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Digital Deep Learning Materials with Culture: Improving Students' Pythagorean Theorem Abstraction Skills

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ABSTRACT

The Pythagorean theorem and the ability to abstract are two important elements in mathematics, but they actually become problems. Therefore, this study aims to determine the impact of digital learning materials based on deep learning integrated with *Batak* culture on students' abstraction abilities in Pythagorean theorem learning. This study used the ADDIE model development design. The participants in the study were 32 students (16 boys and 16 girls, aged 13-14 years) from one of the junior high schools in Medan, Indonesia. The instruments in the study were digital teaching materials and student abstraction ability tests. Data were analyzed using qualitative data analysis and nonparametric statistics. The research results revealed that the integration of culture within the framework of deep learning proved essential in digital teaching materials. The implementation ran smoothly because the materials were developed based on the needs of the students and incorporated cultural elements, making them familiar to the students. The research findings also revealed that the digital teaching materials were able to optimize students' abstraction abilities, with male students showing better abstraction skills than female students. The study recommended that future researchers examine the factors that caused male students to be more dominant in abstraction.

Keywords: Abstraction abilities, *Batak* culture, deep learning, digital teaching materials, Pythagorean theorem

INTRODUCTION

The Pythagorean theorem represents a fundamental mathematical concept with widespread applications across various fields, from analytical geometry to modern technology (Chiotis, 2021; Kapofu & Kapofu, 2020; Sol et al., 2025; Wittmann, 2021). However, despite its numerous benefits, the learning of the Pythagorean theorem continues to face significant challenges (Bariyah et al., 2024; Suanto et al., 2024). One prominent example of these challenges is students' limited abstraction ability (Alghadari & Noor, 2020).

Abstraction ability refers to an individual's capacity to understand concepts without relying on concrete objects (Löhr, 2022). In the context of the Pythagorean theorem, abstraction skills encompass not only conceptual understanding but also the ability to transfer knowledge to new situations and formulate generalizations (Hidayat & Iksan, 2018; Nurhadi & Darhim, 2021). Research in cognitive psychology indicates that integrating cultural context into learning can enhance the abstraction process, as cultural integration provides students with familiar and meaningful mental schemas (Holden et al., 2021; Shadiev et al., 2024). Within the *Batak* cultural context, mathematical and geometric concepts are naturally embedded in various artifacts, including weaving patterns, traditional architecture, and traditional measurement systems. This cultural integration offers potential as a

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cognitive bridge for students' abstract understanding of the Pythagorean theorem (Fachrudin et al., 2020). Hence, embedding cultural artifacts such as *Batak* architecture provides not only contextual relevance but also a cognitive bridge for mathematical abstraction.

While several studies have explored approaches to optimize abstraction skills in Pythagorean theorem learning, significant methodological gaps persist. Moutsios-Rentzos et al. (2014) demonstrated the potential of visual manipulative materials; however, their approach did not integrate digital technology and remained limited to a Western context. Similarly, Alghadari and Noor (2020) identified students' dependence on procedural knowledge but failed to provide a systematic solution for optimizing students' abstract thinking. Lian et al. (2023) showed that the Chinese edition of ZJE learning materials effectively optimized students' abstraction skills through systematic evidence presentation. Nevertheless, this approach remained confined to printed learning materials without incorporating technology and local cultural elements.

A critical gap exists in the scarcity of research that combines three essential elements: leveraging technology and deep learning to personalize learning for enhanced adaptability, integrating local cultural contexts as meaningful cognitive bridges, and focusing comprehensively on developing abstraction skills that encompass not only deductive reasoning but also concept transfer and generalization. The integration of technology and deep learning enables learning adaptation according to individual patterns, which is anticipated to overcome the limitations of printed instructional materials (Fauskanger & Bjuland, 2018; Maspiroh et al., 2025; Omoniyi, 2025; Özer & Demirbatır, 2023). Meanwhile, the integration of *Batak* culture is expected to provide a more meaningful and accessible learning context for abstract Pythagorean theorem concepts compared to cross-cultural comparison approaches (A. S. Abdullah, 2016; Linuhung et al., 2025; Prahmana et al., 2021).

This study addresses the aforementioned gap by developing a systematic learning model that integrates technology and deep learning for personalized instruction, incorporates *Batak* cultural context for meaningful learning experiences, and emphasizes the development of abstraction skills. This integrated approach is anticipated to enhance not only students' conceptual understanding but also their knowledge transfer and generalization capabilities, which constitute the fundamental components of abstract thinking in mathematics. Accordingly, this research aims to examine the effects of culturally integrated, deep learning-based digital instructional materials on students' abstraction abilities in Pythagorean theorem learning. To achieve the research objectives, the researcher formulates several research questions, including:

RQ1: What is the form of teaching materials for the Pythagorean theorem that optimizes abstraction skills?

RQ2: How is the implementation of culturally integrated deep learning teaching materials in the learning of the Pythagorean theorem?

RQ3: How is the description of students' abstraction abilities after the implementation of culturally integrated deep learning teaching materials?

METHOD

Research design

The research design used was developmental research using the ADDIE model combined with quasi-experimental testing. This design was chosen because it was relevant to the research objectives, which aimed to develop learning tools based on a deep learning approach integrated with culture to optimize students' abstraction abilities (Ali, 2021; Shakeel et al., 2023). In this research, 'deep learning' refers to a pedagogical model focusing on higher-order thinking and reflection, not artificial intelligence algorithms. The ADDIE model also assisted researchers in analyzing the cultural context and abstraction needs for learning, helped in formulating a learning approach that integrated culture, aided in the production of culturally based contextual teaching materials, ensured authentic and reflective practices in learning, and helped in providing feedback on students' cultural understanding and abstraction (Spatioti et al., 2022).

Participants

Participants in this study were divided into several groups. The first group of students were made respondents in the learning needs survey activity. The students in this group were those who had already received instruction on the Pythagorean theorem. The second group consisted of six students who were used as participants for the small group trial. The third group consisted of 32 students aged approximately 13 to 14 years (16 boys and 16 girls). This group of students had varying initial mathematics abilities: low, medium, and high. These variations in initial mathematical ability served as baseline measurements to control for confounding variables and ensure that research results were truly attributable to the treatment provided rather than students' pre-existing mathematical abilities (Clarke et al., 2019; Olalowo, 2020). Furthermore, these criteria were employed to assess the effectiveness of learning interventions in groups with heterogeneous abilities, thereby enabling generalization of the research

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findings (Cueli et al., 2019). The group was selected through purposive sampling primarily because they had not yet studied the concept of the Pythagorean theorem in class.

Regarding participant selection, this study had several limitations that limited its generalizability. First, the relatively small sample size of 32 students potentially limited the statistical power of the findings, particularly in detecting learning effect sizes. Second, participants were recruited from only one school in a specific geographic area, thereby constraining the external validity and generalizability of the findings to other educational contexts, particularly cultural settings beyond the *Batak* context. Third, although the purposive sampling method was methodologically appropriate for the study's objectives, it allowed for potential selection bias and limited the random representativeness of the broader population. These limitations suggest that the study's findings should be interpreted cautiously, and replication studies with larger and more diverse samples should be conducted before making recommendations for broader implementation. Specifically, these constraints limit the applicability of the findings to diverse cultural contexts.

Instrumentation

The main instrument in this research was digital teaching materials based on deep learning integrated with *Batak* culture. Digital textbooks were used to obtain data related to student responses during the learning activities. Some additional instruments used included validation sheets, student response questionnaires regarding the learning devices, and abstraction ability tests. The validation sheets were used to obtain data related to the feasibility of all teaching devices used in the learning process. The student and teacher response questionnaires were used to gather data related to the feasibility of the teaching devices from the students' perspective. The teacher response questionnaire consisted of 25 statements, and the student response questionnaire consisted of 20 statements, to which participants responded using a 4-point Likert scale.

