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[Sieng Veasna]

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A Comparative Analysis of the Intended Mathematics Curriculum of Cambodia and Singapore: Focus on Geometry

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ABSTRACT

Cambodian students' achievement is low in geometry problem-solving ability. This study aims to compare the intended mathematics curriculum of Cambodia and Singapore, with a specific focus on geometry. Four recently revised Cambodian mathematics syllabi, published in 2018 and two Singaporean mathematics syllabi, published in 2020, have been collected and analyzed following the General Topic Trace Mapping procedure. This analysis reveals significant differences between Cambodian and Singaporean mathematics curricula in design, structure and coherence, followed by domain, sub-domain, contents, sub-contents and learning outcomes within and across the grade. It also highlighted that the Cambodian mathematics curriculum on geometry lacks coherence in content, sub-content, and learning outcomes, potentially lowering student achievement. Enhancing curriculum coherence could significantly improve student learning outcomes in Cambodia.

1. Introduction

The curriculum forms the basis for an effective education system that ensures quality learning for all learners and prepares operational goals and local citizens (UNESCO, 2016). It was determined as a package of knowledge, skills, and attitude. The curriculum was comprised of three forms: the intended curriculum, the implemented curriculum and the attended curriculum (Kyi & Isozaki, 2023; Schmidt et al., 2001). The intended curriculum consisted of the syllabus and involved textbooks because many teachers trust them as essential resources in classroom teaching, usually in groups with supplementary material such as teachers' guides, lesson planning, workbooks and worksheets (McDonald &

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Abd-El-Khalick, 2017; Valverde, 2002).

Since the curriculum is crucial, many countries are reviewing their national curriculum and asking: "Is the curriculum relevant and responsive to the needs of today's market ?" (MoEYS, 2016). Thus, to meet the world market's needs, many developing countries have revised their curriculum and tried to adapt to the developed countries to strengthen the quality of their education system.

However, Cambodia has no objection to looking back and investigating its curriculum to meet the global context by revising the curriculum, respectively. Cambodia became independent from French colonial rule in 1953, and the current general education practice only started after the end of the civil war of 1975-1979 (Khmer Rouge). The Cambodian general education system was divided into three levels: primary (Grade 1 to Grade 6), lower (Grade 7 to Grade 9), and upper secondary (Grade 10 to Grade 12).

The Ministry of Education, Youth, and Sports (MoEYS) of Cambodia has revised the curriculum for general and technical education (CGTE) five times. First, from 1980 to 1987, it was shaped by the immediate needs of a nation emerging from conflict, mainly focusing on political education, basic literacy, and practical skills for national reconstruction (Dy, 2004).

Second, from 1987-1996, it was characterised by a balance between the need to rebuild and modernise the education system while maintaining a strong emphasis on national identity, culture, preservation, and practical skills development. Third, from 1996 to 2005, the curriculum marked a transition from an education system focused on recovery and ideological indoctrination to one that increasingly embraced modernisation, globalisation, and the holistic development of students (Chealy et al., 2014; Chhinh & Dy, 2009).

Fourth, from 2005 to 2015, MoEYS developed a curriculum policy to develop a CGTE, a core curriculum for basic education (from grades 1 to grade 9), and a basic curriculum for upper secondary education (from grades 10 to grade 12). This period was marked by a transitional phase where Cambodia aimed to align its education system with international standards while addressing local needs and challenges.

Last, from 2015 until today, the Cambodian curriculum emphasises competency-based education, focusing on science, technology, engineering and mathematics (STEM), information communication and technology (ICT) integration, and global citizenship. It promotes inclusivity, environmental sustainability, and life skills while strengthening vocational training and modern assessment methods (MoEYS, 2016, 2019).

Even though the Cambodian curriculum for general education has been revised many times in general education, students' learning achievement remains low (Bhatta et al., 2022; MoEYS, 2023). Various scholars addressed that designing a curriculum as coherent can help to improve student learning achievement (Cuoco & McCallum, 2018b; Schmidt et al., 2005; Wang & Kao, 2022) and necessitate innovative approaches to teaching and learning. On the other hand, an inappropriate curriculum can significantly hinder student learning and achievement, leading to long-term consequences for both individuals and the education system as a whole (Reeves & McAuliffe, 2012; Schmidt et al., 2005).

However, according to the National Learning Assessment (NLA) of November 2021, students' achievement in mathematics remained low compared to the NLA of 2016, where the overall score was only 38%. The lowest average

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achievement was in the Geometry domain, among the others (Algebra, statistics, Measurement, and Numbers), with only 35% of sixth graders and 46% of eighth-grade students completing the assessment test correctly. Similarly, the 12th grader national examination report in the academic year 2020–2021 showed that only 47.93% of students could solve Geometry problems correctly, particularly vector contents, which Geometry covered (Bhatta et al., 2022; MoEYS, 2022, 2023). All these indicators reveal insufficient student achievement.

Factors which influence students' low achievement have been identified as educational policy, curriculum, and school-related, personal, and social factors (Wang & Kao, 2022; Wang & McDougall, 2018). Among these, the curriculum is one of the most influential factors because it is the starting point for teaching and learning activities. Thus, the curriculum should be met and aligned with broader educational goals, objectives, contents, sub-contents, and learning outcomes. In other words, curriculum coherence is the most dominant predictive for student achievement because it refers to the connection and logical progression of contents, skills and learning outcomes within a curriculum framework, syllabus, textbook, and assessment (Cuoco & McCallum, 2018b; Schmidt et al., 2002). For instance, the Singapore mathematics curriculum is designed to provide a clear and coherent framework that aligns with students' developmental needs. It emphasises critical mathematics processes such as reasoning, communication, and modelling, which are essential for teaching students to understand and apply mathematics in a real-world context. Its structured approach, focus on competencies, adaptability to diverse learning needs, integration of technology, real-world relevance, and emphasis on assessment collectively enhance the learning process and improve student achievement (MOE, 2020, 2021).

There are two main types of curriculum coherences: internal coherence and external coherence, which scholars defined. Through a curriculum with internal coherence, students are more likely to experience a logically connected progression of learning experiences, which can contribute to a deeper understanding and mastery of the content (Wang & McDougall, 2018), while the external coherences which can be aligned with social needs and expectation because social needs and expectation does not belong to the education itself. So, both internal and external coherences form the overall coherence of the curriculum. This paper will focus only on internal curriculum coherence because it is assumed to be more directly concerned with student learning achievement. The types of curriculum coherence and their description is shown in Table 1.

Table 1. Type of Curriculum Coherence

Type	Aspects	Descriptions
Internal coherence	Structural	grades or grade bands, content domains, cognitive domains
	Content relation	different contents within a certain topic
	Pedagogical	objectives, instructional processes, learning outcomes, and assessment
External coherence		Relation with social needs and expectation

Sources: (Veasna & Baba, 2024)

Table 1 shows that internal coherence consists of three interrelated aspects:

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structural, content relation, and pedagogical. These relations mean that an effective curriculum design considers the interplay between these three aspects to create a consistent and profound learning experience for students. Among the three, the content relation aspect will be the focus of this paper because it can most effectively direct student learning achievement by ensuring that the curriculum is organised coherently and meaningfully (Confrey et al., 2017; Watson & Ohtani, 2015). By establishing meaningful connections between concepts, educators can help students see the relevance and significance of what they are learning, leading to deeper understanding and retention of the material.

For this purpose, there is a need to confirm the curriculum coherence of Cambodia's curriculum. Along these, according to Trends in International Mathematics and Science Study (TIMSS), the Singapore mathematics curriculum is highly appreciated for several reasons by different scholars and has resulted in Singapore students consistently ranking at the top in international mathematics assessments such as TIMSS and Programme for International Student Assessment (PISA) (Kadijevich et al., 2023; MoEYS, 2024). And the Singaporean curriculum is often noted for its coherence (Grey, 2020; Hairon, 2021). Therefore, in this study, the Singaporean curriculum was selected for comparison with the Cambodian curriculum to examine the differences between them, particularly in terms of curriculum coherence, with a focus on content relationships and structure.

In order to analyse the curriculum from the perspective of coherence, in this paper, curriculum coherence is defined as the relation between corresponding design, structure, and coherence, followed by domains, sub-domains, contents, sub-contents, and learning outcomes within and across grades, and they are all arranged in order as a whole. Therefore, this study intends to do a comparative analysis of the curriculum coherences of Cambodia and Singapore, particularly focusing on Geometry. Two main questions have been raised:

1. What are the key differences and similarities between the Cambodian and Singaporean mathematics curricula in terms of curriculum coherence?
2. To what extent do the geometry curricula in Cambodia and Singapore exhibit coherence in terms of their relation to design, structure, and coherence?

2. Method

2.1. Data Source

This study used four recently revised Cambodian mathematics syllabi (MoEYS, 2018a, 2018b, 2018c, 2018d) and two Singaporean mathematics syllabi (MOE, 2020, 2021) for analysis. These were the latest versions available during the research period of study, and together, they cover primary and secondary education. The Cambodian mathematics curriculum (CMC) was divided into primary education (Grades 1 to Grades 6), lower secondary education (Grades 7 to Grades 9), and upper secondary education (Grades 10 to Grades 12) in general education. The last syllabi for grades 10 to grades 12 are separated into two files: the science track and the social science track. The Singaporean syllabus for primary one to six, which is the implementation starting with the year 2021, primary one cohort, and the mathematics syllabus for secondary one to four

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express course for normal (academic) course published in 2023 was used for this analysis. All syllabi contain goals, objectives, domains, contents, sub-contents, and learning outcomes.

2.2. Data Analysis Method

For the Cambodian mathematics syllabus, all the syllabi were translated from Khmer into English. Contents and sub-contents were translated exactly the same as the original, and the contents and sub-contents within geometry were allocated according to domains and sub-domains. The geometry domains were divided into five sub-domains: plane geometry, solid geometry, relations and transformations, constructions, and vectors. The contents and sub-contents were identified by analysing the syllabi for grades 1–12. Similarly, the learning outcomes were translated and summarised under knowledge, skills, and attitudes. The translation aims to facilitate consultations with mathematics experts regarding consistency and ensure the syllabus analysis's validity and reliability. The original English version of the Singaporean mathematics syllabi was used.

The data were then inputted into an Excel sheet. The domains, sub-domains, contents, sub-contents, and learning outcomes were arranged from grades 1 to 12 and examined within the same grade and across grades to determine whether the domains, subdomains, contents, sub-contents, and learning outcomes were related and corresponded to each other. Similarly, the Singaporean curriculum was examined in the same way.

In this study, the domains, sub-domains, contents, sub-contents and learning outcomes were analysed using General Topics Trace Mapping (GTTM), which was developed for content analysis in the Trends in International Mathematics and Science Study (TIMSS) (Schmidt et al., 2005). It provides a way to compare and analyse curricula across countries, identify the content intended for teaching at each grade level, and examine the relationship between content, sub-contents, and learning outcomes. Based on this GTTM, the following procedures are set:

We first collected both countries' syllabi to identify the overview of the constructed curriculum structure. In this step, the big idea, content, and expected learning outcomes were investigated.

Second, we collected all the geometry contents from both countries' syllabi and arranged each of them into appropriate sub-domains per grade. In this step, the sub-domains and contents are extracted from the syllabi and the grade levels when the contents with the sub-domains are to be addressed to confirm whether they are repeated or sequenced for all sub-contents.

Third, it compares the contents, sub-contents, and learning outcomes across domains, subdomains, and grades. In this step, we compare the sequencing of those contents, sub-contents, and learning outcomes that are clearly related. Then, show the result of the curriculum response to the perspective of curriculum coherence, which has been indicated as the relation between corresponding domains, subdomains, contents, sub-contents, and learning outcomes within and across grades, and they are all arranged in order as a whole.

Finally, it shows the difference between the Cambodian and Singaporean mathematics curricula. This step identified the conclusion of the result of the curriculum comparison and provided better improvement for developing

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curriculum coherence.

3. Results and Discussion

3.1. Result

Based on the comparative analysis through the mathematics curriculum of both countries by the following steps described above, we have obtained the following results:

3.1.1. The comparison of the overview of the constructed curriculum structure

There are different perspectives on developing the curriculum framework for both countries, such as the Cambodian mathematic curriculum (CMC) framework aimed to improve the quality of education by upgrading students, followed by the knowledge, skills, and attitudes necessary to thrive in daily life and further studies. The framework seeks to ensure students develop their full potential, enabling them to contribute to national development and integrate into the global community. It includes fostering competencies in areas such as literacy, numeracy, critical thinking, and the ability to apply knowledge in practical contexts, all in alignment with Cambodia's goal of becoming a middle-income country by the year 2030 and a high-income country by the year 2050. Unlike the standards and the Singaporean Mathematics Curriculum Framework (SMCF), both aim to improve mathematics education in different socio-cultural contexts, emphasising content and learning processes in various subjects with a focus on student learning experiences.

