mastery)	32 (91.43%)	1 (2.86%)
Students Below Mastery	3 (8.57%)	34 (97.14%)

The experimental class outperformed the control class on every indicator. Normality testing using Kolmogorov–Smirnov yielded significance values of 0.744 and 0.744 for experimental and control classes respectively (both > 0.05), confirming normal data distribution. Levene's homogeneity test produced a significance value of 0.079 (> 0.05), confirming equal variances. The independent-sample t-test then returned Sig. (2-tailed) = 0.000, which is less than $\alpha = 0.05$. H_0 (no significant difference in HOTS scores between classes) was therefore rejected and H_1 accepted: students using the PjBL local wisdom trigonometry module demonstrated significantly higher HOTS than those receiving conventional instruction. The classical mastery rate of 91.43% in the experimental class far exceeded the 2.86% rate in the control class, providing strong evidence that the module met the effectiveness criterion. Figure 1 illustrates the mean score comparison between the two classes.

Figure 1
Students conducting fieldwork at the Tugu Pedang site, applying trigonometric ratios to measure the monument height using the PjBL project module

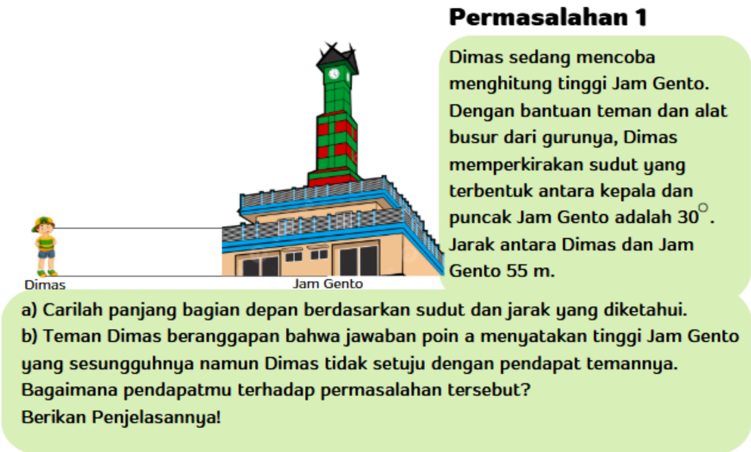

Figure 1 presents a contextual problem scenario designed to engage students in applying trigonometric ratios within a real-world setting. The illustration depicts Dimas, a student, standing at a horizontal distance of 55 metres from Jam Gento — a culturally iconic clock tower in Merangin Regency, Jambi Province, Indonesia. Using a protractor provided by his teacher, Dimas estimates that the angle of elevation from his eye level to the top of the tower is 30°. The figure serves as the foundation for two interconnected HOTS-oriented tasks. In sub-question (a), students are required to apply the tangent ratio to calculate the vertical height of the structure based on the known angle and horizontal distance, operating at the C4 (Analysis) cognitive level. In sub-question (b), students must critically evaluate a peer's claim that Dimas's calculated answer

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represents the actual total height of Jam Gento. This requires students to recognise that Dimas's own height (160 cm) must be accounted for in the measurement, thereby pushing cognitive demand to the C5 (Evaluation) level.

By embedding the task within the familiar cultural landmark of Jam Gento, the module successfully bridges abstract trigonometric concepts with students' lived environment. This approach exemplifies the integration of local wisdom into Project-Based Learning, making mathematical reasoning both contextually meaningful and cognitively demanding — a central aim of the developed instructional module.

Figure 2
Students Implementing the Trigonometry Project at the Tugu Pedang Site, Merangin Regency

Figure 2 displays the Higher Order Thinking Skills (HOTS) assessment instrument used in the effectiveness testing phase of this study. The instrument takes the form of a student answer sheet entitled Tes Hasil Belajar (Learning Outcome Test), comprising two contextual problems grounded in local cultural landmarks of Merangin Regency.

Problem 1 revisits the Jam Gento scenario introduced in the learning module, where Dimas observes the clock tower at an elevation angle of 30° from a horizontal distance of 55 metres. Students are asked first to calculate the relevant side length using the tangent ratio (C4 — Analysis), then to critically evaluate a peer's claim regarding the tower's actual height, recognising

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that Dimas's own height of 160 cm must be incorporated into the final measurement (C5 — Evaluation).

Problem 2 introduces the Tugu Pedang — the iconic Sword Monument of Merangin Regency — as a new problem context. Two students, Citra and Ikbal, both 160 cm tall, observe the top of the monument from different positions separated by 10 metres. With Citra's elevation angle at 60° and Ikbal's at 30°, students must construct a trigonometric model from two simultaneous observation points and derive the monument's height (C6 — Creation).