Meanwhile, the abstraction ability test was used to obtain information related to the students' level of abstraction, both before and after the learning process. In fact, the abstraction test had already integrated cultural elements. As illustrated in **Figure 1**, cultural integration utilized traditional architectural elements, traditional clothing, and spatial arrangements to create a culturally meaningful mathematical context. **Figure 1** presents examples of employing the structure of a traditional Toraja house, which shares the same cultural roots as the traditional *Batak* house, as a platform for investigating geometric relationships and spatial reasoning. Additionally, the integration incorporated the configuration of traditional ceremonial settings to explore abstract mathematical thinking and traditional weaving patterns (Ulos) to examine mathematical sequences and pattern recognition.

Figure 1. Excerpt on the Integration of *Batak* Culture in Abstract Ability Test Questions

This test instrument was designed to activate students' prior cultural knowledge while simultaneously assessing their mathematical abstraction abilities at various cognitive levels.

The abstraction ability test was systematically designed based on cognitive theory and relevant indicators of abstraction, including pattern recognition, generalization, symbolic representation, and conceptual knowledge transfer. The abstraction ability test items were structured to progress from concrete manipulative tasks to increasingly abstract symbolic operations, integrating Piaget's cognitive development framework with Van Hiele's

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geometric thinking levels (Cerovac & Keane, 2025; Moore et al., 2024). The test instrument consisted of two contextual problems with two derived questions related to *Batak* and Malay culture, distributed across four levels of abstraction ability to ensure comprehensive assessment.

A comprehensive, four-level assessment rubric was developed and validated by experts. Level 1 (concrete) referred to students' ability to physically manipulate or use visual aids to solve problems. Level 2 (semi-concrete) is related to students' ability to effectively use pictorial and diagrammatic representations. Level 3 (semi-abstract) addressed students' ability to use simplified symbolic notation with minimal visual support. Meanwhile, Level 4 (abstract) was demonstrated through students' ability to fully manipulate symbols and make generalizations. Each test item was assessed using the rubric with detailed criteria and established inter-researcher reliability protocols. Content validity was rigorously established through assessments from three experts in mathematics education and two experts in cultural education who evaluated the items' suitability, cultural authenticity, and alignment with indicators of mathematical abstraction ability. The validation results indicated that the abstraction ability test met the evidence of validity requirements with recommendations for minor improvements. A snippet of the cultural integration used in the test questions was shown in **Figure 1**. All additional instruments were accessible on the following page: student and teacher response questionnaires, as well as the abstraction ability test.

Data collection procedure

The data collection procedure in this study followed the ADDIE steps: analysis, design, development, implementation, and evaluation (Ali, 2021; Shakeel et al., 2023). In the analysis stage, the researcher analyzed the learning needs by conducting a student needs survey. During the design phase, the researcher designed a deep learning-based learning tool integrated with *Batak* culture. In the development stage, the researcher developed the product, starting with the creation of a learning video based on a previously designed storyboard. At this stage, the researcher also provided engaging and culturally appropriate text and images. Additionally, the researcher validated the learning tool with two material experts and three media experts. Afterwards, the researcher revised the learning tool based on the validators' suggestions for improvement.

The implementation stage in this study was divided into two activities: a small group trial involving six students and a large group trial involving 32 students. Finally, the researcher evaluated all stages to revise the previously developed learning tool. The research procedure was illustrated in **Figure 2.**

Figure 2. Research Procedure

Data analysis procedure

The data in this study were analyzed by combining various analytical techniques. Survey, implementation, and evaluation data were analyzed using qualitative data analysis consisting of three steps: data reduction, data display, and conclusion (Moon et al., 2022; Sridana et al., 2025; Sukarma et al., 2024).

The researcher reduced data that were considered less relevant to the research objectives and did not further analyze those data during the data reduction phase. The researcher presented representations of important data using various forms, such as descriptions, tables, or images, during the data display phase. At the conclusion stage, the researcher made connections between the representation results and the research objectives. Inter-rater reliability yielded a $\varkappa$ value of 0,83 based on independent qualitative coding performed by two trained researchers, indicating substantial agreement.

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Concerning abstraction ability, data were analyzed quantitatively. Assumption tests revealed that the data were not normally distributed (Shapiro-Wilk test: $W = 0,89$, $p < 0,05$ for all measures) with non-homogeneous variance (Levene's test: $F = 4,23$, $p < 0,05$). Therefore, nonparametric statistical analyses were employed. The non-parametric analyses utilized the Wilcoxon signed-rank test and the Mann-Whitney U test to determine whether the culturally integrated deep learning instructional materials significantly improved students' abstract thinking skills. A significance criterion of $p < 0,05$ was established, whereby values below this threshold indicated that the instructional materials had produced a significant effect on abstract thinking skills (Holmes, 2020; Thakkar, 2025). The bootstrap method was employed to calculate robust 95% confidence intervals for all effect size estimates, thereby providing precise indicators of the magnitude of the observed differences.

Descriptive statistics employed included measures of central tendency, variability, and distribution shape for all variables. Percentage achievement was calculated for each abstraction ability indicator under pre- and post-test conditions and was stratified by gender to examine potential differential effects. Data were analyzed separately for male and female students. Subsequently, the analysis results were compared to determine whether gender had affected students' abstraction abilities during mathematics learning using the *Batak* culture-integrated deep learning approach. The gender-based analysis involved calculating separate effect sizes and confidence intervals to determine both the statistical significance and practical significance of any observed differences in the development of abstraction abilities between male and female students.

RESULTS AND DISCUSSION

RESULTS

RQ1: What is the form of teaching materials for the Pythagorean theorem that optimizes abstraction skills?

Based on the results of the previous survey, it was found that the developed teaching materials were recommended to integrate Batak cultures. This was because most of the students came from the Batak ethnic groups. In other words, integrating that culture was expected to be one of the efforts to preserve the culture. After understanding the form of integration and the appropriate learning framework, the researcher developed a digital teaching module based on Batak cultures. The recommended learning framework based on survey results was deep learning. An example of the initial appearance of the digital teaching module can be seen in **Figure 3**.

Figure 3. Main Menu of the Deep Learning-Based Digital Teaching Module Integrated with Culture

Figure 3 contained several cultural elements from the *Batak* people of Indonesia. First, the traditional *Batak* house, namely *Batak Toba*, appeared on the left and right upper sides of the image. Second, the traditional *Batak* clothing that used *Ulos* woven fabric. Third, the traditional *Batak* musical instruments, namely *Gondang* or *Taganing*, were shown on the lower right side of the image. Fourth, the *Tor-Tor Sipitu Cawan* dance, which was a traditional dance of the *Batak* people.

The digital teaching module was designed systematically by following a deep learning framework that consisted of nine learning steps. First, students explored the awareness of the benefits of the material being studied in the context of cultural preservation, making the learning more meaningful. Second, students listened to the learning objectives conveyed by the teacher to ensure the targets of the learning. Third, students answered several prompting questions about their previous experiences and knowledge related to the Pythagorean theorem, making

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the learning more meaningful because the students were prepared to learn. Fourth, students were oriented towards the problem. At this step, students strove to understand the problem according to their comprehension.

Fifth, the organization of students for learning. In this activity, students sought relevant information and began asking guiding questions to solve the problem. Sixth, students conducted an investigation using the information and answers from the guiding questions to develop strategies for solving the problem. Seventh, students developed and presented the results. At this step, students implemented the strategies previously devised and then presented the results in the form of a written report and a presentation in front of the class. Eighth, students analyzed and evaluated the problem-solving process through reflective discussions during the presentation of the previous results. Students validated each other's solutions at this step. Ninth, students reflected on the concepts learned.

At this step, students also received appreciation from the teacher for the learning that had been carried out. A summary of the framework was shown in **Table 1**.

Table 1. Nine-step framework

Learning Steps	Learning Stages	Description of Main Activities
1	Contextual awareness	Students explored the benefits of the material being studied in a cultural context.
2	Goal setting	Students listened to the learning objectives presented by the teacher.
3	Prior knowledge activation	Students answered prompt questions about the Pythagorean theorem to explore their prior experiences and knowledge.
4	Problem orientation	Students understood the problem presented by the teacher.
5	Learning organization	Students explored the information needed to formulate a solution to the problem.
6	Investigation	Students investigated the problem to develop a strategy for solving it.
7	Development and presentation	Students implemented the strategy and then presented their solution.
8	Analysis and evaluation	Students analyzed other groups' answers and evaluated the concepts learned together.
9	Reflection and appreciation	Students reflected on the solutions or concepts learned and received recognition from the teacher.