Additionally, the Cambodian curriculum exhibits challenges of incoherence due to misalignment across educational levels, limited integration of subjects, and lack of coherent skill progression. In contrast, the core competencies outlined in the Singapore mathematics curriculum are designed to equip students with essential skills for the 21st century, including mathematical concepts, skills, processes, metacognition, and attitudes. These interrelated competencies support students in applying mathematics knowledge and skills for future changes in various fields. There are different perspectives on developing curriculum frameworks between Cambodian and Singaporean curricula. The summary of the differences in the curriculum framework of both countries is shown in Table 2.

Table 2. The Summary of Overview of the Constructed Curriculum Structure

No.	Cambodia	Singapore
1.	Focus on developing student's awareness of how mathematics is used in their own and other communities.	Emphasises a conceptual and ideological approach.
2.	Stress analysing a mathematical concept, such as logical reasoning.	In-depth conceptual understanding, skills, proficiency, and mathematical procedure and emphasis on attitudes and metacognition.
3.	Emphasis on applying the learning outcomes with a focus on knowledge, skills, and attitude.	Build a strong foundation in mathematical concepts based on student learning experiences, mainly focusing on problem-solving skills.

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Table 2 highlighted that both Cambodia and Singapore value a comprehensive approach to mathematics education. Although their methods and emphases differ, with Cambodia focusing more on practical application and awareness and Singapore on deep conceptual understanding and problem-solving.

3.1.2. The comparison of sub-domains and contents

The arrangement of sub-domains and contents extracted from syllabi and grade level are to be addressed and indicated with the symbol ■. In this case, the sub-domain is plane geometry. An example of a comparison of sub-domains and contents is shown in Table 3.

Table 3. Example of a Comparison of Sub-Domain and Contents

Cambodia

Plane Geometry	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Point, line, and curve	■											
Pattern	■											
Two-dimensional geometry shape		■					■					
Rectangle and the triangle			■									
Area and perimeter			■	■		■						
Angle				■	■		■					
Square and rectangle				■								
Construction geometry					■							
Area of a triangle					■							
Foundation of geometric shape							■					
Perimeter and the area of polygon							■					
Rectangle								■				
Polygon								■				
Area of rectangular								■				
Circle						■						
Perimeter and area of circles							■					
Circle and position between a circle and a line								■				
Lines and a special segment meet inner the triangle								■				
Circles and lines									■			
Properties of the angle of the circle and regular polygons									■			
The thales theorem									■			

Singapore

Plane Geometry	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2D Shapes	■	■										
Perpendicular and parallel-lines			■									
Area and perimeter			■	■	■							
Angles			■	■	■							
Rectangle and square				■								
Area of triangle					■							
Triangle					■							
Parallelogram, rhobus, and trapesium					■							
Area and circumference of circle						■						
Angles, triangles, and polygons							■	■				
Pythagoras' theorem and trigonometry								■				
Mensuration								■				

Note: Bold font indicates a sub-domain; others are contents; ■ the content within the sub-domain content is to be addressed.

Table 3 illustrates the comparative analysis of the Cambodian and Singaporean mathematics curricula on plane geometry domains. Cambodian curriculum, comprehensive analysis shows that the relation of some sub-

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domains and contents are not continuously dealt with or are repeated by simply adding superficial complexities to the contents without much difference in geometrical ideas from lower to upper grade. An example of non-continuous treatment is the 'Two-dimensional geometry shape' content. It was addressed in grade 2 and again in grade 7, meaning it is not continuously treated from grade to grade. Similarly, 'Area and parameter' and 'Angle' are also not continuously treated from grade to grade.

However, the Singaporean curriculum was designed and addressed coherently and continuously from grade to grade. For example, the contents of 'Area and parameter ' and 'Angle' are repeated with the same contents. In contrast, the whole curriculum has less content than the Cambodian curriculum and each content is followed by student learning experiences. The curriculum shows a structured progression of geometric concepts, beginning with basic shapes in early grades and gradually introducing more complex topics as students advance. There is a clear emphasis on foundational concepts like 2D shapes, area, and perimeter in the early grades, which serves as the basis for more complex topics like trigonometry and mensuration in later grades. The curriculum appears to be designed to build upon students' knowledge incrementally, ensuring that by the time they reach higher grades, they have a solid understanding of the basics, enabling them to tackle more challenging topics.

3.1.3. The comparison of contents, sub-contents, and learning outcomes between both mathematics curriculum

The results of the analysis of both curricula highlighted that different structures are addressed in each country's curriculum. The example of the differences between them is shown in Table 4.

Table 4. The Example of the Mathematics Curriculum of Both Countries for Grade 1

Cambodia			Singapore		
Contents	**Sub-contents**	**Learning Outcome**	**Contents**	**Sub-contents**	**Learning experiences: The students should have opportunities to:**
Point, Line, and curve	- Point and line - Curve and neckless (not straight line)	- set a point, draw a line, curve and neckless, connection the point to create a line and another shape.	2D Shapes	1.1) identifying, naming, describing and clasifying 2D shapes • rectangle • square • circle • triangle 1.2) making/completing patterns with 2D shapes according to one or two of the following attributes • size • shape • colour • orientation	a) recognise, name and describe the 4 basic 2D shapes (rectangle, square, circle and triangle) from real objects and pictures (drawings and photographs). b) trace the outline of 2D shapes from 3D objects. c) identify and describe 2D shapes in different sizes and orientations. d) form a 2D shape from cut-out pieces of the shape. e) guess a 2D shape from a description of the shape f) recognise and describe the differences/similarities betwewen two 2D shapes according to attributes such as sides, corners, sizes and colours. g) work in groups to sort 2D shapes in different ways and explain how the shapes are sorted. h) use 2D shapes or applets to create patterens according to one or two attributes (size, shapre, colour and orientation) and describe the pattterns, i) work in groups to create a pattern and invite other
Geometry shape	- set a point, draw a line, curve and neckless, connection the point to create a line and another shape.	- draw a two-dimensional geometry shape that has 4 sides by using a line and draw a circle by using a thing as a circle - compare and describe the size of things that they used to know as two-dimensional (eg. a Whiteboard is a rectangle) - compare and describe the size of things that they used to know as two-dimensional (eg. a box of chalk, Cubes...) - Draw shape and geometry at a point or sample that has given - fill the pattern by size, and color, and create samples by size, and color...			
Patterns	- Patterns by shape - Patterns by size - Patterns by color	- fill the pattern by shape, size, and color - create a sample by shape, size, color			

Table 4 indicates that there is more geometry content in the first grade of the Cambodian mathematics curriculum. Students need in-depth thinking skills to understand this content. The sub-contents depend heavily on each main content. However, the sub-contents and learning outcomes do not correspond to each

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other, as it is unclear which learning outcomes align with specific sub-contents and contents. For example, the content of 'Point, line, and curve' consists of three knowledge and skill areas, but the sub-content is addressed in only one paragraph, combining all three. This can confuse teachers when preparing teaching materials, and textbook writers may face difficulty distinguishing between them.

In contrast, at the same grade level, the Singaporean mathematics curriculum (SMC) consists of less content. For instance, the sub-contents listed cover the knowledge of 2D shapes. The learning outcomes are structured as steps in the learning trajectory, progressing from one step to the next. This approach can help teachers develop teaching materials more easily and guides textbook writers in following each step. Therefore, the analysis can determine that the CMC is still not fully coherent compared to SMC.

However, to better meet students' needs through this comparative analysis, the curriculum should enhance its existing spiral approach by strengthening the connections between different contents, sub-contents, and learning outcomes. This will help show geometry as connected and coherent. It's essential to clearly define objectives, contents, sub-contents, and learning outcomes and to investigate their interrelations thoroughly.

Additionally, for the curriculum to be effective, it must provide comprehensive coverage of essential skills and knowledge, ensuring that the selected content is age-appropriate. It should also improve clarity regarding learning outcomes, specifying the concepts, conventions, techniques, results, and geometry processes intended for each content. Therefore, coherence is crucial; the curriculum should ensure that design, structure, and coherence, followed by the relation to domain, sub-domains, contents, sub-contents, and learning outcomes, are maintained within and across years.

3.2. Discussion

This comparative analysis between the Cambodian and Singaporean mathematics curricula, focusing on geometry, reveals critical differences in curriculum design, structure, and coherence. These should provide consistency in the intended direction of the curriculum by clarifying, developing and summing up the most important goals and missions of the teachers and school. This finding supports the suggestion that clear educational goals are essential for building coherence in the educational system (Fullan & Quinn, 2015; Newmann et al., 2001). These differences significantly impact the effectiveness of each system in promoting student learning outcomes, especially in geometry.

The result illustrated that the Cambodian curriculum emphasises practical application, critical thinking, and developing awareness of how mathematics is used in everyday life, aligning with national development goals. However, it faces challenges such as misalignment across educational levels and limited subject integration. In contrast, the Singaporean curriculum emphasises deep conceptual understanding, problem-solving skills, and metacognitive development, providing students with essential 21st-century skills through a strong foundation approach. This result aligned with Schmidt et al. (2002), who found that logically organised curriculum contents and concepts built in relation from one grade to the next grade are crucial for effective learning because it ensures that students progressively develop their understanding and skills as

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they advance within and across the grades.

The different development of curriculum coherence in relation to contents and sub-contents for the Cambodian curriculum is not yet well constructed compared to the Singaporean curriculum. The Singaporean mathematics curriculum is a crucial example of strong curriculum coherence. The curriculum with a lack of coherence in relation to contents and sub-contents within the grade and across the grade level can make it difficult to see the connection between contents and understand how those concepts are related (NIE & PRI, 2021; Schmidt et al., 2002). It allows the students to progress in specific content knowledge from lower to upper grades (Schmidt et al., 2005).

A well-designed curriculum aligns its content with clear learning outcomes, ensuring that what students are taught directly contributes to their educational goals. The Singaporean mathematics curriculum is noted for its strong alignment between content, sub-content, and learning outcomes. The learning outcomes are clearly defined and carefully sequenced, guiding both teachers and students through a logical progression of skills and knowledge.

Conversely, the Cambodian curriculum struggles with coherence. In many cases, the learning outcomes in Cambodia's curriculum do not clearly correspond to the content being taught. This lack of coherence can lead to confusion in the classroom and may prevent students from fully mastering the concepts they need to succeed in mathematics.

The result is also supported by previous scholars who have indicated that the curriculum lacks coherence in terms of the relation to domain, contents, sub-contents, and learning outcomes do not correspond to each other, which can lead to the student's difficulty in understanding the geometrical concepts and tending to achieve low achievement (Cuoco & McCallum, 2018a; Prawat & Schmidt, 2006; Veasna & Baba, 2024).

The findings of this study suggest that improving curriculum coherence in Cambodia could lead to better student outcomes in mathematics, particularly in geometry. By adopting a more structured approach to curriculum design, similar to that of Singapore, Cambodia could ensure that students are gradually building their knowledge and skills in a logical and consistent manner.

Additionally, clear alignment between content and learning outcomes is essential for helping students achieve educational goals. If the Cambodian curriculum were to focus on better aligning its content with specific learning outcomes, it could make the learning process more transparent and effective for both teachers and students.

4. Conclusions

Curriculum coherence is crucial for improving student outcomes in mathematics, particularly in geometry. Through the comparative analysis, the Singaporean mathematics curricula are highly coherent in terms of design, structure, and coherence, followed by domain, content, sub-contents, and learning outcomes within and across the grade. It is well organised with a logical progression of geometric concepts that correspond with each other compared to the Cambodian mathematics curriculum, which lacks coherence and has significant gaps in how geometric concepts are introduced and developed.

The study suggests that Cambodia could improve its students' mathematical achievements by investigating a more structured and coherent approach similar

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to Singapore's. The findings offer valuable insights for countries facing similar challenges in curriculum design. Although this research is limited to comparing the curricula' overall structure and content relationships in the two countries through the intended curriculum, further studies should compare the implemented and attended curriculum to gain a deeper understanding of geometry concepts.

Author Contributions
The result of this finding is not only for the Cambodian context but can be used for other countries that have faced the same situation.

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Declaration of Competing Interest
This study belongs to the author. There is no conflict of interest for this study.

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Comparison of Decomposition and Triple Exponential Smoothing Methods to Improve Rice Production Forecasting in East Java Province

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ABSTRACT

This study forecasts rice production in East Java using Triple Exponential Smoothing (Holt-Winters) and Decomposition. Data includes rice production in dry milled grain (GKG) from January 2018 until December 2023, sourced from the Central Statistics Agency (BPS) of East Java. The analysis identifies the Holt-Winters Multiplicative model as the most effective, with the lowest error values: Mean Absolute Percentage Error (MAPE) of 0.1452, Mean Absolute Deviation (MAD) of 0.1078, and Mean Squared Error (MSE) of 0.0286 during training, and MAPE of 0.1974, MAD of 0.1909, and MSE of 0.0858 during testing. The Holt-Winters Multiplicative model is recommended for future rice production predictions, providing reliable method for accurate forecasting, and aiding in future rice demand planning in East Java.