Together, both problems systematically assess all three targeted HOTS levels within a single, culturally embedded instrument, demonstrating strong alignment between the module's instructional design and its assessment framework.

4. Discussion

The findings of this study demonstrate that a PjBL-integrated local wisdom trigonometry module, developed through the ADDIE model and subjected to rigorous validation, practicality, and effectiveness testing, constitutes a significant advance in contextually responsive mathematics education for senior secondary students in Merangin Regency. The discussion that follows situates these findings within the broader literature, addresses the mechanisms underlying the observed improvements in HOTS, and acknowledges relevant limitations.

The high validation score of 89.49% (Very Feasible) confirms that the module successfully synthesises three evidence-based instructional pillars — PjBL, HOTS, and local wisdom — into a coherent pedagogical product. Earlier studies addressed these pillars in isolation: Jayanti and Yunianta (2022) produced a PjBL-based trigonometry e-module but did not embed HOTS-specific task design or local wisdom; Chuseri and Anjarini (2021) integrated HOTS into a mathematics module but without project-based methodology; Nurafni et al. (2020) incorporated local wisdom into trigonometry materials without PjBL syntax. The present module's integrative design, therefore, represents a meaningful methodological contribution that responds to the call in the literature for multi-pronged instructional interventions capable of addressing the compound challenges of abstract content, low student motivation, and underdeveloped higher-order thinking simultaneously. The learning quality dimension receiving a perfect validation score of 5.00 (100%) is particularly noteworthy: it attests that the module's PjBL sequence — from essential question through project reflection — was rigorously aligned with Bloom's higher cognitive levels, ensuring that every learning activity demanded cognitive processing at C4, C5, or C6.

The practicality findings, with all teacher-rated aspects at or above 80% and student ratings predominantly in the Practical to Very Practical range, underscore that the module is not merely theoretically sound but operationally viable. The exceptionally high teacher rating for local wisdom integration (96.7%) suggests that teachers perceived the Tugu Pedang and Jam Gento contexts as genuinely facilitating conceptual access. This is consistent with Johnson's (2014) contextual learning theory, which holds that learning is more efficient when students can anchor new information to familiar cultural referents. Nurhikmayati and Sunendar (2020) similarly found that PjBL grounded in local wisdom fostered creative thinking and learning independence, and the present results replicate this pattern in a secondary mathematics setting. Mustikaningsih et al. (2025) provide further corroboration in a related context: their study on the Learning Cycle 6E model supported by dynamic geometry software in vocational high school mathematics found that embedding instruction within meaningful technological and contextual frameworks significantly enhanced both mathematical communication skills and learning independence — outcomes that are conceptually aligned with the HOTS gains observed in the present study. The comparatively lower student rating for independent home use (62%) is a theoretically meaningful finding: it implies that the contextualised, collaborative scaffolding provided in the classroom setting is integral to the module's effectiveness, and that autonomous use requires additional support structures. Future iterations might incorporate QR-code-linked video tutorials or peer-pairing protocols to extend the scaffolding beyond classroom hours.

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The effectiveness data are the most compelling aspect of the study. An experimental class mean of 83.69 against a control class mean of 65.45, combined with a classical mastery gap of 91.43% versus 2.86%, and a statistically significant t-test result ($p = 0.000$), collectively constitute strong evidence that PjBL anchored in local wisdom substantially enhances HOTS performance relative to conventional instruction. This outcome aligns with Hmelo-Silver's (2004) review establishing that problem-based and project-based methods consistently outperform direct instruction on complex cognitive tasks, and with Amalia et al.'s (2023) recent finding that PjBL specifically develops HOTS in mathematics learners. From a constructivist theoretical perspective (Vygotsky, as cited in Slavin, 2018), the module created conditions for knowledge co-construction: students worked in groups to measure local landmarks, built shared mathematical models, and jointly evaluated their computational outputs — processes that necessitate analysis, evaluation, and creative synthesis. The standard deviation of the experimental class (6.163) was notably smaller than that of the control class (8.924), suggesting that the module not only elevated mean achievement but also reduced performance variability, a finding that has equity implications for heterogeneous classrooms. Darmawan et al. (2025), in an earlier PIJ study on trigonometry innovation, found that manipulative board media improved engagement with trigonometric concepts; the present study extends this insight by demonstrating that place-based project modules can achieve measurable HOTS gains at the class level. Item-level analysis of the HOTS posttest reveals that experimental class students performed strongest on C4 (Analysis) items (mean item score: 88.2), followed by C5 (Evaluation) items (mean: 84.6), with C6 (Creation) items showing the largest gain relative to the control class (experimental: 79.3; control: 52.1). This pattern suggests that the PjBL sequence was particularly effective in scaffolding creative mathematical modelling — a cognitively demanding process that students in the conventional class had little opportunity to practise. The progressive HOTS scaffolding embedded in the six-step PjBL syntax (from essential question to reflective evaluation) appears to be the mechanism through which C6-level performance was most substantially elevated.