Meanwhile, the student worksheets developed in this research contained problems and the steps students took to solve them. The problem involved the use of the *Batak* traditional house, namely the Bolon House. Students in the worksheet were asked to investigate how the Pythagorean theorem was applied to the structure of the Bolon House. The excerpt of the problem used in the students' worksheet can be seen in **Figure 4.**

RQ2: How is the implementation of culturally integrated deep learning teaching materials in the learning of the Pythagorean theorem?

The learning implementation was systematically documented through three key phases: initial

The *Bolon* house is a traditional house of the *Batak* people of North Sumatra. Its architecture features a high, towering roof, resembling a triangle. Triangular shapes are also found on the entrance stairs and supporting pillars. Let's explore how mathematical elements, specifically the Pythagorean Theorem, are applied to the structure of the *Bolon* house.

Figure 4. Example Problems on Student Worksheets

abstraction, geometric abstraction, and application of the Pythagorean theorem. In general, the implementation of deep learning teaching materials integrated with *Batak* cultures ran according to the learning scenarios outlined in the teaching module. At the beginning of the activity, the teacher conveyed the learning objectives, which were to understand the concept of the Pythagorean theorem. Thereafter, the students expressed that quite a few houses or traditional clothing of the *Batak* tribes used triangular motifs, including right-angled triangles. The students were then given several preliminary questions about

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the square and square root of a number to ensure their prerequisite skills were adequate for learning related to the Pythagorean theorem.

The following outlined phase 1 (initial abstraction/problem understanding). In this phase, students were asked to solve the problem. The initial step that students took when solving a problem was understanding the problem. This activity was the initial stage of the abstraction process that students undertook. In this activity, students answered several prompting questions provided on the student worksheet. Some examples of prompting questions presented were: What shape was the roof of a Bolon house? What was the type of geometry of the Bolon house structure? How did you use the Pythagorean theorem to find the height of the Bolon house roof? Analysis of student responses revealed that approximately 85% of students correctly identified the roof shape as a triangle, while 78% correctly recognized the right triangle within the structure. Most students answered that the shape of the Bolon house roof was triangular. Some students answered that the geometry of the Bolon house structure was right-angled and wrote down the Pythagorean theorem formula when asked to find the height of the Bolon house roof. Examples of student answers can be seen in **Figure 5.**

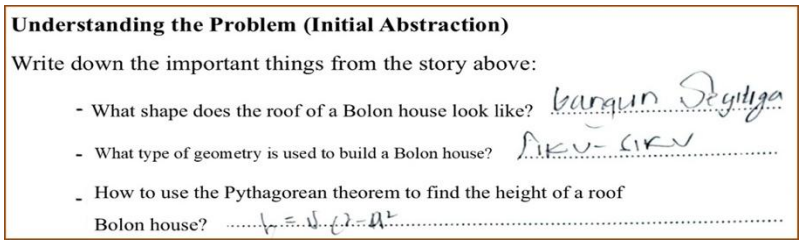

Figure 5. Example of Student Answers in Geometry Abstraction Activities

The second phase focused on geometric abstraction and visual representation. After performing the initial abstraction, the students presented a visual representation. In this activity, students performed geometric abstraction on the model of the Bolon traditional house roof. Students drew the shape of a triangle along with the names for each side of it. Systematic analysis of student work revealed that 82% of students were able to create accurate geometric representations with appropriate labeling of triangular components. A snippet of the students' answers in this activity could be seen in **Figure 6**.

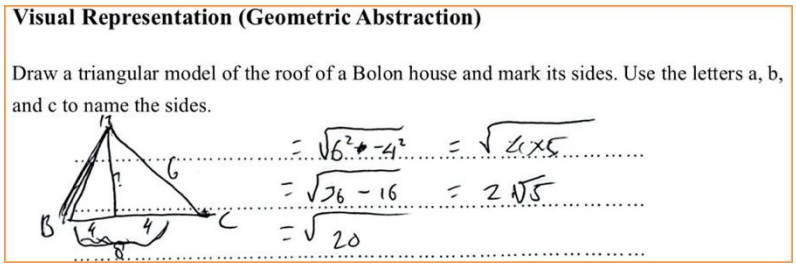

Figure 6. Example of Student Answers in the Initial Abstraction Activity

The third phase focused on the application of the theorem and problem solving. The next activity was for students to solve problems by applying the Pythagorean theorem to the problems that had been presented earlier. In this activity, students implemented the Pythagorean theorem formula to determine the height of the *Bolon* traditional house. Quantitative analysis of student solutions revealed that 76% of participants provided mathematically correct answers, while the remaining 24% exhibited procedural errors primarily in calculations rather than conceptual understanding. Some students provided correct answers, while others made mistakes in their responses. However, most students were able to correctly determine the height measurement of the traditional house's roof. A snippet of the students' answers could be seen in **Figure 7**.

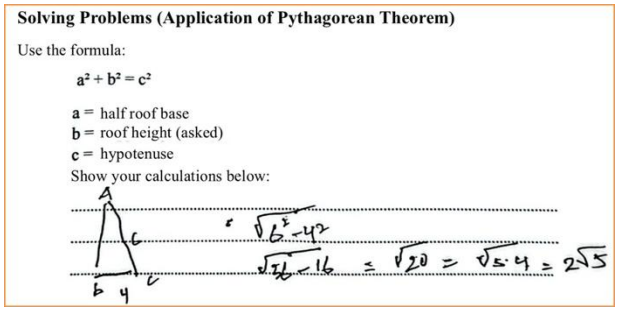

Figure 7. Example of Student Answers in the Application of the Pythagorean Theorem Activity

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After ensuring that all students were able to determine the height measurement of the Bolon house roof, the learning activity continued with the final one. The activity began with students summarizing the material they had learned that day. The students then expressed that the Pythagorean theorem played a significant role in the *Batak* cultural context. This was because almost all buildings, clothing, or traditional objects contained the concept of the Pythagorean theorem. The learning activity was then concluded with some information related to the material that would be studied in the next meeting and a closing greeting from the teacher.

RQ3: How is the description of students' abstraction abilities after the implementation of culturally integrated deep learning teaching materials?

Following implementation, student abstraction abilities were analyzed to determine overall improvement in mathematical abstraction skills. Statistical analysis revealed that the abstraction abilities of all participants (n = 32) improved significantly, with effect sizes indicating practical significance beyond statistical significance. Based on the results of the descriptive analysis, it was found that most male students scored above 80 on the post-test. In fact, there were several students who scored 100. When compared to the pre-test scores, there was an improvement in students' abstraction abilities. During the pre-test, most students scored abstraction values ranging from 43,75 to 56,25.

The following describes the results based on the abstraction ability indicator performance. In relation to the indicators, around 52% of students were able to identify mathematical objects, whereas after the implementation, information showed that around 87% of students were able to identify the characteristics of mathematical objects well. Regarding the indicator of generalizing patterns, about 51% of students were able to do so before the implementation. However, around 89% of students were able to generalize patterns after the implementation. This improvement represented a 35% increase in the object identification indicator and a 38% increase in pattern generalization ability.

Gender-based analysis with methodological considerations was conducted in this section. In other words, the implementation of culturally integrated deep learning teaching materials was able to optimize the abstraction abilities of male students. Similarly, the analysis results also indicated that there was an increase in the abstraction abilities of female students after the implementation of culturally integrated deep learning teaching materials. It was proven that during the pre-test, the average percentage for the indicator of identifying mathematical objects was only 48,44% and 45,31% for the indicator of generalizing patterns. Meanwhile, during the post-test, 76,56% of students were able to identify object characteristics, and 78,13% were able to generalize patterns.