1. Introduction

Rice is one of the most essential carbohydrate-producing food crops in the world. Rice plants are annual plants with a round and hollow stem shape called Straw, with an elongated leaf shape and internodes in the direction of the leaf stem (Widiyawati et al., 2023). The agricultural sector is a sector that has a vital role in Indonesia's economy, and rice is one of the leading agricultural commodities. It is the main food crop that is a source of income for farmers and communities in Indonesia (Negara et al., 2023). Almost 95% of the Indonesian population

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consumes rice or processed rice as a staple food, so the demand for rice yearly will continue to increase along with population growth (Afiyah et al., 2021).

East Java Province is the largest rice-producing region in Indonesia. Governor Khofifah stated that until 2023, East Java province will continue to maintain its position as the National Food Barn. The possibility that the amount of rice production will continue to decline is caused by the uncertainty of what will happen. Therefore, research on how rice production in the future can be used as a reference for making a policy or strategy to maximize rice production (Zamahzari & Puryantoro, 2023). One of the first steps that can be used to handle fluctuations in rice production in East Java province is to predict or estimate future rice production, which is done so that the government can know the availability of rice in all regions of Indonesia (Nurwahdania & Sulistijanti, 2020).

There are several previous studies relevant to rice production forecasting that are used as reference materials in writing this research, including research conducted by Afiyah et al. (2021) which forecasts rice production in East Java by applying the Double Exponential Smoothing method, research conducted by Kurniawan et al. (2023) which forecasts rice production in Indonesia by applying Generalized M Estimation Robust Regression, then forecasting conducted by Putra et al. (2023) by implementing the Simple Linear Regression and Single Exponential Smoothing methods to predict East Java rice production. In spatial research, Nurdiansyah et al. (2024) showed that rice predictors have varying influences depending on their location in each subdistrict in Bojonegoro Regency.

The forecasting method is used to project, estimate, or predict the level of uncertain events in the future. Several forecasting methods can be used, one of which is the Exponential Smoothing method, which is an exponential weighting method that reduces the value of previous observations. One of the advantages of using this method is that it significantly reduces data storage problems. It means that only the last observation, forecast, and constant value must be stored, not all historical data or only a part of it. Because this method is simple and effective in forecast calculations, easy to adjust to changes in data, and the accuracy of this method is significant, it is widely used in forecasting (Nurdiansyah & Wafa, 2021). There are three models in the Exponential Smoothing method: Single Exponential Smoothing, Double Exponential Smoothing, and Triple Exponential Smoothing. Each part has a different smoothing rate and will be used according to the pattern of historical data. Identifying the data pattern can be done by looking at the curve of the number of cases over a certain period (Islamiati et al., 2020). An example of previous research that applies the Exponential Smoothing method is by Hasanah (2023), where the Single Exponential Smoothing method is applied to rice production in Sumenep district. The results show that the method is already included in the accurate category and can be used to predict rice production in the Sumenep district. In Makridakis et al. (1998), exponential smoothing is simple, efficient, and effective for forecasting data with consistent patterns but lacks the ability to handle complex trends or seasonality. Extensions like Holt-Winters are needed for more advanced patterns.

In addition to the Exponential Smoothing method, analysis with the Decomposition method is also introduced. This method shows the results of various factors, such as trend, cycle, seasonal, and randomness (irregular) (Kristiyanti & Sumarmo, 2020). The advantages of the Decomposition method,

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according to Hendra (2020) explained that the Decomposition method has advantages over other methods, namely that the pattern or component can be broken or decomposed into subpatterns that display each part of a separate periodic series. It often increases the accuracy of a forecast and helps to distinguish the behaviour of the data series better. Some previous research relevant to the decomposition method was conducted by Satyawati et al. (2022), who used decomposition analysis to predict data on the percentage of poor people in Indonesia. The results showed that the additive decomposition model has a lower error value, so it can be interpreted that the additive decomposition model is better than the multiplicative decomposition model. Then, Andriawan and Muflihah (2023) research aims to forecast the demand for UD blessing jaya offset cardboard boxes by comparing the Decomposition, Winter's Exponential Smoothing, and Holt's Exponential Smoothing methods. The results show that the decomposition method is the best, with an error value of MAPE of 19, MAD of 28000, and MSD of 1247419480, indicating a low forecasting error level compared to other approaches. In Hyndman and Athanasopoulos (2018), decomposition models are useful for analyzing time series by separating trend, seasonality, and residuals, making them ideal for data with strong patterns. However, they rely on simplified assumptions and struggle with irregular or highly volatile data.

In this research, Decomposition and Triple Exponential Smoothing methods are used. The novelty of this research lies in using observational data in the form of monthly data on rice production in East Java province by applying the Decomposition and Triple Exponential Smoothing methods that have yet to be widely analyzed. Judging from previous research, the approach with these methods can handle many examples of time series data and provide reasonably accurate results. Thus, proposing a study entitled "Comparison of Decomposition and Triple Exponential Smoothing Methods to Improve Rice Production Forecasting in East Java Province" is necessary. For the implementation of rice production forecasting, the monthly rice production data in East Java from January 2018 to December 2023. The application of this research is implemented using R-based programming, as explained by Nurdiansyah and Sulistiawan (2023).

Based on the problems that have been described, the objectives of this study are to determine the descriptive statistics of rice production in East Java province, to analyze the results of the comparison of Decomposition and Triple Exponential Smoothing methods in forecasting rice production in East Java province, and to obtain the results of forecasting the amount of rice production in East Java province using the best method. This research will likely be a source of reference or information that can be used to determine the level of rice production in East Java province in the future and can be used as a reference in decision-making related to rice production.

2. Method

2.1. Research Design

The research conducted used quantitative methods. A quantitative method is research that finds knowledge by using numbers to analyze information about what you want to know. The numbers used come from secondary data, which is

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obtained from other parties for research purposes or others (Ilmiah et al., 2020). The data used in this study is secondary data in the form of monthly data on rice production in East Java province from January 2018 to December 2023 obtained from the website of the Central Bureau of Statistics of East Java province.

2.2. Research Variables

This study used variables, namely rice production variables in East Java province. In the form of monthly data from January 2018 to December 2023. An explanation of the variables to be used is described in Table 1 below:

Table 1. Variable Definition

No.	Variable	Operational Definition	Unit	Scale
1.	Rice production in East Java province	Total rice production in the form of milled dry grain (MDG)	Ton	Ratio

The time series data variable in this study is denoted by Y, which stands for rice production, and t, which stands for time or period.

2.3. Analysis Steps

This research uses two methods: Decomposition and triple exponential smoothing. The two methods will be compared to determine the best method for rice production data in East Java province by looking at the minor error value in each method and forecasting results for the next period. The steps in analyzing rice production data in East Java province for the period 2018 - 2023 using the Decomposition and Triple Exponential Smoothing method comparison are as follows:

1. Perform descriptive statistical analysis and see whether the pattern of time series data forms a seasonal pattern or not. For rice production data in East Java province for the period 2018 - 2023, find out the general description of the data.
2. Perform data division into training data and testing data. This study used a training data composition of 70% and testing data of 30%. Then, the training and testing will be conducted to determine the results of comparing the Decomposition Triple Exponential Smoothing methods. The training and testing process is carried out with the same steps as in the following:

   a. Testing with the Triple Exponential Smoothing method Additive model and Triple Exponential Smoothing Multiplicative model with the following procedure:
      i. Determine the parameter values of alpha (α), beta (β), and gamma (γ), where the parameter values are in the range of 0 to 1 to get the optimum value.
      ii. Before performing the smoothing calculation, it is necessary to initialize the level, trend, and seasonality.
      iii. Perform level, trend, and seasonal smoothing processes on the estimated parameters.
      iv. Forecasting Calculation.

   b. Testing with the Additive model Decomposition and Multiplicative

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model Decomposition methods with the following procedures:

i. The first step is to determine the 12-month moving average because the time series data is monthly to estimate the influence of the trend (Tx) and cyclic (Cx).
ii. Calculate the effect of seasonality (Ix).
iii. Identify the trend effect that fits the data (linear, exponential, quadratic, etc.) using the least squares method as in the regression model.
iv. Calculate the cycle effect (Cx) by separating the combined value of the trend component and the cycle component to obtain the cycle factor by dividing the moving average value by the value of the trend component.
v. Then forecasting is done

c. Calculating model error, MAPE, MSE, and MAD values for Triple Exponential Smoothing Additive model, Triple Exponential Smoothing Multiplicative model, Decompocition Additive model, and Decompocition Multiplicative model.
d. Conduct a comparison study between the four models based on the smallest MAPE, MSE, and MAD criteria to determine the best model.

3. Forecast rice production with the original data using the best model and interpret the forecasting results.

2.4. *Flowchart*

The research used research steps following the Mursidah flow chart (Mursidah et al., 2021) as in Figure 1 below

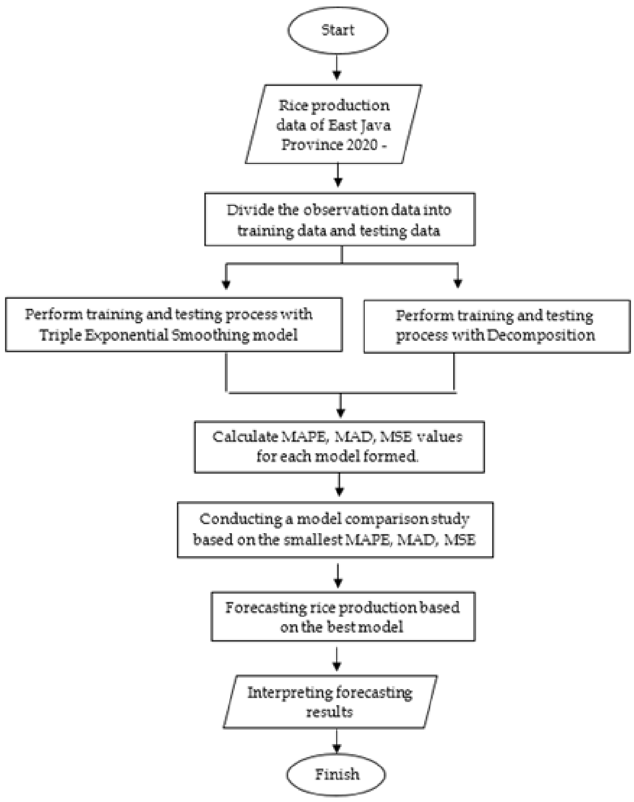

Figure 1. Research Flowchart

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3. Results and Discussion

3.1. Results

The data used in this study are monthly data on rice production in East Java province from January 2018 to December 2023. As much as 72 data were obtained through the website of the Central Bureau of Statistics of East Java Province. The data was divided into two parts, namely 70% training data and 30% testing data. The following data descriptive statistics are presented in Table 2 below:

Table 2. Descriptive Analysis of Rice Production

Statistic	Full Data	Training Data	Testing Data
Minimum	0.2100	0.2100	0.3200
Q1	0.4875	0.4825	0.4900
Median	0.6200	0.6200	0.6350
Mean	0.8160	0.8086	0.8327
Q3	0.9825	0.9825	0.9700
Maximum	2.2900	2.2900	2.2900

Before conducting a forecasting analysis, it is necessary to analyze data patterns to make it easier to determine the proper forecasting method. The following is the monthly data pattern of rice production in East Java province in the period January 2018 to December 2023, shown in Figure 2 below:

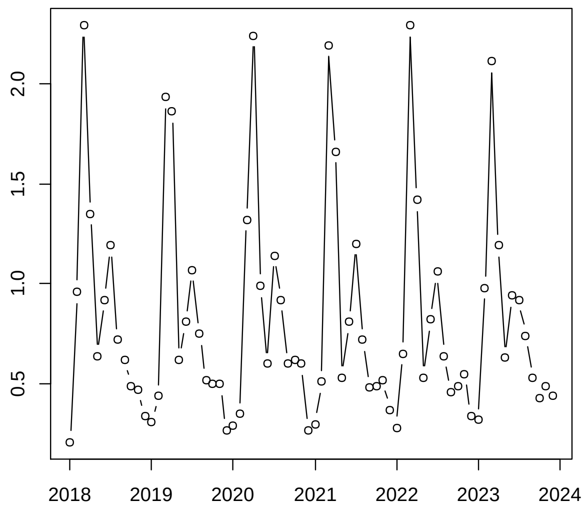

Figure 2. Time Series Plot of Rice Production Data

The data plot in Figure 2 shows that the rice production in East Java province from January 2018 to December 2023 experienced periodic fluctuations each year, with peak production in certain months and valley production in other months.