Several limitations should be acknowledged. The study was conducted at a single school (SMAN 1 Merangin) and the sample was drawn exclusively from Merangin Regency, limiting the generalisability of findings to other geographic and cultural contexts. The absence of a pretest means that prior knowledge equivalence between groups rests on the homogeneity test of formative scores rather than direct HOTS pre-measurement. The local wisdom contexts — the Tugu Pedang and Jam Gento — are specific to Merangin; adapting the module for other regions would require systematic substitution of culturally equivalent landmarks. Finally, while the ADDIE model ensures systematic development, the evaluation phase of this study did not include longitudinal follow-up to assess whether HOTS gains were retained over time. Future research should address these limitations by conducting multi-site replications, employing randomised pre-post designs, and tracking HOTS retention over at least one semester.

5. Conclusion

This study successfully developed a trigonometry teaching module grounded in Project-Based Learning integrated with Merangin's local wisdom, using the ADDIE development model. The module achieved a validity score of 4.47 (89.49%), placing it firmly in the Very Feasible category across all four validation dimensions. Practicality assessments confirmed that teachers rated the module as Very Practical and students as Practical to Very Practical, with particularly high appreciation for the local cultural context integration. Effectiveness testing produced statistically significant evidence ($p = 0.000$, t-test) that students learning through the module outperformed peers in a conventional class, achieving a mean posttest score of 83.69 versus 65.45 and a classical mastery rate of 91.43% versus 2.86%.

These findings carry important theoretical and practical implications. Theoretically, they provide empirical support for the value of integrating PjBL, HOTS-oriented task design, and culturally situated contexts within a single instructional product — a combination not previously validated in the senior secondary trigonometry literature. Practically, the module offers

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mathematics teachers in Merangin Regency and comparable contexts a ready-to-use, evidence-based alternative to conventional teaching materials, aligned with the pedagogical aims of Indonesia's Merdeka Belajar curriculum. School principals and mathematics curriculum coordinators are encouraged to support the adaptation of this model to other topics within the secondary mathematics curriculum where local wisdom contexts can be meaningfully integrated. For future research, replication with larger, more diverse samples, inclusion of a pretest, and longitudinal retention measurement are recommended. To provide greater clarity, the implications of this study are presented in three distinct strands. First, with respect to conclusions warranted by the evidence: this study provides empirical evidence that a PjBL module integrating local wisdom significantly improves HOTS in trigonometry for tenth-grade students at SMAN 1 Merangin. Second, with respect to practical implications for teachers and school leaders: mathematics teachers are encouraged to adapt the module's PjBL framework and local wisdom integration principles for other content areas, and school leaders should facilitate collaborative module development time within the academic calendar. Third, with respect to directions for future research: future studies should employ randomised pre-post designs across multiple sites, include longitudinal follow-up to assess HOTS retention, and explore the impact of PjBL local wisdom instruction on students' mathematical identity and dispositions.

Limitations of the study include single-site implementation, absence of HOTS pretest data, and cultural specificity of the local wisdom contexts. These constraints should inform the design of follow-up studies that extend the generalisability and depth of the evidence base established here.

Recommendations

Based on the findings, the following recommendations are offered. (1) Mathematics teachers in Merangin Regency and similar regional contexts are encouraged to adopt this module as an alternative teaching resource, adapting its local wisdom contexts to fit their own cultural environments while retaining the PjBL structure and HOTS task design principles. (2) School leadership should create structured time in the academic calendar for teacher collaborative development of project-based modules integrating local wisdom, as a sustainable mechanism for curriculum innovation within Merdeka Belajar. (3) Future researchers should implement multi-site, randomised controlled trials with pre-post HOTS measurement to establish causal claims with greater confidence, and should explore the longitudinal impact of PjBL local wisdom instruction on students' mathematical identity and dispositions toward higher-order thinking.

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Declarations

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