Statistical validation of the improvements was conducted in this section. Statistical analysis revealed a significant improvement in students' abstraction abilities following the implementation of the instructional materials. The output from SPSS Statistics 25 is shown in **Figures 8** and **9**. **Figure 8** provided information that all the ranks formed were positive ranks. In other words, there was an increase in students' abstraction ability scores after the implementation.

Ranks

		N	Mean Rank	Sum of Ranks
Total_Post - Total_Pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	32[b]	16.50	528.00
	Ties	0[c]		
	Total	32		

a. Total_Post < Total_Pre
b. Total_Post > Total_Pre
c. Total_Post = Total_Pre

Figure 8. Ranks of All Students' Abstract Thinking Abilities

Test Statistics[a]

	Total_Post - Total_Pre
Z	-4.963[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Figure 9. Statistical Test of Abstract Thinking Ability of All Students

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Meanwhile, Figure 9 provided information that there was a significant increase in students' abstraction ability scores after the implementation. It was proven that the significance of Z was 0,000 (less than 0,05). The analysis results also reached a similar conclusion when the analyzed data were separated based on gender. The analysis results for male students revealed a significant improvement in abstract thinking ability. This improvement was evidenced by all male students having positive ranks (Figure 10) with a Z significance value of 0,000 (less than 0,05) (Figure 11).

Ranks

		N	Mean Rank	Sum of Ranks
Total_Post - Total_Pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	16[b]	8.50	136.00
	Ties	0[c]		
	Total	16		

a. Total_Post < Total_Pre
b. Total_Post > Total_Pre
c. Total_Post = Total_Pre

Figure 10. Ranks of Male Students' Abstraction Ability

Test Statistics[a]

	Total_Post - Total_Pre
Z	-3.545[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Figure 11. Test Statistics of Male Students' Abstract Thinking Ability

Likewise, for female students, the analysis results revealed a significant improvement in the abstraction abilities of female students after the implementation of deep learning teaching materials. It was proven that all data showed positive ranks (Figure 12) with a Z significance value less than 0,05; namely, 0,000 (Figure 13).

Ranks

		N	Mean Rank	Sum of Ranks
Total_Post - Total_Pre	Negative Ranks	0[a]	.00	.00
	Positive Ranks	16[b]	8.50	136.00
	Ties	0[c]		
	Total	16		

a. Total_Post < Total_Pre
b. Total_Post > Total_Pre
c. Total_Post = Total_Pre

Figure 12. Ranks of Female Students' Abstraction Abilities

Test Statistics[a]

	Total_Post - Total_Pre
Z	-3.535[b]
Asymp. Sig. (2-tailed)	.000

a. Wilcoxon Signed Ranks Test
b. Based on negative ranks.

Figure 13. Test Statistics of Female Students' Abstract Thinking Ability

Gender differences were examined from the perspective of findings and limitations. Abstraction ability scores of male students differed significantly from those of female students following implementation. It was proven that the Z significance value for the post-test data was less than 0,05, namely 0,007 (Figure 14). Meanwhile, the Z

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significance value for the pre-test data was greater than 0,05, namely 0,073. Although a statistically significant difference emerged between the post-test scores of male and female students (p = 0,007), several important limitations should be acknowledged in interpreting these findings.

Test Statistics[a]

	Total_Post	Total_Pre
Mann-Whitney U	58.000	80.000
Wilcoxon W	194.000	216.000
Z	-2.676	-1.865
Asymp. Sig. (2-tailed)	.007	.062
Exact Sig. [2*(1-tailed Sig.)]	.007[b]	.073[b]

a. Grouping Variable: JK

b. Not corrected for ties.

Figure 14. Test Statistics Comparison of Abstract Thinking Ability Between Male and Female

First, this study did not control for potential confounding variables that could influence the observed gender differences, such as prior math achievement levels that may differ between groups, varying levels of engagement with digital learning materials, sociocultural expectations regarding math performance that may influence student motivation and effort, and differences in spatial reasoning abilities that were not independently measured. Second, the sample size for the gender-based analysis was relatively small (16 male and 16 female students), which limited the generalizability of these findings. Third, the study design did not include qualitative data collection that could provide insight into the mechanisms underlying potential gender-based differences in learning outcomes.

Therefore, although the statistical analysis indicated a significant difference, the results of this study should be interpreted with caution. The observed differences may reflect a variety of unmeasured factors rather than inherent gender-based learning differences. Future research should use larger sample sizes, control for relevant covariates, and include qualitative investigations to better understand gender-related patterns in the development of abstraction skills. In other words, there was a significant difference in scores between male and female students after the implementation of culturally integrated deep learning teaching materials, although the initial scores of abstract thinking abilities for both genders were the same. In fact, male students had higher abstract thinking scores than female students, both before and after the implementation (**Figure 15**). The combined boxplot of pre-test and post-test abstraction ability scores by gender was shown in **Figure 16**.

Ranks

	JK	N	Mean Rank	Sum of Ranks
Total_Post	1	16	20.88	334.00
	2	16	12.13	194.00
	Total	32		
Total_Pre	1	16	19.50	312.00
	2	16	13.50	216.00
	Total	32		

Figure 15. Ranks Comparison of Abstract Thinking Ability between Male and Female Students

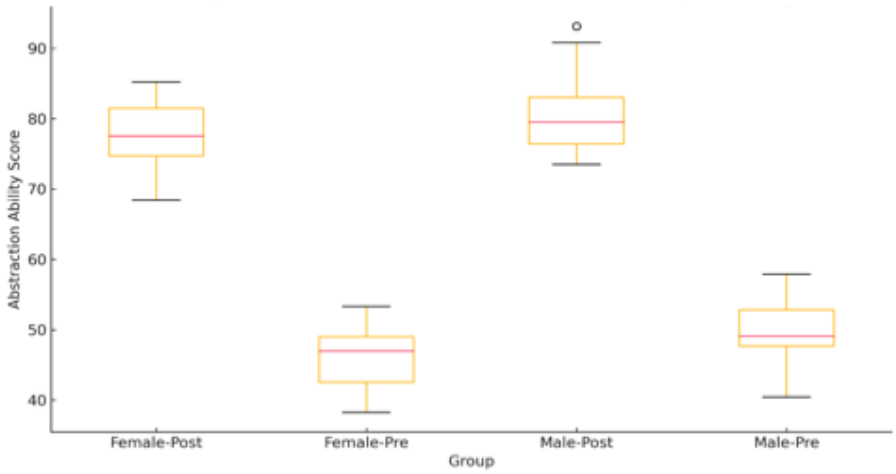

Figure 16. Combined Boxplot of Pre-test and Post-test Abstraction Ability Scores by Gender

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DISCUSSION

The study's results revealed that integrating *Batak* cultural elements into a digital learning module for learning the Pythagorean theorem improved students' mathematical abstraction skills. While these results align with those of Nur et al. (2020) and Kusaeri et al. (2019), who found the learning experiences relevant to the students' cultural context, a more critical analysis of these findings is needed. Like other research in this area, this study encountered challenges in separating the specific contributions of cultural content from other pedagogical factors. Several previous studies have reported positive results from integrating culture into mathematics learning (Deda et al., 2024; Padang & Lubis, 2023; Prahmana et al., 2021; Supriadi, 2019). However, other literature suggests that these positive results may be due to other pedagogical factors. For example, while Fouze and Amit (2018) found that cultural integration is beneficial in mathematics learning, other research also suggests that cultural relevance alone may not be sufficient to guarantee improved mathematical competence for students but rather requires alignment between the cultural context and other learning objectives and aspects (Kolovou, 2023; Shultz et al., 2022). The limitations of this study's experimental design, which lacked a control group, such as the use of a digital deep learning module that did not integrate cultural elements, are critical to this finding.

Furthermore, this integration was expected to support achieving national education goals through the realization of one of the dimensions of the graduate profile: global diversity. The existence of various forms of traditional objects was expected to habituate students to be able to abstract various contextual objects encountered in daily life (Kusuma et al., 2024). The formation of number sense was another goal expected through the integration of that culture (Linuhung et al., 2025).