The first step to calculating forecasting with the Triple Exponential Smoothing method (Holt-Winters method) is required to determine the parameter values of alpha (α), beta (β), and gamma (γ), where the parameter values are in the range of 0 to 1 to get the optimum value. The following results calculate the three parameters to get the optimum value. The optimal parameters on monthly data of rice production in East Java province from January 2018 to

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December 2023, obtained from R software, are shown in Table 3 below:

Table 3. Parameter Estimation in Triple Exponential Smoothing method

Method	Parameter	Estimate
Holt-Winters Additive	α	0.0197
	β	0.4942
	γ	0.0000
Holt-Winters Multiplicative	α	0.0279
	β	0.2770
	γ	0.0000

After obtaining the parameter values of alpha (α), beta (β), and gamma (γ), these parameter values are used to find the initial values of level smoothing, trend smoothing, and seasonal smoothing. After obtaining the initial value, find the smoothing value for level, trend, and seasonal. Then, calculate the forecasting value for the next period. After receiving the forecasting value, the next step is to see the extent of the applied model's accuracy or accuracy. In this study, to determine the accuracy of forecasting, it was carried out by looking at the MAPE, MAD, and MSE values with the help of R software, and the results obtained are shown in Table 5 and Table 6.

To perform a forecasting analysis using the Decomposition method, it is first necessary to determine a 12-month moving average since the time series data is monthly in nature to obtain an estimate of the trend (Tx) and cyclic (Cx) effects. The least squares method is used in regression models to identify the trend effect that fits the data (linear, exponential, quadratic, or otherwise). After that, calculate the influence of the cycle (Cx) by separating the combined value of the trend component and the cycle component to obtain the cycle factor, namely by dividing the moving average value by the value of the trend component. Then, the forecasting calculation is carried out for the next period.

After the model training process (training) and the model evaluation process (testing), the model comparison results with forecasting or forecasting for the next period are obtained. The accuracy value of the model can be seen by calculating the MAPE, MAD, and MSE values. For the accuracy value of the Additive Decomposition model method, the accuracy value of the model is shown in Table 4 and Table 5.

Table 4. Accuracy Value of Training Process

Training	MAPE	MAD	MSE
Holt-Winters Additive	0.1553	0.1097	0.0296
Holt-Winters Multiplicative	0.1452	0.1078	0.0286
Decomposition Additive	**0.0759**	**0.0684**	**0.0152**
Decomposition Multiplicative	0.4569	0.7590	0.7703

Table 5. Accuracy Value of Testing Process

Testing	MAPE	MAD	MSE
Holt-Winters Additive	0.2135	0.1978	0.0731
Holt-Winters Multiplicative	**0.1974**	**0.1909**	**0.0858**
Decomposition Additive	4.8738	0.7920	0.7006
Decomposition Multiplicative	0.2616	0.2736	0.1544

In Table 4 and Table 5, it can see the results of the model error comparison

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by looking at the MAPE, MAD, and MSE values. The accuracy value of training data is used to assess the accuracy of model estimation. In contrast, the accuracy value of the testing data illustrates the accuracy of the model forecast.

The Additive Decomposition model method has the lowest MAPE, MAD, and MSE values in the training process but performs poorly in the testing process. It indicates that the model is overfitting. For the Triple Exponential Smoothing method, the Multiplicative model, although it has slightly higher MAPE, MAD, and MSE values in the training process than the Additive model Decomposition method, has better and consistent performance on testing data in training and testing data.

Based on the results of the above analysis, with a MAPE value of 0.1452, MAD of 0.1078, MSE of 0.0286 in the training process, and a MAPE value of 0.1974, MAD of 0.1909, MSE of 0.0858 in the testing process, the Triple Exponential Smoothing method Multiplicative model is the best method overall, because it has excellent and consistent performance on training and testing data, which means that of the four models above, the Triple Exponential Smoothing Multiplicative model is more appropriate to use to forecast rice production in East Java province. So, forecasting is carried out with monthly data on rice production in East Java from January 2018 to December 2023 to forecast rice production in the future. In this study, rice paddy production in 2024 will be forecasted using the selected method, namely the Triple Exponential Smoothing method of the Multiplicative model.

After determining the best forecasting method, the forecasting process will be carried out using the original rice production data with the selected model, namely the Triple Exponential Smoothing method Multiplicative model. Forecasting is carried out with the Triple Exponential Smoothing method Multiplicative model using R software, and the results are obtained in Figure 3.2 below:

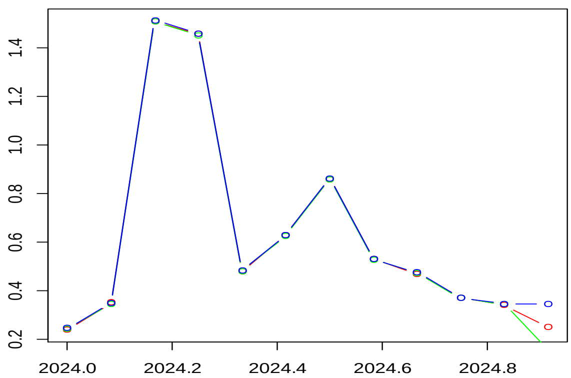

Figure 3. Plot of Rice Production Forecasting Results in 2024

Based on Figure 3, the forecasting results using the Triple Exponential Smoothing Multiplicative model method can be seen. The red graph is the forecasting result, the green graph is the lower limit value with 95% confidence, and the blue graph is the upper limit value with 95% confidence. In addition, the results of rice production forecasting in East Java province in 2024 are presented in Table 6 below:

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Table 6. Forecasting Results of Rice Production in 2024

No.	Period	Point Forecast	Lo 95	Hi 95
1.	January 2024	0.2434	0.2427	0.2442
2.	February 2024	0.3460	0.3451	0.3470
3.	March 2024	1.5128	1.5098	1.5159
4.	April 2024	1.4561	1.4531	1.4591
5.	May 2024	0.4823	0.4810	0.4835
6.	June 2024	0.6278	0.6262	0.6294
7.	July 2024	0.8605	0.8584	0.8626
8.	August 2024	0.5290	0.5276	0.5306
9.	September 2024	0.4733	0.4719	0.4747
10.	October 2024	0.3696	0.3683	0.3708
11.	November 2024	0.3441	0.3429	0.3454
12.	December 2024	0.2490	0.1529	0.3451

Table 6 shows the results of rice paddy production forecasting in 2024 using the selected method, namely the Triple Exponential Smoothing method Multiplicative model. Rice production in the year tends to decrease, with the highest amount of rice production being 1.51 million tons, which occurred in March 2024. The results of forecasting future rice production can provide an overview to the government and the community regarding future conditions so that the government and the community can prepare strategies to overcome the situations that occur in the future.

3.2. Discussion

The findings indicate that rice production in East Java exhibits a pattern of periodic fluctuations each year, with clear peaks and valleys in output across different months. The use of the Additive Decomposition model in the analysis initially showed promising results in terms of low error metrics, such as MAPE, MAD, and MSE, during the training phase. However, this model struggled in the testing phase, suggesting that it might be overfitting the training data. On the other hand, the Triple Exponential Smoothing method with a Multiplicative model, despite slightly higher error values in training, provided more stable and reliable performance on testing data. This indicates a stronger ability to generalize and accurately predict rice production trends outside the training dataset.

For 2024, the Triple Exponential Smoothing Multiplicative model forecasts a general decline in rice production, with the highest production level anticipated at 1.51 million tons in March. This projection provides valuable insight for both the government and local communities, allowing them to anticipate future rice production trends and implement proactive strategies. By understanding the likely decreases in production, authorities can better prepare for potential shortfalls, possibly developing policies to stabilize rice supplies and support affected farmers. This foresight highlights the importance of robust forecasting models in agricultural planning, particularly in regions where production fluctuations can impact food security and economic stability.

4. Conclusions

This study demonstrates that the Triple Exponential Smoothing Multiplicative method is the most effective approach for forecasting rice

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production in East Java Province, based on monthly data from January 2018 to December 2023. With a MAPE value of 0.1452 for training data and 0.1974 for testing data, this method proved to deliver accurate and consistent predictions compared to other models. The periodic fluctuations in rice production each year, with peak production in certain months, were effectively captured by the model. Forecasting results for 2024 indicate a general decline in rice production, with the highest production level estimated at 1.51 million tons in March. These findings provide valuable insights for the government and stakeholders to design proactive policies to manage rice production and ensure food security.

Author Contributions

The first author is a student who worked on the scientific article as the output of the final project, the second author is the primary advisor who assisted with the research material, and the third author is the second advisor who provided support in the writing process.

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Declaration of Competing Interest

The authors affirm that no conflicts of interest exist in relation to the development of this scientific article.

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Ethnomathematics in *Buna-Insana Motif* Weaving Activity and its Link to School Mathematics

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ABSTRACT

This study explores ethnomathematics in the activity of weaving *Buna-Insana* motifs and its connection to school mathematics using an ethnographic case study with weavers from Botof Village, Insana District, guided by Bishop's ethnomathematics concepts: counting, measuring, designing, and reasoning. The results of the study indicate that the counting activity, mathematical knowledge in the form of addition operations is obtained. The measuring activity, hand spans are used as a unit of measurement. In the designing activity, the motifs produced are related to plane geometry concepts and similarity concepts. After the designing activity, reasoning activities are carried out. Implication logic is also found in weaving activities, namely when determining the selling price of woven fabrics and the length of weaving time.

1. Introduction

As one part of formal education, mathematics education plays a role in preserving culture and instilling cultural values and developing the nation's culture. This is in line with the opinion of Risdiyanti & Prahmana (2020) that mathematics education needs to contextualize mathematics with the environment and culture of students because, in essence, science arises from the needs and expectations of community members in a particular culture to respond to the environment and answer various problems faced in their lives. For this reason, cultural studies from mathematics are needed because mathematics is a

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construction of the culture itself. Cultural studies from the aspect of mathematics are known as ethnomathematics. One that can bridge education and culture, especially mathematics education, is ethnomathematics (Rosa & Orey, 2016).

Ethnomathematics means the study of the relationship between mathematics and the emerging cultural knowledge of a member of a cultural group (Silva et al., 2022). Currently, ethnomathematics has become a field of research focused on the relationship between culture and mathematics. Ethnomathematics aims to use diverse examples to solve problems from various cultures and recognize that learning mathematics is a unique process for each individual. Ethnomathematics will differ depending on the cultural environment (Dominikus, 2021).

Ethnomathematics broadly uses mathematical concepts related to various mathematical activities. Bishop identified six universal mathematical activities found in every cultural group: counting, locating, measuring, designing, playing, and explaining – CLMDPE (Bishop, 1988). These six activities form the basis for the development of mathematics, which is then known as the characteristics of ethnomathematics (Mukhopadhyay & Greer, 2011; Shirley, 2006)

Several studies related to ethnomathematics have been conducted with different focuses. These include traditional musical instruments, games, artifacts and crafts, language, wedding traditions, and work or workplace (Aini et al., 2019; Astria & Kusno, 2023; Dominikus et al., 2016b, 2016a; Febriyanti et al., 2019; Hidayatulloh & Hariastuti, 2018; Utami et al., 2019; Zayyadi, 2017). In addition, several of studies related to the application of ethnomathematics have been conducted in mathematics education (Disnawati & Nahak, 2019; Nurbaeti et al., 2019). The research results of Novitasari et al., (2022) also stated that the use of ethnomathematics-based student worksheets with an effective STEM approach improves students' critical thinking skills. All the research results expressed above state that the mathematical elements obtained can be used in mathematics learning

Other studies that used the woven fabric of the Dawan-Timor tribe as a research subject were Disnawati & Nahak (2019) develop student worksheets based on ethnomathematics of Timor woven fabric on number pattern material. Deda & Disnawati (2017) has examined the relationship between the woven fabric of the Dawan-Timor tribe and mathematics in schools. As well as research conducted by Deda & Disnawati (2019) has developed ethnomathematics-based student worksheets (LKM) using the context of Timor woven fabric motifs. The above studies also examine ethnomathematics in Timorese woven fabrics, but the research context is directly related to woven products used to design LKS and LKM. No researcher has specifically examined the weaving activity of the *buna-Insana motif*.

The Dawan tribe in North Central Timor Regency, East Nusa Tenggara, consists of three tribes in three swaprajas: Biboki, Insana, and Miomaffo (Biinmafo). Weaving (*nteun*) for the Dawan community is a routine activity carried out since long ago and is a legacy of the ancestors that is still being carried out and maintained by the local community, especially the village community (Utomo et al., 2023). One of the woven motifs in the Dawan-Timor tribe is the *buna motif*, which the people of Insana District usually weave.

Ethnomathematics can facilitate students' construction of mathematical concepts with the initial knowledge they already have because of their environment. One way to achieve this is through weaving activities, which are

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part of the local content curriculum in schools. Previous research has shown that woven fabrics can serve as an effective medium for teaching mathematics. Risdiyanti & Prahmana (2020) emphasize that mathematics learning should begin with real contexts derived from the sociocultural and reality around students.

So far, there has been no research related to weaving activities associated with school mathematics, so this research was conducted to describe the mathematical content contained in the *Buna motif* weaving activity, which includes the tools used, motif design, weaving process, and marketing of woven fabrics and then relate it to school mathematics. The math content includes numbers, algebra, measurement, geometry, data analysis, and chance. The activity of weaving *buna motifs* was chosen because weaving activities began to be included in local content subjects, so it is essential to educate students, teachers, and the community that mathematical activities are indirectly often done and experienced.

2. Method

This study aims to determine the relationship between Buna motif weaving activities and school mathematics. This research is qualitative research with an ethnographic design. Creswell (2012) defines ethnography as a qualitative research procedure that describes, analyzes, and interprets parts of a cultural group gathering, such as behavior patterns, beliefs, and language that develop over time. So, the ethnographic design was chosen for this study because it is to the problem and research objectives. With ethnographic design, the weaving activity of Buna motifs can be described, and then the mathematical knowledge contained in the weaving activity can be defined according to the characteristics of ethnomathematics expressed by Bishop. This is based on the idea that every weaving activity in a tribe/region or type of woven fabric has different knowledge (mathematical knowledge) according to its needs (Dominikus, 2021).

The subjects in this research were a group of weavers who live in Botof Village, Insana District. The main instrument in this research is the researcher, who is equipped with supporting instruments such as observation guides, interview guides, voice recorders, video recorders, and image recorders. This research collected data in the field using non-participatory observation, in-depth interviews, photographs, and audio/video recordings. The data collection process began with non-participatory observation of the weaving activities carried out by the research subjects that had been determined previously. In this non-participatory observation activity, the researcher is in the environment to observe what the research subject does while making field notes and taking photos/videos.

The data concerning Bishop's ethnomathematics characteristics were analyzed to identify, collect, and describe various mathematical knowledge in weaving activities. However, it does not rule out the possibility that researchers also find other findings. All of these findings will be described in detail so that mathematical knowledge can be clearly known in the activity of weaving buna motifs. Furthermore, the relationship between ethnomathematics content in weaving activities and school mathematics content is also analyzed to describe the relationship between ethnomathematics in buna motif weaving activities and school mathematics.

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3. Results and Discussion

This section describes the research findings on mathematical knowledge in the weaving activities weavers perform. In these activities, weavers engaged with mathematics in their daily lives. The final part will elaborate on the relationship between ethnomathematics in weaving activities and school mathematics, particularly at the junior high school level.

3.1. Mathematical Knowledge in Weaving Activities

For Dawan-Timor women, weaving was initially an activity to fill their free time. The weaving skills they possess have been naturally passed down from generation to generation (Utomo et al., 2023). Over time, woven fabrics have gained commercial value, and weaving has become a livelihood for many. In the past, woven fabrics were used solely as body coverings, clothing for traditional ceremonies, bride price exchanges in marriage traditions, death rituals, and other customary events. Woven fabrics are used today to make suits, ties, decorative materials, souvenirs, dresses, skirts, and uniforms. As a result, woven fabrics now hold both economic and social value.

Based on interviews with weavers, weaving activities generally consist of two stages: the thread production stage and the fabric production stage. In the thread production stage, weavers currently rely on the available thread, which is sold for IDR 2,500 per spool. The type of fabric used among the Dawan-Timor community varies depending on the weaving technique. Three types of woven fabrics are *Futus* (*ikat* weaving), *Buna*, and *Sotis*. These three types of fabrics differ in weaving techniques and the methods of creating motifs. Additionally, the fabric used for men is commonly referred to as *bete* or blankets, while the fabric for women is called *tais* or sarongs(Utomo et al., 2023). In the use of *bete* and *tais*, a complementary fabric is commonly used, known as bet'ana or a shawl.

The *Buna* motif woven fabric is one of the motifs frequently crafted by weavers in the Insana region. The *Buna* motif is a distinctive feature and a cultural heritage of the Insana community. Weavers typically purchase threads sold in markets at prices ranging from IDR 2,000 to IDR 2,500 per spool. Two threads are used: wood thread as the base color thread and silk thread for creating the *Buna* motif (Figure 1a). Wood thread is priced between IDR 17,500 and IDR 20,000. Producing one requires approximately ten spools of wood thread, while the amount of silk thread depends on the number of *Buna* motifs to be created.

In the initial stage, the weavers manually roll the threads into hand-sized spools (Figure 1b). Weavers generally avoid using tools for rolling threads to maintain flexibility, allowing the process to be done anywhere. The rolled threads are then arranged on the loom in a stage called *non*. After *non*, the weavers form the *Buna* motif by tying colored silk threads onto the base threads. The choice of colors typically depends on the preferences of buyers or clients. The color selection is based on the weaver's creativity if there are no specific buyers or orders. Generally, the *Buna* motif is created using six colors in addition to the base color. Figure 1 illustrates the threads used for weaving.

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Figure 1a. A single spool of thread

Figure 1b. The thread that has been rolled

Figure 1. Threads used for weaving

When creating *buna motifs*, the weaver first determines the motif's size according to the fabric type to produce. The more intricate and dense the *buna* design, the more thread is required. At the beginning of the process, the weaver selects the color combination to create the *buna*. The production begins by manually tying the colored threads onto the base threads. It takes 60 rows of inner threads (*monaf*) to form a *buna motif*, after which the subsequent rows repeat the pattern of the first 60 rows. This repetition continues until the motif is fully formed at the end of the threads. The weaving process for the *buna motif* is shown in Figure 2 below.

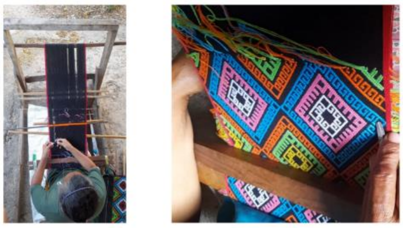

Figure 2. The Process of Weaving the *Buna* Motif

The *buna* motif consists of *manoeb* and *mabata* motifs (Natun et al., 2021). *Manoeb* comes from the Dawan language (a regional language in Timor) and means "interconnected." This indicates that the motif is continuous, with no gaps, and seamlessly links together. In contrast, *mabata* features spaced motifs. Fabrics with *buna manoeb* and *buna mabata* motifs are of the same size. The motifs in *Buna Manoeb* symbolize community unity and the interconnectedness of individuals. This interconnectedness is evident in the *mak'aif*, which intertwine with one another.

3.2. The Relationship Between Ethnomathematics in the Weaving Activities of the Dawan Tribe and School Mathematics

In the entire weaving process, mathematical knowledge can be identified and explained based on Bishop's ethnomathematics characteristics, as follows:

3.2.1. Counting

Counting activities are performed to determine the number of threads in each row and to create motifs during the thread-dyeing process. The number of threads is never written down but instead memorized. Similarly, when tying the threads (*non*) to form motifs, the fabric's pattern is never drawn but only remembered and visualized mentally or replicated from existing weaving patterns. This indicates that calculating thread count and color arrangement for fabric motifs relies heavily on the weaver's memory, experience, and references to existing woven fabrics.

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The number of threads required in weaving depends significantly on the number of *buna* motifs created or the type of fabric being produced, such as this, *bete*, or *bet'ana*. In this study, weaving *bet'ana* (which includes two *buna* motifs) requires two rolls of black thread for the base and inner threads (*monaf*), as well as colored threads in green, orange, yellow, pink, blue, and white, each amounting to two spools.

The number of threads required to weave *Bet'ana Buna Insana* can be observed in the following excerpt from the interview (R : researcher; S : Subject) :

R : For the *bet'ana* weaving, how much thread is needed?
S : For the *bet'ana*, we use two spools of black thread for the base and *monaf*. Then, for the colored threads used in the *buna* motif, we need two spools for each color. Additionally, red thread is used for the edges, requiring two spools.

Based on the interview excerpt above, it can be written in a mathematical sentence as follows:

2 rolls of black thread + 2 spools of green thread + 2 spools of yellow thread + 2 spools of orange thread + 2 spools of blue thread + 2 spools of pink thread + 2 spools of white thread + 2 spools of red thread = 16 spools of thread

The addition operation performed to weave tais, as represented in the mathematical sentence above, shows that when determining the number of threads for each color, the weavers perform addition as an abstraction of the number of threads in each color. In addition to numbers and addition, there is the concept of sets and subsets. The set is the collection of threads used to weave this, while the subsets are the colors of the threads used, which include black, red, green, orange, yellow, pink, blue, and white. In the counting activity, there is an operation related to addition. This activity involves adding elements from two different subsets of the same set. For example, six spools of red thread + two spools of green thread = 8.

Mathematically, the example above shows a difference when related to algebraic concepts in school. Six spools of red thread + two spools of green thread = 8 spools of thread; when written in algebraic form as $6m + 2h = 8$, where m represents red thread and h represents green thread, this algebraic form is incorrect. In algebra, variables represent numbers; adding algebraic terms only applies to like terms. Therefore, while students can learn concepts like sets, subsets, set operations, and number addition through the weaving activity, it may also confuse students when learning algebraic addition in school (Dominikus, 2021).The relationship between counting activities in weaving culture and school mathematics is shown in Figure 3 below.

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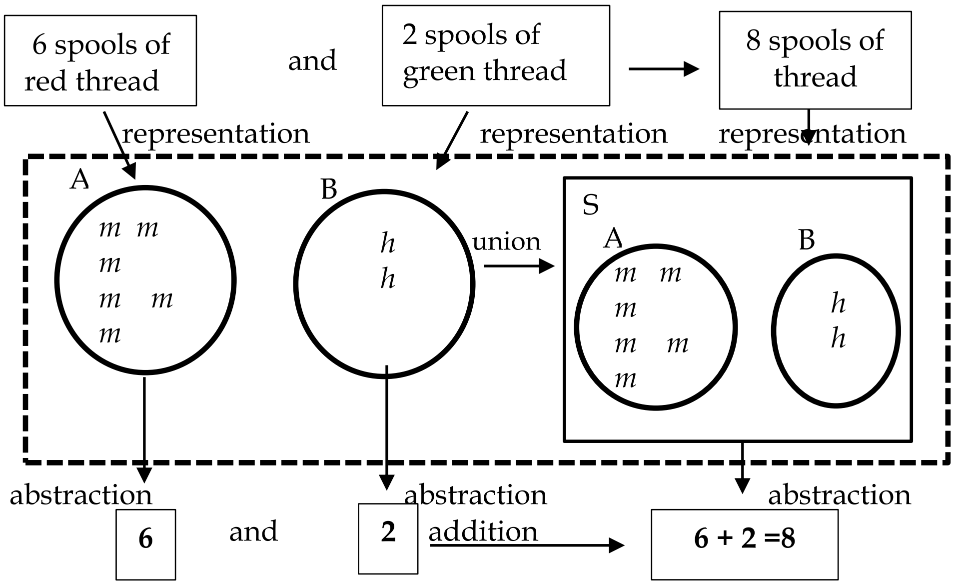

Figure 3. The Relationship Between Counting Activities in Weaving Culture and School Mathematics

The notations used in Figure 3 are description as follows:

Table 1. Notation Description

Notation	Description
A	{red thread used for weaving}
B	{green thread used for weaving}
S	{the set of thread colors used for weaving}

Figure 3 shows that in the counting activity, there are concepts of sets, subsets, set operations, addition operations, and processes of representation and abstraction. The representation process is marked by expressing the number of red and green threads and the total number of threads in set notation and set operations. On the other hand, the abstraction process is shown by expressing six spools of red thread as the number 6 and 2 spools of green thread as the number 2, then performing the addition operation: 6 + 2 = 8. Abstraction in this context means ignoring other aspects of the actual object and focusing only on the quantity or number of actual objects present (Nunes, 1992). In this case, the different colors of the threads are disregarded, and attention is focused only on the number of red or green threads.

3.2.2. Measuring

Measuring activities generally relates to "how much" (length, width, height, duration, quantity). The measurement tools used in weaving activities are typically the fingers and hands. For instance, the standard size of woven fabric (*tais*) used by weavers is six hand spans in length, and five hand spans in width. Meanwhile, the typical size for a bete is eight hand spans in length and six hand spans in width. These measurements can change depending on customer requests or the buyer's body size.

Measuring is also seen in determining the size of thread spools, typically measured by the fist size. Weavers do not use standardized measurements but

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rely on customary sizes or measurements they frequently use. Teachers do not use non-standard measurements like those described above in classroom learning, even though measuring activities carried out outside the classroom like this provide students with real experience in learning mathematics. These experiences increase students' interest in learning when integrated into school lessons. Rosa & Orey (2006) suggest that incorporating cultural and daily experiences into teaching school mathematics, particularly measurement concepts, can be highly beneficial in fostering meaningful learning.