Moreover, the integration of a deep learning framework appears to support a more engaging and meaningful learning experience. The results of this study are consistent with the findings of Fauskanger and Bjuland (2018). However, various studies reveal more nuances in the implementation of deep learning. For example, while Feriyanto and Anjariyah (2024) found that deep learning can increase student engagement and understanding, other studies reveal that such implementation faces several challenges, such as time constraints, teacher preparedness, and varying student receptivity to student-centered learning approaches (Haji et al., 2025; Matobobo & Risinamhodzi, 2022).

This research also tended to rely heavily on teacher facilitation and the use of prompting questions. While theoretically sound, these two factors may actually be contributing factors to the positive outcomes of cultural integration in this study. Noor et al. (2025) suggest that the quality of scaffolding is often more important than the integration of cultural content into learning. These findings raise a new question regarding whether a digital teaching module that does not integrate *Batak* culture but uses the same trigger questions and teacher facilitation scheme will also have a positive impact on students' mathematical abstraction abilities in learning the Pythagorean theorem.

Furthermore, some examples of meaningful learning in this deep learning teaching material include the integration of culture, the use of prompting questions to explore students' experiences, the identification of real-world problems, the development of communication and collaboration skills, and the reinforcement of meaning through reflection activities during learning. Some examples of enjoyable learning implementation in this teaching material include the use of learning media through storyline applications, as well as providing recognition and building student motivation through appreciation during the learning process. This is based on the theory that the use of learning media tends to make learning more enjoyable because it is more contextual (Arthur et al., 2022; Boozer & Simon, 2020; Isnawan et al., 2025; Romadiah et al., 2022). These activities are expected to facilitate the optimization of students' abstraction abilities. An example of conscious learning in this teaching material is student-centered learning by positioning the teacher as a facilitator during the learning process. The teacher does not provide direct answers while students solve problems but only presents prompting questions and scaffolding when students encounter obstacles in solving them (Sukarma et al., 2024). The approach is intended so that students become accustomed to abstraction when there is no teacher, as in everyday life contexts.

Regarding the implementation results, this research reveals that the implementation of culturally integrated deep learning-based digital teaching materials was implemented successfully. This is due to good planning before the implementation. The results of this study align with the research by Isnawan, Alsulami, and Sudirman (2024), which reveals that planned learning tends to proceed smoothly. This is because various possible student responses during the learning process have been well-considered by the teacher who prepares the teaching materials (Fitriati et al., 2023; Isnawan, Alsulami, Bonyah, et al., 2024). Even when discussing lesson study activities, the existence of a plan becomes the main step before conducting open class activities or implementing learning (Joubert et al., 2020; Nursyahidah et al., 2023; Xu & Meng, 2023).

From a more critical perspective, this successful implementation does not necessarily validate the effectiveness of the learning. It is possible that the results found in this study represent the Hawthorne effect, which assumes that students perform better in learning because they receive more attention during the lesson (Tamur et al., 2021).

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Furthermore, it could be that the integration of digital technology is actually the cause of the positive response, rather than the integration of cultural elements, as previously described. Future studies should replicate this design with control groups to isolate cultural and digital factors.

In the initial learning activities, students express that there are quite a few traditional houses or clothing, especially *Batak*, that involve triangular shapes. The results of this study align with Prahmana and D'Ambrosio (2020), who reveal that a significant number of geometric shapes are used in the motifs of traditional fabrics or houses. This indicates that the concept of geometry has become an inseparable part of the culture in Indonesia (Anwar et al., 2024). The results of this study also reveal that students are classified as being able to understand problems well. This is because the students are presented with a picture of the traditional house, allowing them to clearly see the shape of the roof of the house. Students can answer several questions given by the teacher. The results of this study align with Lee et al. (2017), who reveal that students will understand problems when presented with real images of an issue. This is because students are able to optimize their sense of sight during learning. In other words, students are already able to perform initial abstraction well when encountering relevant real objects (Hershkowitz et al., 2001; Ruamba et al., 2025).

These positive results raise critical questions about the generalizability of the findings. *Can a digital learning module based on deep learning and integrated with Batak culture optimize students' abstraction skills in other regions?* This question arises because, unlike *Batak* culture, not all local cultural contexts possess appropriate geometric patterns that are easily accessible for mathematics learning. This concern is grounded in studies that reveal that cultural artifacts with less explicit geometric features demonstrate more limited competency improvements. These results suggest that the instructional approach employed in this study may not be fully transferable to teaching the Pythagorean theorem in regions with diverse cultural backgrounds.

After answering several questions, the students then perform a geometric abstraction of the Bolon traditional house roof by drawing a triangle as a representation of the roof. The students are also seen dividing the triangle into two right triangles to make it easier to identify the traditional house roof. The students then calculate the height of the roof using the concept of the Pythagorean theorem. The results of this study align with T. P. Siregar (2024), who reveals that students tend to easily implement a mathematical concept when they are able to create geometric illustrations well. This is because students know the details of the elements of geometric shapes when they see the actual objects directly, making it easier to identify other elements that are not yet known (Hwang et al., 2020).

The implementation activities are concluded with a reflection activity to ensure that the learning objectives are achieved effectively. The results of this study align with Sukarma et al. (2024), who reveal that reflection activities are an important element during classroom learning implementation. This is because reflection activities can serve as an indicator to confirm whether the learning objectives have been achieved or not (Gunawan et al., 2025). In addition, these activities also play a role in identifying the strengths and weaknesses of the learning activities, which can be used as recommendations for improvement in the implementation of future learning activities (Aghakhani et al., 2023).

Considering the successful implementation results, the results of the research then align with the abstraction abilities possessed by the students after the implementation. Based on the research findings, it is found that the implementation of culturally integrated digital learning materials based on deep learning is capable of optimizing students' abstraction abilities. The results of this study align with Safrudin et al. (2021) , who reveal that enjoyable, meaningful, or conscious learning can optimize students' abstraction abilities. This is because students integrate various sources of information, student engagement and interest are better, and collaboration among students occurs during deep learning (Mende et al., 2024). Additionally, the use of digital technology also significantly aids practicality during learning (Rhodes et al., 2024; van Keulen, 2018) . The results of this study also align with Zuliana et al. (2025), who reveal that the integration of culture in mathematics learning can optimize students' abstraction abilities. This improvement is because students feel that the learning is more relevant or closer to everyday life, making it easier to abstract during culturally integrated learning (A. S. Abdullah, 2016; Fouze & Amit, 2018; Hayati et al., 2024; Mustika et al., 2022; Padang & Lubis, 2023; Shahbari & Daher, 2020; Turmuzi et al., 2023).

The results of this study also reveal that male students showed relatively higher abstraction scores than those of female students. These findings are consistent with Azizah et al. (2021) and Grewe (2025), who state that the abstraction ability of male students is relatively better than that of female students, especially in the conversion from visual to verbal or symbolic. There is no clear description regarding the reasons for this finding. If men are considered more dominant in traditional ceremonies, in fact, women and men have the same roles in *Batak* culture (Veronica & Aulia, 2024). Additionally, male students tend to have better spatial and logical abilities, allowing them to build abstractions more quickly (Silitonga et al., 2024). It is proven that the pre-test scores of male students' abstraction abilities are better than those of female students.

Although a considerable amount of previous research supports this study's findings, some studies have shown conflicting results. For example, Ganley and Lubienski (2016) reveal that while small gender differences exist in

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mathematics achievement, the relationships between mathematical performance, confidence, and interest are generally similar for boys and girls. Furthermore, prior to intervention implementation, male students in this study demonstrated better abstraction ability. However, it is important to note that gender effects tend to be quite complex to examine in mathematics learning.

These critical considerations suggest that the culturally integrated deep learning-based digital instructional module in this study may interact with other pedagogical aspects. Therefore, to better understand the relationship between gender and learning, a more comprehensive research design is needed to address this question. Future research requires a factorial design with various control groups, including conventional learning, digital instructional materials without cultural content, and cultural content without digital instructional materials

CONCLUSION

Based on the previous analysis, this research yielded several key findings. First, digital instructional materials based on deep learning and integrated with *Batak* culture demonstrated the capacity to optimize students' abstraction abilities. This was evidenced by the significance of the Z value obtained after implementation, which was less than 0,05 (specifically, p = 0,000). However, because this study employed a small sample, integrated a single cultural element, and lacked a control group, these findings are more appropriately considered preliminary evidence than definitive proof of effectiveness. Second, the digital instructional materials based on a deep learning framework and integrated with culture performed effectively because they were designed according to students' learning needs and were relevant to the cultural context of their daily lives. However, more comprehensive research is needed to determine whether cultural integration specifically contributes to students' abstraction abilities. Digital technology integration, deep learning implementation, or instructional quality could have influenced these findings. Third, male students' abstract thinking ability exceeded that of female students, although this finding contradicts several previous studies on gender effects in mathematical abstraction ability. This finding lacks clear explanation, particularly given that the *Batak* cultural context demonstrates gender equality in traditional rituals.

Based on these findings, mathematics teachers interested in integrating culture into their instruction are advised to systematically identify mathematical concepts embedded in local cultural artifacts, develop open-ended problems that maintain mathematical rigor while integrating cultural elements, and develop scaffolding to facilitate cognitive transitions from contextual cultural recognition to mathematical abstraction. Educational technology developers should design digital learning platforms that are easily customizable for diverse cultures and facilitate teacher reflection and content adaptation. Future research is recommended to use a larger, more representative sample size and a larger participant group, as well as a control group for comparison to strengthen the research findings. This analysis is intended to address the methodological limitations identified in this study. The small sample size (n = 32) and the absence of a control group are due to the naturally occurring nature of school classes, making it impossible to divide students into two groups and provide them with different treatment based on ethical considerations to ensure equal learning opportunities. Also, future research should include diverse cultures to be more relevant to students of different ethnicities and to be used in a broader context. Future research is also expected to examine in depth whether there are differences in learning styles between male and female students and their impact on student learning outcomes and thinking styles. Educational practitioners and policymakers are encouraged to validate and investigate student readiness before replicating this approach, especially in regions beyond the *Batak* context and for mathematical concepts other than the Pythagorean theorem.

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REFERENCES

Abdullah, A. S. (2016). Ethnomathematics in perspective Sundanese culture. *Journal on Mathematics Education*, *8*(1). https://doi.org/10.22342/jme.8.1.3877.1-15

© 2025 by Author/s

Aghakhani, S., Lewitzky, R. A., & Majeed, A. (2023). Developing reflective practice among teachers of mathematics. *International Electronic Journal of Mathematics Education*, *18*(4), em0755. https://doi.org/10.29333/iejme/13715

Alghadari, F., & Noor, N. A. (2020). Students depend on the pythagorean theorem: Analysis by the three parallel design of abstraction thinking problem. *Journal of Physics: Conference Series*, *1657*(1), 012005. https://doi.org/10.1088/1742-6596/1657/1/012005

Ali, C. A. (2021). A comparative study of SAM and ADDIE models in simulating STEM instruction. *African Educational Research Journal*, *9*(4), 852–859. https://doi.org/10.30918/AERJ.94.21.125

Anwar, L., Sa'dijah, C., Fauzan, A., Johar, R., Sugiman, & Cahyani, S. D. (2024). Exploring ethnomathematics in the traditional house of Suku Tengger: Bridging structures and classrooms. *Journal of Ecohumanism*, *3*(6), 1872–1882. https://doi.org/10.62754/joe.v3i6.4143

Arthur, Y. D., Dogbe, C. S. K., & Asiedu-Addo, S. K. (2022). Enhancing performance in mathematics through motivation, peer assisted learning, and teaching quality: The mediating role of student interest. *Eurasia Journal of Mathematics, Science and Technology Education*, *18*(2). https://doi.org/10.29333/EJMSTE/11509

Azizah, N., Budiyono, B., & Siswanto, S. (2021). Students' conceptual understanding in terms of gender differences. *Journal of Mathematics and Mathematics Education*, *11*(1), 41. https://doi.org/10.20961/jmme.v11i1.52746

Bariyah, N., Prabawanto, S., & Afgani Dahlan, J. (2024). Learning obstacles and students' difficulties in solving the problem of Pythagorean theorem: A systematic literature review. *Jurnal Pendidikan MIPA*, *25*(4), 1939–1960. https://doi.org/10.23960/jpmipa/v25i4.pp1939-1960

Boozer, B. B., & Simon, A. A. (2020). Teaching effectiveness and digital learning platforms: A focus on mediated outcomes. *Journal of Instructional Pedagogies*, *24*, 1–13. http://www.aabri.com/copyright.html

Cerovac, M., & Keane, T. (2025). Early insights into Piaget's cognitive development model through the lens of the Technologies curriculum. *International Journal of Technology and Design Education*, *35*(1), 61–81. https://doi.org/10.1007/s10798-024-09906-5

Chiotis, E. D. (2021). Pythagoras' mathematics in architecture and his influence on great cultural works. *Scientific Culture*, *7*(1), 57–77. https://doi.org/10.5281/zenodo.4107172

Clarke, B., Doabler, C. T., Smolkowski, K., Turtura, J., Kosty, D., Kurtz-Nelson, E., Fien, H., & Baker, S. K. (2019). Exploring the relationship between initial mathematics skill and a kindergarten mathematics intervention. *Exceptional Children*, *85*(2), 129–146. https://doi.org/10.1177/0014402918799503

Cueli, M., Areces, D., García, T., Rodríguez, C., Vallejo, G., & González-Castro, P. (2019). Influence of initial mathematical competencies on the effectiveness of a classroom-based intervention. *British Journal of Educational Psychology*, *89*(2), 288–306. https://doi.org/10.1111/bjep.12239

Deda, Y. N., Disnawati, H., Tamur, M., & Rosa, M. (2024). Global trend of ethnomathematics studies of the last decade: A bibliometric analysis. *Infinity Journal*, *13*(1), 233–250. https://doi.org/10.22460/infinity.v13i1.p233-250

Fachrudin, A. D., Ekawati, R., Kohar, A. W., Widadah, S., Kusumawati, I. B., & Setianingsih, R. (2020). Learning Pythagorean theorem from ancient China: A preliminary study. *Journal of Physics: Conference Series*, *1470*(1), 012018. https://doi.org/10.1088/1742-6596/1470/1/012018

Fauskanger, J., & Bjuland, R. (2018). Deep learning as constructed in mathematics teachers' written discourses. *International Electronic Journal of Mathematics Education*, *13*(3). https://doi.org/10.12973/iejme/2705

Feriyanto, F., & Anjariyah, D. (2024). Deep learning approach through meaningful, mindful, and joyful learning: A library research. *Electronic Journal of Education, Social Economics and Technology*, *5*(2), 208–212. https://doi.org/10.33122/ejeset.v5i2.321

Fitriati, F., Rosli, R., & Iksan, Z. H. (2023). Enhancing prospective mathematics teachers' lesson planning skills through lesson study within school university partnership program. *Journal on Mathematics Education*, *14*(1), 69–84. https://doi.org/10.22342/JME.V14I1.PP69-84

Fouze, A. Q., & Amit, M. (2018). On the importance of an ethnomathematical curriculum in mathematics education. *Eurasia Journal of Mathematics, Science and Technology Education*, *14*(2), 561–567. https://doi.org/10.12973/ejmste/76956

Ganley, C. M., & Lubienski, S. T. (2016). Mathematics confidence, interest, and performance: Examining gender patterns and reciprocal relations. *Learning and Individual Differences*, *47*, 182–193. https://doi.org/10.1016/j.lindif.2016.01.002

Grewe, F. (2025). The Need for Diffraction in STEM-Fields: An ethical feminist consideration of the concept of gender scripting. *Feminist Encounters: A Journal of Critical Studies in Culture and Politics*, *9*(2), 28. https://doi.org/10.20897/femenc/16786

 © 2025 by Author/s

Gunawan, R., Sridana, N., Hayati, L., & Subarinah, S. (2025). The ability of prospective mathematics teachers in preparing TPACK integrated student worksheet. *Jurnal Pendidikan Matematika*, *16*(1), 35–43. https://doi.org/10.36709/jpm.v16i1.270