3.2.3. Explaining (use of implication logic)

In weaving activities, logic is applied in various aspects, particularly in determining the duration of weaving and the sale of woven fabric, as explained below:

a. Duration Required to Produce a Piece of Fabric

   The time required by a weaver to produce a piece of fabric is expressed in months, where 1 month consists of 30–31 days. The daily weaving process is accumulated into months. Based on interviews and observations, no weaver calculates the duration in hours instead of days, summed into months, as understood by the weavers. Even if weaving is done for only a few hours daily, it is still counted as one full day.

   In the weaving process, implication logic is used. This logic is evident in the duration of weaving and the sale of woven fabrics. The complexity of the motif produced affects the weaving time. Additionally, weavers explained that interruptions or other activities, such as mourning periods or family events, influence the weaving duration they must attend to. If there are interruptions, the time required for weaving becomes longer. In this study, each weaver typically requires approximately three months to complete a piece of fabric.

b. Selling Price of Woven Fabric

   Generally, a single tais is sold at a price ranging from IDR 2,500,000 to IDR 3,500,000. This selling price represents the typical market rate. For weavers, the most critical aspect of selling their woven fabric is that the generated income can meet daily needs, support children's education, and purchase more thread for future weaving.

   The selling price of woven fabric may vary depending on the seller's or buyer's needs. The price will align with the market rate if the buyer urgently requires the fabric. However, the price may decrease if the weaver or seller needs funds and decides to sell the fabric.

3.2.4. Designing

In the woven fabrics of the Dawan tribe, there are several fabric motifs and processes for creating these motifs, which generally share similarities. In this study, the *buna* motif produced takes the shape of a rhombus; however, the weavers do not know the exact origin or the historical story behind the motif. The weavers continue the existing motifs and were commonly made by their ancestors.

To create the *buna* motif, the base threads are tied using colored threads. The quantity of buna produced is adjusted to the size of the *tais* or *bete* (traditional

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fabric types) to be created. The *buna* motifs produced are continuous and identical in shape. The large rhombus shape is formed by tying 101 rows of thread. The threads tied in each row vary to create the desired buna motif. The sequential thread tie design follows a pattern of 1-2-3-4-...-49-50-51-50-49-...4-3-2-1.

In addition to the large rhombus shape, there is a medium-sized rhombus within the large rhombus. The medium rhombus is formed by tying 65 threads. The thread tie design for the medium rhombus sequentially follows a pattern of 1-2-3-4-...-31-32-33-32-31-...4-3-2-1. Finally, a small rhombus is in the center, formed by tying 37 threads. The threads tied for the small rhombus follow the sequential pattern of 1-2-3-4-...-17-18-19-18-17-...4-3-2-1. This process reflects the intellectual and creative capacity of the weavers, who indirectly create rhombus shapes (geometrical patterns) in the woven fabric.


Figure 4. *Buna* Motif


Figure 5. *Buna* motif design

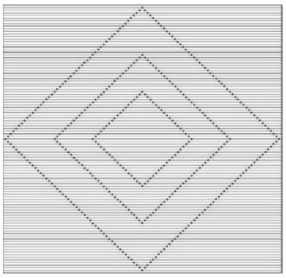
Figure 6. *Buna* motif representation

When observed closely, the change in size of the *buna* motifs—large, medium, and small—can be associated with the concept of similarity taught in junior high school mathematics. This can be seen in the length of each side of the *buna* motifs, which maintains a consistent proportional relationship, as well as in the corresponding angles, which are identical. For further clarification, please refer to the following illustration:

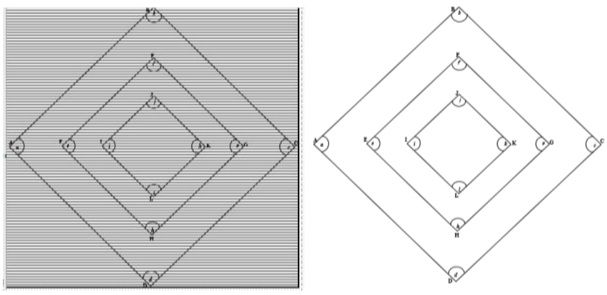
Figure 7. *Buna* motif in mathematics

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Based on the *buna* motif patterns described above, from the large *buna* motif (rhombus $ABCD$) to the medium *buna* motif (rhombus $EFGH$) and the small *buna* motif (rhombus $IJKL$), the properties of similarity can be identified as follows:

1) Assume that rhombus $ABCD$ is similar to rhombus $EFGH$, then
   a. The corresponding side lengths have the same proportional ratio, which is:
   $$\frac{AB}{EF} = \frac{BC}{FG} = \frac{CD}{GH} = \frac{AD}{EH} = \frac{51}{33}$$
   b. The corresponding angles are equal, namely :
   $$\angle A = \angle E; \angle B = \angle F;\ \angle C = \angle G; \angle D = \angle H$$
2) Assume that rhombus $ABCD$ is similar to rhombus $IJKL$, then
   a. The corresponding side lengths have the same proportional ratio, which is:
   $$\frac{AB}{IJ} = \frac{BC}{JK} = \frac{CD}{KL} = \frac{AD}{IL} = \frac{51}{19}$$
   b. The corresponding angles are equal, namely :
   $$\angle A = \angle I; \angle B = \angle J;\ \angle C = \angle K; \angle D = \angle L$$
3) Assume that rhombus $EFGH$ is similar to rhombus $IJKL$, then
   a. The corresponding side lengths have the same proportional ratio, which is:
   $$\frac{EF}{IJ} = \frac{FG}{JK} = \frac{GH}{KL} = \frac{EH}{IL} = \frac{33}{19}$$
   b. The corresponding angles are equal, namely :
   $$\angle E = \angle I; \angle F = \angle J;\ \angle G = \angle K; \angle H = \angle L$$

In addition to the weaving activity, geometric concepts are present in the shapes and motifs of woven fabrics. Plane shapes such as rhombus and similarity are evident in the weaving process. Thus, weaving activities and woven fabrics can serve as context and media for learning mathematics. Woven fabrics can be used to teach plane shapes and geometric transformations. This allows students to explore and discover the geometric concepts being studied.

Moreover, woven fabrics can help identify elements of plane shapes such as sides, vertices, angles, and diagonals. Students can also delve into the process of creating the materials and the cultural meanings associated with the media used. This aligns with Turmudi's, (2018) opinion that cultural artifacts can be used as a bridge for acquiring new mathematical knowledge taught in the classroom and expertise outside the school.

This approach allows students, individually or in groups, to interview community members with expertise as a learning resource, thereby actively involving the community in school mathematics learning. Additionally, students are encouraged to think critically and creatively, fostering communication and collaboration with the community and their peers during the learning process.

In summary, the connection between ethnomathematics in the weaving activities of the Dawan-Timor community and school mathematics concepts, as well as the scope of mathematics, can be summarized in the following table:

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Tabel 2. Connections Between Ethnomathematics in the Weaving Activities of the Dawan-Timor Community and School Mathematics

No	Ethnomathematics in Weaving Activities	School Mathematics Concepts	School Mathematics Concepts
1.	Counting	Sets, Set Operations, Algebraic Expressions, Arithmetic Operations	Numbers, Algebra
2.	Measuring	Standard and Non-standard Measuring Tools, Units of Measurement	Geometry and Measurement
3.	Explaining	Logic, Drawing Conclusions	Logic
4.	Designing	Plane Shapes, Similarity	Geometry and Measurement, Numbers

This table illustrates how ethnomathematics in weaving activities can be a rich source of context and inspiration in teaching mathematical concepts in schools. Dominikus (2021) research results also state that mathematical knowledge exists in weaving Adonara cloth. In woven fabric motifs, numbers, geometry, and symmetry patterns are found, which can be used as a mathematics learning medium. Vygotsky's theory (Zone of Proximal Development) shows that learning occurs more effectively in the student's cultural context. This research can encourage cultural integration in the mathematics curriculum to increase students' understanding of abstract concepts. This research enriches mathematics learning resources with local cultural context, promoting socially relevant education.

4. Conclusions

Based on the data presentation, data analysis, and discussion outlined earlier, it can be concluded that various mathematical knowledge exists in the weaving activity of the *buna-Insana* motif, referred to as ethnomathematics in weaving activities. Counting involves addition operations to determine the number of threads used for weaving. If linked to school mathematics, addition operations here are related to combining two or more subsets from the same set. This process also involves representation and abstraction. Such out-of-class counting activities provide students with real-world experiences in learning mathematics. These activities can be enriched and incorporated into various counting lessons in schools.

Measuring activities are associated with measuring tools like hand spans and fists. In school learning, measuring activities are related to standard units of measurement, such as length, weight, area, and others. Non-standard measurements are usually not taught in schools, but this could serve as input for teachers to utilize students' real-world experiences and link them to school material.

Designing involves the concept of plane geometry. Elements and concepts of geometry, such as points, lines, angles, parallel lines, and quadrilateral plane shapes, are found in woven fabrics. Properties of similarity are also present in weaving activities. These geometric concepts align with those used in mathematics teaching in schools. Thus, weaving activities can be used as context,

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media, and learning resources.

Logical implications are also found in weaving activities among the Dawan tribe. For instance:

a. The weaving process takes longer if disruptions include mourning, family events, or time spent farming.
b. In determining the selling price, the woven fabric price will be lower if the weaver initiates the sale. Conversely, the price will align with market rates if the buyer seeks the fabric.

Such reasoning in the weaving process relates to mathematical logic. Explaining is an activity that everyone engages in, anywhere and anytime. The cognitive activity of answering "why" is part of presenting and asking "why" in school learning, which is crucial for shaping students' reasoning and training them to think critically.

The above explanation demonstrates that integrating cultural elements into school mathematics learning benefits students by enabling them to construct their knowledge. Additionally, students are trained to develop collaboration and communication skills. Woven fabric can also serve as a medium for teaching corresponding geometry concepts. This research is only limited to North Central Timor district woven fabric motifs. This research also does not discuss the motifs on woven fabrics further, so in future research, we can discuss the motifs on woven fabrics in more detail.

Author Contributions

The first author served as the data collector, data processor, data analyst, and writer of the scientific article. The second and third authors provided feedback and suggestions for developing the study, analysis, and manuscript.

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Declaration of Competing Interest

The author stated that there was no potential conflict of interest in this research.

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Development of Mathematics E-Modules with Cultural Context to Support Mathematical Literacy

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ABSTRACT

This research aims to develop a culture-based mathematics E-Module to support students' mathematical literacy in a valid, practical, and effective way. The ADDIE development model was used in this research. Data was collected with validation sheets, response questionnaires, and evaluation questions and analyzed descriptively qualitative and quantitative. The validity of the E-Module, with a validation score of 81.5%, fits the valid criteria. Practicality with a response questionnaire score of 90.49% according to practical criteria. Effectiveness was assessed from student evaluation results with an average $N-Gain$ percentage of 63.166% according to somewhat effective criteria. The results showed that the E-Module with cultural context is feasible and practical and has a positive impact on improving students' mathematical literacy skills.

1. Introduction

Mathematical literacy is the ability to use mathematics in valuable ways in various daily activities to understand the surrounding environment and make better decisions (Burkhardt et al., 2024). Mathematical literacy is a person's ability to efficiently formulate, use, and interpret mathematics in various contexts of daily life problems (Sari, 2015). According to OECD (2023), mathematical literacy is an individual's capacity to reason, formulate, use, and interpret mathematics to solve problems in various real-world contexts. The PISA 2022 framework explains that the three main aspects of mathematical literacy are content, context, and 21st-century competencies. Mathematical content is the category of mathematical concepts used to solve problems. Context refers to the real-world

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situations in which mathematics is applied, and contexts are divided into four categories: personal, occupational, social, and scientific. 21st-century competencies are the skills needed to face challenges, including critical thinking, creativity, research, inquiry, etc.

Mathematical literacy is used to solve real-world problems systematically and relevant to the context of life. The context in question consists of personal, work, social, and scientific. One of the contexts easily found in students' daily lives is the social context; culture is included in the social context. According to Poernomo et al (2021), the context of numeracy literacy is part of mathematics that relates to practical and conceptual matters, such as using mathematical components in the fields of work, arts, sports, and others by geographical and socio-cultural conditions. Culture has great potential to bridge students' understanding of mathematical concepts through meaningful daily experiences; by utilizing this context, students can more easily understand the material while appreciating local wisdom. Some studies that discuss cultural contexts can support mathematical literacy include research that discusses students' numeracy literacy skills in solving socio-cultural context problems on geometry topics at the junior high school level (Rezky et al., 2022), the effectiveness of character-based contextual approaches and local culture on the mathematical literacy skills of junior high school students (Wahyuningtyas et al., 2020).