Haji, R. M., Mohammed, R. A., & Husamalddin, A. H. (2025). Challenges and solutions in transitioning to student-centred learning: Insights from university lecturers in the Kurdistan Region of Iraq. *Journal of Further and Higher Education*, 1–16. https://doi.org/10.1080/0309877X.2025.2546914

Hershkowitz, R., Schwarz, B. B., & Dreyfus, T. (2001). Abstraction in context: Epistemic actions. *Journal for Research in Mathematics Education*, *32*(2), 195. https://doi.org/10.2307/749673

Hidayat, R., & Iksan, Z. H. (2018). Mathematical modelling competency for Indonesian students in mathematics education programmes. *Creative Education*, *09*(15), 2483–2490. https://doi.org/10.4236/ce.2018.915187

Holden, L. R., LaMar, M., & Bauer, M. (2021). Evidence for a cultural mindset: Combining process data, theory, and simulation. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.596246

Holmes, D. T. (2020). Statistical methods in laboratory medicine. In *Contemporary Practice in Clinical Chemistry* (pp. 15–35). Elsevier. https://doi.org/10.1016/B978-0-12-815499-1.00002-8

Hwang, W.-Y., Zhao, L., Shadiev, R., Lin, L.-K., Shih, T. K., & Chen, H.-R. (2020). Exploring the effects of ubiquitous geometry learning in real situations. *Educational Technology Research and Development*, *68*(3), 1121–1147. https://doi.org/10.1007/s11423-019-09730-y

Isnawan, M. G., Alsulami, N. M., & Sudirman, S. (2024). Optimizing prospective teachers' representational abilities through didactical design-based lesson study. *International Journal of Evaluation and Research in Education (IJERE)*, *13*(6), 4004. https://doi.org/10.11591/ijere.v13i6.29826

Isnawan, M. G., Alsulami, N. M., Bonyah, E., & Dejarlo, J. O. (2024). Learning number patterns in middle school: A lesson study activity based on didactical design research. *Edumatica: Jurnal Pendidikan Matematika*, *14*(1), 1–13. https://doi.org/10.22437/edumatica.v14i01.28645

Isnawan, M. G., Alsulami, N. M., Rasilah, R., Sukarma, I. K., & Lavicza, Z. (2025). Didactic design research through lesson study activities: STEM-based courses for representative abilities of prospective mathematics teachers. *European Journal of STEM Education*, *10*(1), 12. https://doi.org/10.20897/ejsteme/16758

Joubert, J., Callaghan, R., & Engelbrecht, J. (2020). Lesson study in a blended approach to support isolated teachers in teaching with technology. *ZDM-Mathematics Education*, *52*, 907–925. https://doi.org/10.1007/s11858-020-01161-x

Kapofu, L. K., & Kapofu, W. (2020). "This maths is better than that maths" – Exploring learner perceptions on the integration of history of mathematics in teaching the theorem of Pythagoras: A case study. *International Electronic Journal of Mathematics Education*, *15*(3), em0604. https://doi.org/10.29333/iejme/8446

Kolovou, M. (2023). Embracing culturally relevant education in mathematics and science: A literature review. *The Urban Review*, *55*(1), 133–172. https://doi.org/10.1007/s11256-022-00643-4

Kusaeri, A., Pardi, H. H., & Quddus, A. (2019). Culture and mathematics learning: Identifying students' mathematics connection. *Beta: Jurnal Tadris Matematika*, *12*(1), 82–93. https://doi.org/10.20414/betajtm.v12i1.264

Kusuma, A. B., Hanum, F., Abadi, A. M., & Ahmad, A. (2024). Exploration of ethnomathematics research in Indonesia 2010-2023. *Infinity Journal*, *13*(2), 393–412. https://doi.org/10.22460/infinity.v13i2.p393-412

Lee, Y.-Y., Chen, H.-R., & Chang, S.-C. (2017). Learning effects of iconic representation animation teaching on the mathematics problem solving process. *2017 10th International Conference on Ubi-Media Computing and Workshops (Ubi-Media)*, 1–4. https://doi.org/10.1109/UMEDIA.2017.8074132

Lian, J., Yu, X., Kang, Q., & Jia, S. (2023). A comparative study of secondary school mathematics teaching materials from the perspective of reasoning--taking "Pythagorean theorem" as an example. *Asian Journal of Education and Social Studies*, *49*(4), 190–198. https://doi.org/10.9734/ajess/2023/v49i41198

Linuhung, N., Sudarman, S. W., & Agustina, R. (2025). Development of ethnomathematics-based numeracy literacy questions in peci tapis lampung. *JTAM: Jurnal Teori dan Aplikasi Matematika*, *9*(2), 629–642. https://doi.org/10.31764/jtam.v9i2.30095

Löhr, G. (2022). What are abstract concepts? On lexical ambiguity and concreteness ratings. *Review of Philosophy and Psychology*, *13*(3), 549–566. https://doi.org/10.1007/s13164-021-00542-9

Maspiroh, I., Prasetyo, Z. K., Hermanto, H., Rohmatillah, N., & Kuswidyanarko, A. (2025). Improving digital literacy of elementary teacher candidates through digital-based RADEC learning model. *European Journal of STEM Education*, *10*(1), 07. https://doi.org/10.20897/ejsteme/16530

Matobobo, C., & Risinamhodzi, D. T. (2022). IT skills and language challenges hindering student-centred learning: A case of a rural Eastern Cape University in South Africa. *2022 IEEE Global Engineering Education Conference (EDUCON)*, 1221–1227. https://doi.org/10.1109/EDUCON52537.2022.9766383

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Mende, S., Proske, A., & Narciss, S. (2024). Generative preparation tasks in digital collaborative learning: actor and partner effects of constructive preparation activities on deep comprehension. *Frontiers in Psychology*, *15*. https://doi.org/10.3389/fpsyg.2024.1335682

Moon, C. Y., Larke, P., & James, M. (2022). Examining Mathematics Achievement: An Analysis of Fourth and Eighth Grade TIMSS U.S. Data by Ethnicity, Gender, and Sociocultural Variables. *Journal of Ethnic and Cultural Studies*, *9*(1), 226–243. https://doi.org/10.29333/ejecs/942

Moore, K. C., Wood, E., Welji, S., Hamilton, M., Waswa, A., Ellis, A. B., & Tasova, H. I. (2024). Using abstraction to analyze instructional tasks and their implementation. *The Journal of Mathematical Behavior*, *74*, 101153. https://doi.org/10.1016/j.jmathb.2024.101153

Moutsios-Rentzos, A., Spyrou, P., & Peteinara, A. (2014). The objectification of the right-angled triangle in the teaching of the Pythagorean Theorem: an empirical investigation. *Educational Studies in Mathematics*, *85*(1), 29–51. https://doi.org/10.1007/s10649-013-9498-y

Noor, N. A. M., Mahamod, Z., & Nasri, N. M. (2025). Enhancing Malay essay writing through scaffolding: A pedagogical approach. *Journal of Education and Learning (EduLearn)*, *19*(4), 2212–2219. https://doi.org/10.11591/edulearn.v19i4.22820

Nur, A. S., Waluya, S. B., Rochmad, R., & Wardono, W. (2020). Contextual learning with Ethnomathematics in enhancing the problem solving based on thinking levels. *JRAMathEdu (Journal of Research and Advances in Mathematics Education)*, 331–344. https://doi.org/10.23917/jramathedu.v5i3.11679

Nurhadi, M., & Darhim. (2021). Analysis the ability of thinking abstractly of mathematics and self-efficacy through TPACK. *Journal of Physics: Conference Series*, *1764*(1). https://doi.org/10.1088/1742-6596/1764/1/012122

Nursyahidah, F., Albab, I. U., & Mulyaningrum, E. R. (2023). Learning design of quadrilateral STEM-based through lesson study. *Eurasia Journal of Mathematics, Science and Technology Education*, *19*(11). https://doi.org/10.29333/ejmste/13747