Mathematical literacy is measured in the Program for International Student Assessment (PISA). PISA is an international study that assesses the quality of education systems. Indonesia's ranking in mathematical literacy is 70, with an average score of 366 (OECD, 2023). The number is relatively low compared to the PISA conducted in 2018, with the average mathematical literacy score obtained by Indonesia being 379 (OECD, 2019). The government, through the Ministry of Education, held a National Assessment (AN) to support PISA. The national assessment is one form of evaluation of the education system by the ministry at the primary and secondary education levels (Peraturan Menteri Pendidikan, Kebudayaan, Riset, Dan Teknologi Nomor 17 Tahun 2021 Tentang Asesmen Nasional, 2021). AN aims to measure cognitive learning outcomes, non-cognitive learning outcomes, and the quality of the learning environment in educational units. Cognitive learning outcomes include reading literacy and numeracy. Schools are essential in supporting the government's efforts to improve student literacy and numeracy. The strategic role of schools in supporting students' literacy and numeracy can be realized in various forms, including supporting teachers in developing innovative and engaging learning.(Feriyanto, 2022)

In 2023, one of the private secondary schools in Banyumas district participated in the National Assessment, which measured reading literacy, numeracy literacy, and environmental survey. The 2023 school report card poster showed that students' numeracy skills decreased from 2022; the skills assessed were students' understanding of the domains of numbers, algebra, and geometry. This makes researchers want to create teaching materials that can support students' mathematical literacy skills with a cultural context easily found in everyday life. One of the fascinating cultures to learn is the art of Begalan, which has many equipment in its performance. Each tool has a diverse shape and can be used to study geometry, such as ilir and iyan, which are square, conical steamer, circular coins, etc. (Kusno et al., 2023). Mathematics learning related to culture and tradition allows students to reflect on and appreciate local and other tribal cultures.(d'Entremont, 2015)

Based on observations in one of the private secondary schools in Banyumas Regency, it was found that mathematics learning is still dominated by the use of printed books and teacher presentations. This approach makes it difficult for students to understand math concepts, especially geometry. To overcome this problem, the developer developed a cultural context-based math E-Module that contains pictures, interesting illustrations, and interactive media. This E-Module is designed to make it easier for students to learn independently while supporting their mathematical literacy skills.

Previous research shows that E-Modules have a positive impact on mathematical literacy. (Efendi et al., 2024) developed E-Modules that directly support improving mathematical literacy. (Fathani & Pangestu, 2024) also found that integrating local culture into mathematics learning can improve students' understanding of mathematical concepts. In addition, research by (Cahyono & Budiarto, 2020; Susanto et al., 2022) showed that culture-based math E-Modules not only help students understand the material but also support the development of mathematical literacy by linking abstract mathematical concepts to real experiences based on local culture. Therefore, this E-Module is expected to improve students' mathematical literacy with an ethnomathematics approach significantly

Many E-Module development studies have been conducted to support mathematical literacy in mathematics learning. However, the development of interactive E-Modules by integrating cultural contexts in improving mathematical literacy skills has not been widely carried out. Therefore, researchers developed mathematics E-Modules with cultural contexts, to support valid, practical, and effective mathematical literacy skills with the ADDIE development model. This research can introduce local culture as a context in supporting students' mathematical literacy and can provide new experiences for students to learn by connecting technology with mathematics.

2. Method

The development of this E-Module refers to the ADDIE development model. The model is used because it has coherent, structured steps and can achieve development needs. The ADDIE model has five stages: Analyze, Design, Develop, Implement, and Evaluate.

2.1. E-Module Development Stages

2.1.1. Analyze

The analysis stage aims to determine the product that needs to be developed through observation and information gathering. The information was collected from an interview with a mathematics teacher from one of the private secondary schools in Banyumas. The selection of one teacher as a resource person was based on the consideration that the teacher has direct experience in teaching geometry materials, especially cone space, and understands the difficulties that students often experience. The analysis included needs analysis, student characteristics, and task analysis. Needs analysis aims to identify field problems and teaching materials to develop efficient and effective learning modules. Student analysis studies student characteristics based on education level and relevant materials.

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Task analysis identifies solutions by developing culture-based E-Modules to support students' mathematical literacy.

2.1.2. Design

The design of this E-Module includes determining the learning objectives of the material arrangement and interactive features that will be used in the module, such as animations, learning videos, and interactive practice questions. The E-Module is also equipped with cultural contexts related to cones, such as bamboo steamers (kukusan), and historical buildings, such as Monjali (monument jogja kembali). The E-Module is designed to be accessible through computer and smartphone devices, making it easier for students to learn outside the classroom. Storyboarding is done at this stage to map the learning flow.

2.1.3. Development

At this stage, the E-Module begins to be developed in accordance with the design. Development is carried out using Canva to design and develop modules until they are suitable. The developed module includes material about the basic concepts of cones and how to calculate the surface area and volume. Material expert validators and media experts also carried out the validity test of the E-Module at this stage.

2.1.4. Implementation

The implementation phase was conducted in one of the private junior high schools in the Banyumas district, involving 22 seventh-grade students who became the research sample. Students were given E-Modules to study for four meetings, and teachers provided guidance on the use of E-Modules in the learning process. During the implementation, students used the module outside class hours to deepen their understanding of cones. Practicality and effectiveness tests were conducted at this stage. The practicality test was conducted by distributing response questionnaires to use E-Modules to teachers and students of the research subjects, and the effectiveness test was conducted by distributing mathematical literacy test questions to students. The mathematical literacy test questions with cone material relate to problems in everyday life, such as conical farmer's hats and cone-shaped tumpeng rice.

2.1.5. Evaluation

Evaluation is done after receiving suggestions and input from validity, practicality, and effectiveness tests. The suggestions and input are then improved so that the E-Modules developed can be valid, practical, and effective.
This study's subjects were 22 seventh-grade students at one of the private secondary schools in Banyumas. The sample selection was based on communication with the mathematics teacher.

2.2. Processing of Data

This research will produce a mathematics E-Module product with a cultural context to support mathematical literacy skills that are valid, practical, and effective so that it needs proper data collection and processing. Data were collected through instruments that had been prepared and then analyzed using qualitative and quantitative descriptive analysis techniques. Qualitative data is

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data obtained from respondents' input and suggestions. The respondents in question include material and media expert validators, teachers, and students. Quantitative data is data obtained in the form of results of filling out questionnaires by validators of material experts and media experts, teachers, and students in the form of assessment scores. The following is an explanation of each test used in this study:

2.2.1. Validity Test

The validation sheet consists of an E-Module validation sheet, teacher and student response questionnaire validation sheet, and test question validation sheet. The E-Module validation sheet is used to determine the validity/feasibility of the E-Module, which material experts and media experts assess. The teacher and student response questionnaire validation sheet are used to determine the feasibility of teacher and student response questionnaires before use. The test question validation sheet is used to determine the feasibility of the test questions before use. Expert validators carried out this validation. Expert validators are lecturers from the field of Mathematics Education. The validation sheet uses four options, namely very suitable with a score of 4, ideal with a score of 3, less suitable with a score of 2, and not perfect with a score of 1. Analysis of the assessment results from the validator is based on the average score obtained. The data analysis technique of the E-Module validation test results was analyzed from the formula adapted from the following:

$$P = \frac{\sum X}{\sum X_i} \times 100\% \quad (1)$$

Description:

P	:	Validity Percentage
X	:	Response Score per Item
X_i	:	Maximum Total Score per Item

The calculation results using the formula are interpreted and concluded as follows, according to the evaluation classification criteria shown in Table 1.

Table 1. Validation Assesment Criteria

Criteria	Category	Validity
$90\% \leq P \leq 100\%$	Very good	No need for revision
$75\% \leq P \leq 89\%$	Good	No need for revision
$65\% \leq P \leq 74\%$	Fair	Revision
$55\% \leq P \leq 64\%$	Less	Revision
$0\% \leq P \leq 54\%$	Very Less	Revision

Source: (Santosa et al., 2017)

2.2.2. Practicality Test

The practicality of E-Modules was measured using teacher-response questionnaires and student-response questionnaires. Teacher and student response questionnaires use four options, namely very suitable with a score of 4, ideal with a score of 3, less suitable with a score of 2, and not perfect with a score of 1. The data analysis technique of practicality is carried out in five stages. The first stage is to recapitulate the scores of teacher and student response

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questionnaire sheets, and the second stage is to calculate the average score of each response with the following formula.

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n} \quad (2)$$

Description:

$\bar{x}$: Average Score
x_i : The Score of the Question- i, with $i \epsilon N$
n : The Number of Students

The third stage is to complete the answer criteria on each teacher response questionnaire and student response questionnaire according to the following table.

Table 2. Criteria of Response Questionnaire

Average Interval	Response Criteria
$3{,}251 < \bar{x} \leq 4{,}00$	Excellent
$2{,}501 < \bar{x} \leq 3{,}250$	Good
$1{,}751 < \bar{x} \leq 2{,}500$	Less
$0{,}00 \leq \bar{x} \leq 1{,}750$	Not Good

Source: modified from (Purnomo & Palupi, 2016)

The fourth stage is to calculate the percentage of practicality, namely K, with the following formula.

$$K = \frac{S}{N} \times 100\% \quad (3)$$

Description:

K : Practicality Percentage
S : Number of Students who Gave Good and Excellent Responses
N : The Number of Students

The fifth stage is to conclude the criteria for the practicality of E-Modules according to the following Table 3.

Table 3. Criteria for E-Module Practically

Practicality Criteria	Description
$85\% \leq K \leq 100\%$	Very practical, can be used without revision
$70\% \leq K \leq 85\%$	Moderately practical, can be used but needs minor revisions
$50\% \leq K \leq 70\%$	Less practical, and not recommended for use because it needs significant revisions
$0\% \leq K \leq 50\%$	Not practical, cannot be used

Source: modified from (Akbar, 2013)

2.2.3. *Effectiveness Test*

The effectiveness of E-Modules in supporting mathematical literacy skills can be known through pretest and posttest scores. The pretest was conducted before

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students studied cones using E-Modules, and the posttest was conducted after students studied cones using E-Modules. The scores obtained are then analyzed using the $N - Gain$ score to determine the significant difference between the test results before and after the use of E-Modules.

The $N - Gain$ test, which stands for Normalized Gain, is a commonly used method to measure the effectiveness of a learning or intervention in improving student learning outcomes. The $N - Gain$ scores range from -1 to 1. A positive value indicates an increase in learner learning outcomes after learning. Meanwhile, negative values indicate a decrease in learner learning outcomes. The $N - Gain$ score can be calculated as follows.

$$N - Gain = \frac{Posttest\ score - Pretest\ score}{Ideal\ score\ - \ Pretest\ score} \tag{4}$$

The level of significant of the E-Module being developed is interpreted using the $N - Gain$ score criteria in Table 4.

Table 4. The $N - Gain$ Score Criteria

$N - Gain$ **Value**	**Criteria**
$0{,}70 \leq N - Gain \leq 1{,}00$	High
$0{,}30 \leq N - Gain < 0{,}70$	Medium
$0{,}00 < N - Gain < 0{,}30$	Low
$N - Gain = 0{,}00$	No Increase
$-1{,}00 \leq N - Gain < 0{,}00$	There is a Decrease

Source: (Sukarelawa et al., 2024a)

The level of effectiveness of implementing interventions is determined by using the $N - Gain$ percentage, as Equation 5.

$$N - Gain\ Percentage = \frac{Posttest\ score - Pretest\ score}{Ideal\ score\ - \ Pretest\ score} \times\ 100\% \tag{5}$$

The criteria of $N - Gain$ percentage result shows the level of effectiveness that is obtained.

Table 1. Criteria of Effectiveness Level

Percentage (%)	**Criteria**
$N - Gain\ Percentage < 40\%$	Not effective
$41\% \leq N - Gain\ Percentage \leq 55\%$	Less effective
$56\% \leq N - Gain\ Percentage \leq 75\%$	Moderately effective
$N - Gain\ Percentage \geq 76\%$	Effective

Source: (Sukarelawa et al., 2024b)

Researchers and observers assessed the test scores obtained to ensure consistency of assessment and to ensure that they were not influenced by subjective factors. Inter-rater reliability testing was conducted using Cohen's kappa coefficient. The formula for determining Cohen's kappa coefficient is as follows (Viera & Garrett, 2005).

$$KK = \frac{p_o - p_e}{1 - p_e} \tag{6}$$

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Description:

KK	:	Cohen's Kappa Coefficient
p_o	:	The Observed Agreement Aroportion between Raters
p_e	:	The Expected Agreement Proportion due to Chance

Cohen's kappa coefficient interprets the strength of agreement as shown in Table 6.