Olalowo, I. E. (2020). Accounts and thoughts of overage children: A qualitative study on the physical and emotional environment of preschools in ibadan, nigeria. *American Journal of Qualitative Research, 4*(3), 1-13.https://doi.org/10.29333/ajqr/8390

Omoniyi, T. O. (2025). Redefining electoral literacy: An appraisal of content adequacy, audience alignment, and reform prospects in INEC's voter education programmes (VEP). *Asia Pacific Journal of Education and Society, 13*(2), 1. https://doi.org/10.20897/apjes/17299

Özer, Z., & Demirbatır, R. E. (2023). Examination of STEAM-based digital learning applications in music education. *European Journal of STEM Education*, *8*(1), 02. https://doi.org/10.20897/ejsteme/12959

Padang, D. S., & Lubis, M. S. (2023). Ethnomathematical exploration of traditional agricultural tools in hutamanik village, Sumbul regency. *Indonesian Journal of Science and Mathematics Education*, *6*(2), 137–151. https://doi.org/10.24042/ijsme.v6i2.17003

Prahmana, R. C. I., & D'Ambrosio, U. (2020). Learning geometry and values from patterns: Ethnomathematics on the batik patterns of yogyakarta, indonesia. *Journal on Mathematics Education*, *11*(3), 439–456. https://doi.org/10.22342/jme.11.3.12949.439-456

Prahmana, R. C. I., Yunianto, W., Rosa, M., & Orey, D. C. (2021). Ethnomathematics: Pranatamangsa system and the birth-death ceremonial in yogyakarta. *Journal on Mathematics Education*, *12*(1), 93–112. https://doi.org/10.22342/jme.12.1.11745.93-112

Rhodes, M. J., Visscher, A. J., van Keulen, H., & Gijsel, M. A. R. (2024). A review of the effects of integrated language, science and technology interventions in elementary education on student achievement. *European Journal of STEM Education*, *9*(1), 1–23. https://doi.org/10.20897/ejsteme/14570

Romadiah, H., Dayurni, P., & Fajari, L. E. W. (2022). Meta-analysis study: The effect of android-based learning media on student learning outcomes. *International Journal of Asian Education*, *3*(4), 253–263. https://doi.org/10.46966/ijae.v3i4.300

Ruamba, M. Y., Sukestiyarno, Y. L., Rochmad, R., & Asih, T. S. N. (2025). The impact of visual and multimodal representations in mathematics on cognitive load and problem-solving skills. *International Journal of Advanced and Applied Sciences*, *12*(4), 164–172. https://doi.org/10.21833/ijaas.2025.04.018

Safrudin, F. M., Budiyanto, C. W., & Yuana, R. A. (2021). The influence of educational robotics to abstraction skill in high school. *Journal of Physics: Conference Series*, *1808*(1), 012018. https://doi.org/10.1088/1742-6596/1808/1/012018

Shadiev, R., Chen, X., Reynolds, B. L., Song, Y., & Altinay, F. (2024). Facilitating cognitive development and addressing stereotypes with a cross-cultural learning activity supported by interactive 360-degree video technology. *British Journal of Educational Technology*, *55*(6), 2668–2696. https://doi.org/10.1111/bjet.13461

Shahbari, J. A., & Daher, W. (2020). Learning congruent triangles through ethnomathematics: The case of students with difficulties in mathematics. *Applied Sciences (Switzerland)*, *10*(14), 1. https://doi.org/10.3390/app10144950

 © 2025 by Author/s

Shakeel, S. I., Al Mamun, M. A., & Haolader, M. F. A. (2023). Instructional design with ADDIE and rapid prototyping for blended learning: Validation and its acceptance in the context of TVET Bangladesh. *Education and Information Technologies*, *28*(6), 7601–7630. https://doi.org/10.1007/s10639-022-11471-0

Shultz, M., Nissen, J., Close, E., & Van Dusen, B. (2022). The role of epistemological beliefs in STEM faculty's decisions to use culturally relevant pedagogy at Hispanic-Serving Institutions. *International Journal of STEM Education*, *9*(1), 32. https://doi.org/10.1186/s40594-022-00349-9

Silitonga, R. H. Y., Ratumanan, T. G., & Telaumbanua, E. (2024). Gender difference in mathematical spatial ability and factors that may affect it. *MaPan*, *12*(1), 87–99. https://doi.org/10.24252/mapan.2024v12n1a6

Siregar, T. P. (2024). The effect of project-based learning method on understanding geometry concepts in secondary school students. *Attractive: Innovative Education Journal*, *6*(3), 302–310. https://doi.org/10.51278/aj.v6i3.1545

Sol, T., Ledezma, C., Sánchez, A., & Font, V. (2025). Teachers' practical argumentation on the teaching of the Pythagorean theorem. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-025-10591-6

Spatioti, A. G., Kazanidis, I., & Pange, J. (2022). A comparative study of the ADDIE instructional design model in distance education. *Information*, *13*(9), 402. https://doi.org/10.3390/info13090402

Sridana, N., Soeprianto, H., & Amrullah, A. (2025). Analysis of TPACK incorporated learning devices: An exploratory descriptive study of mathematics teachers. *European Journal of STEM Education*, *10*(1), 09. https://doi.org/10.20897/ejsteme/16757

Suanto, E., Rianti, E., Armis, A., & Zulnaidi, H. (2024). Development of Pythagorean theorem content worksheets based on creative problem solving to facilitate mathematical reasoning skills. *Kreano, Jurnal Matematika Kreatif-Inovatif*, *15*(2), 463–480. https://doi.org/10.15294/0hvj4181

Sukarma, I. K., Isnawan, M. G., & Alsulami, N. M. (2024). Research on nonroutine problems: A hybrid didactical design for overcoming student learning obstacles. *Human Behavior and Emerging Technologies*, *2024*(Article ID 5552365), 1–12. https://doi.org/10.1155/2024/5552365

Supriadi, S. (2019). Didactic design of sundanese ethnomathematics learning for primary school students. *International Journal of Learning, Teaching and Educational Research*, *18*(11), 154–175. https://doi.org/10.26803/ijlter.18.11.9

Tamur, M., Kusumah, Y. S., Juandi, D., Wijaya, T. T., Nurjaman, A., & Samura, A. O. (2021). Hawthorne effect and mathematical software based learning: A meta-analysis study. *Journal of Physics: Conference Series*, *1806*(1), 012072. https://doi.org/10.1088/1742-6596/1806/1/012072

Thakkar, B. (2025). Continuous variable analyses: Student's t-test, mann–whitney u test, wilcoxon signed-rank test. In *Translational Cardiology* (pp. 165–167). Elsevier. https://doi.org/10.1016/B978-0-323-91790-2.00052-6

van Keulen, H. (2018). STEM in early childhood education. *European Journal of STEM Education*, *3*(3), 1–3. https://doi.org/10.20897/ejsteme/3866

Veronica, S., & Aulia, A. N. (2024). Exploration of the use of Tongkonan space based on the Toraja community's perspective on gender [Eksplorasi pemanfaatan ruang tongkonan berdasarkan perspektif masyarakat Toraja terhadap gender]. *JAUR: Journal of Architecture and Urbanism Research*, *7*(2), 188–195. https://doi.org/10.31289/jaur.v7i2.11617

Wittmann, E. C. (2021). Designing teaching: The pythagorean theorem. In *Connecting Mathematics and Mathematics Education* (pp. 95–160). Springer International Publishing. https://doi.org/10.1007/978-3-030-61570-3_7

Xu, W., & Meng, Q. (2023). The development of mathematical model consciousness in junior secondary students: A lesson study of the instruction of congruent triangles. *Science Insights Education Frontiers*, *14*(1), 1991–2012. https://doi.org/10.15354/sief.23.or088

Zuliana, E., Dwiningrum, S. I. A., Wijaya, A., & Hukom, J. (2025). The effect of culture-based mathematics learning instruction on mathematical skills: A meta-analytic study. *Journal of Education and Learning (EduLearn)*, *19*(1), 191–201. https://doi.org/10.11591/edulearn.v19i1.21172

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