Table 6. Interpretation of the Kappa Value

Cohen's Kappa Coefficient	Agreement
$KK < 0$	Less than chance agreement
$0{,}01 \leq KK \leq 0{,}20$	Poor agreement
$0{,}21 \leq KK \leq 0{,}40$	Fair agreement
$0{,}41 \leq KK \leq 0{,}60$	Moderate agreement
$0{,}61 \leq KK \leq 0{,}80$	Substansial agreement
$0{,}81 \leq KK \leq 0{,}99$	Almost perfect agreement

Source: (Viera & Garrett, 2005)

3. Results and Discussion

This section will explain the research results on the development of mathematics E-Modules with a cultural context to support mathematical literacy.

3.1. Analysis

This analysis stage is carried out to obtain the data needed in E-Module planning. At this stage, researchers made initial observations about the situation and conditions in learning at one of the private secondary schools in Banyumas. Mathematics learning is carried out using an the Merdeka curriculum based on the general curriculum used at this time. The use of the Merdeka curriculum has a significant impact on the teaching and learning process. Based on interviews with teachers, he said that one of the positive impacts of using this curriculum is that teachers can choose the material to be taught according to student abilities and school readiness. However, the school is still constrained by the selection of textbooks that are used only as a single learning source and teachers who only present the material as a supplement. This attracts researchers to introduce teaching materials that are easy to use and interactive so that they can increase student

The researchers made observations related to the situation and initial conditions of mathematics learning at school; from this, it was found that schools had difficulty carrying out the learning system using the Merdeka curriculum reference, especially in learning mathematics. This is due to students needing more time to be ready to use the system, and the time allocated to math learning activities tends to decrease with many targets and achievements; this makes teachers required to be creative and innovative in teaching and learning activities. In learning mathematics, teachers use the Merdeka curriculum package textbook as a learning resource and added several 2013 curriculum package books as support. The teacher stated that students are interested in learning geometry, especially curved-sided spaces that are associated with the context of everyday life. One of the contexts that is closely related to everyday life is the

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cultural context.

Based on interviews with several students, it was found that students like mathematics because students are curious about the final answer to the problem they are solving. However, many of them stop solving the problem because they are confused and doubtful about solving the solution. Another thing that students expressed in the interview process was that students like learning that can be related to everyday life. Students are also interested in learning that uses digital or internet-based teaching materials so that students can more easily access materials and practice questions. From several analyses that researchers have carried out, researchers feel the need to overcome this by providing a solution in the form of an E-Module or electronic module by linking culture to learning mathematics on cone material.

3.2. Design

At this stage, the researcher creates an E-Module design that will be developed and starts preparing E-Module content and instruments for valid, practical, and effective E-Module assessment. The following is a description of the design compiled in the study.

3.2.1. Preparation of E-Module Content

The preparation of E-Module content refers to the Merdeka curriculum. The E-Module content contains learning outcomes, keywords, student profiles of Pancasila learning activities, student reflections, and assignments. The E-Module content is organized into storyboards to facilitate the E-Module development process. The prepared E-Module content is associated with the cultural context of the E-Module. The addition of cultural context at the beginning of the E-Module as an example of objects in everyday life that are cone-shaped, such as traffic cones or the traditional house of Wae Rebo village called "Mbaru Niang" then there are also examples and practice questions that use the context of cones so that the E-Module that is compiled is easier for students to understand.

3.2.2. Preparation of E-Module Assesment Instruments

The preparation of E-Module assessment instruments on cone material to support mathematical literacy skills is done by compiling five E-Module validation sheets, student response questionnaire sheets, and evaluation test questions. The E-Module validation sheets prepared are material expert validation sheets, media expert validation sheets, teacher response questionnaire validation sheets, student response questionnaire validation sheets, and evaluation test question validation sheets.

3.3. Development

At this stage, the researcher compiled the E-Module according to the design made at the previous stage. E-Modules are compiled using the *Canva* application. The results of this stage are described in 4 sections as follows:

3.3.1 Development of E-Module Content

The final product is an E-Module used on cone material to support mathematical literacy skills. The E-Module design was developed into an easy-to-use module using the *Canva* application. At this stage, cone material was also added, and

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other media, such as learning videos, interesting animations, and images that are under the material, were selected as support. Sample problems and practice questions that support mathematical literacy skills began to be added at this stage.

Figure 1. Math E-Modules with Cultural Context that have been Developed

3.3.2 Validity Test

Material experts and media experts conducted the validity test of the E-Module. In the validity test by the material experts, the average score obtained was 80%, so the developed E-Module falls into the good/suitable category according to Table 1 of the validity criteria. Suggestions from the material experts include (1) Adding cone volume proof practices. (2) Adding evaluation components to the module.

In the validity test of the E-Module by the media experts, the average score obtained was 83%, so the developed E-Module falls into the good/suitable category. Suggestions from the media experts include (1) providing clear and detailed instructions for using the E-Module and (2) correcting writing errors in the E-Module. Furthermore, revisions were carried out according to the suggestions that had been received. In addition to the validity test of the E-Module, the researcher also tested the validity of the teacher response questionnaire, student response questionnaire, and test questions that would be used to test students' mathematical literacy skills.

The results of the teacher response questionnaire validity test, the average score obtained was 82%, so the teacher response questionnaire was included in the good/suitable for use category according to Table 1 validity criteria. The validator's suggestion is to add an assessment indicator about "evaluation". The results of the student response questionnaire validity test were 89%, so the student response questionnaire can be used with revisions according to suggestions. The validator's suggestion is to add an assessment indicator about "evaluation".

The results of the test question validity test were 87.5%, so the test questions were included in the good/suitable for use category. The validator's suggestion is (1) Correcting spelling errors in the questions and (2) Rewriting the questions in question number two. The results of the validity test that have been carried out are in accordance with research (Santi et al., 2024), which shows the importance of validating materials and media in developing learning tools to ensure their effectiveness in the classroom. This finding supports the results of (Fahrurrozi & Rahmawati, 2021), which also found that the validity of evaluation instruments,

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such as questionnaires and test questions, had a significant effect on the success of implementing learning tools. This shows the importance of validity in the instruments used to measure learning outcomes.

3.4. Implementation

The results of the implementation stage are described as follows

3.4.1. Preparing Teachers

Mathematics teachers guide learning by applying mathematics E-Modules with cultural contexts to support mathematical literacy. The teacher explains the learning activities in the E-Module.

3.4.2. Preparing Students

The subject of the implementation was the seventh grade at a private junior high school in Banyumas in 2023/2024, totalling 22 students. Learning was carried out using an E-Module on the cone material. The learning process was carried out according to the plan agreed upon with the school for four meetings. Before carrying out the learning process, students were asked to take a pretest on mathematical literacy skills. Students were also guided to learn the stages of cooperative learning in 3 meetings using an E-Module. Learning took place through the stages of learning activities in the E-Module. At the last meeting, a posttest was carried out as a learning achievement.

3.4.3. Practically Test

The practicality assessment of the E-Module was carried out by teachers who teach mathematics in the class using a response questionnaire. The results of the teacher response questionnaire obtained an average result of 93.48%, which means that the E-Module is included in the very practical criteria according to Table 3 of the practicality criteria for the E-Module. The advice given by the teacher on the response questionnaire sheet is that the developed E-Module is in accordance with the indicators and is interesting, the input for the E-Module is given a page so that students/teachers can quickly mention the parts to be delivered or marked.

Practicality is also measured using a student response questionnaire. The response questionnaire was given to students after using the E-Module. The average student response questionnaire of 87.5% is included in the very practical criteria according to Table 3 of the practicality criteria for the E-Module so that the developed E-Module can be used without revision and is easy to use. Other comments given by students regarding the use of the E-Module are as follows.

Table 7. Criticisms and Suggestions from Student Response Questionnaires

No.	Comments
1.	*Asyik, bisa dijadiin pengalaman! Terimakasih ust.*
2.	*Sebaiknya lebih dijelaskan lebih lanjut*
3.	*Pembelajaran kerucut ini sangat baik sehingga saya mengerti tentang kerucut*
4.	*Usahakan menjelaskan lebih lanjut, juga jangan cepat-cepat menjelaskannya*
5.	*E-Modulnya bagus, soalnya jangan susah*
6.	*Terimakasih telah membimbing dan mengajari kami semua*
7.	*Pembelajarannya harus lebih beragam lagi ya. Makasi materinya ust*

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Based on the comments given, there are several constructive inputs and positive sentences after using the E-Module. This supports the results of the average value obtained so that it can strengthen the statement that the developed E-Module is practical to use. This statement is in line with research conducted by (Safitri & Astuti, 2023), which states that E-Modules with a practical and easy-to-use cultural context can be a success factor in learning and supporting students' literacy mathematics skills.

3.4.4. Effectiveness Test

The effectiveness test was carried out by providing test questions consisting of two questions discussing the application of cones that can support mathematical literacy skills. The duration of the questions is 60 minutes. The results of the scores obtained by students after working on the mathematical literacy test questions are then tested with $N - Gain$.

Table 8. The $N - Gain$ Assesment

Average $N - Gain$ Score	Percentage
0,632772	63,166%

Based on the results of the analysis according to the results of the $N - Gain$ test and Table 4 $N - Gain$ criteria and Table 5 $N - Gain$ Percentage, it was identified that all students increased their mathematical literacy skills with two different categories, namely medium and high. 18 students were included in the medium category, 81.81%, and four students were included in the high category, 18.18%. Overall, the average $N - Gain$ score was 0.632273 and was included in the moderate increase category. Determining the effectiveness of developing a mathematics E-Module with a cultural context to support mathematical literacy skills can be seen from the $N - Gain$ percentage. The $N - Gain$ percentage obtained was 63.166% and was included in the moderately effective category.

Most students showed an increase in their' mathematical literacy skills in the moderate category. Some students showed an increase in the high category. Factors that influenced this increase include the E-Module only discussing the cone material, not thoroughly discussing curved side space shapes or other materials, and students need to be used to non-routine questions related to the cultural context to support mathematical literacy. Research conducted by (Rezky et al., 2022) explains the recommendations from their study that teachers need to provide questions that can measure students' numeracy literacy skills and can renew the implementation of the learning process in the classroom to support these competencies.

Based on the analysis results, Cohen's Kappa value obtained was 0.723, which is included in the "substantial agreement" category based on the interpretation in Table 6. This means that there is substantial agreement between observers in assessing the test data. It shows that the researcher are quite consistent in their assessments and are not influenced by subjectivity.

3.5. Evaluation Stage

The evaluation stage is carried out along with the E-Module development process. There were no revisions at the analysis and design stages, so that could be continued at the development stage. At the development stage, based on the

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validity test, the E-Module was evaluated according to the suggestions of expert validators until the E-Module was suitable for use without revision. At the implementation stage, input from teachers was in the form of additional pages to complete the material. At the same time, students suggested a more in-depth explanation that was not too fast, questions that were more appropriate to the difficulty level, and more diverse learning. Students also appreciated the E-Module as a fun learning experience and helped them understand the conic material. In the effectiveness stage, using more data with a quasi-experiment approach is recommended to increase the validity of the results. This improvement aims to make the E-Module more practical, effective, and relevant to the needs of students and teachers.

4. Conclusions

This development produced mathematics E-Modules with cultural context to support mathematical literacy. The developed mathematics E-Modules with cultural context are valid, practical and effective. The validity of the E-Module is based on the results of the validation of material experts and media experts with the average score obtained, which meets the valid criteria. The practicality of the E-Module is based on the results of the response questionnaire filled out by educational practitioners and students with the average score obtained, which meets the practical criteria. The effectiveness of the E-Module is based on the results of the scores of the evaluation questions filled in by students, who had an average percentage of N Gain score to meet the criteria quite effectively. E-Modules are feasible to use in learning activities, easy to use and can support mathematical literacy skills. The developed mathematics E-Module with cultural context is limited to cone material. Therefore, further research can be done to develop mathematics E-Modules with cultural contexts in other cultures and mathematics materials.

Author Contributions

The first author collected, processed, and analyzed the data and drafted the scientific article. The second and third authors provided feedback and suggestions for developing the research, analysis, and manuscripts.

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Declaration of Competing Interest

The authors declare that there are no conflicts of interest.

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How Adversity Quotient and Learning Independence Affect Students' Mathematical Problem-Solving Ability

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ABSTRACT

This study aims to analyze the influence of Adversity Quotient (AQ) and learning independence on students' mathematical problem-solving abilities and to explore problem-solving strategies based on differences in AQ and learning independence levels. The study employed a mixed-methods approach with a sequential explanatory design, involving 150 secondary school students. Results showed that AQ and learning independence significantly influenced problem-solving abilities, with learning independence having a greater impact. Students with high learning independence were more innovative and persistent, while those with low independence faced challenges. This study highlights the importance of developing AQ and learning independence to enhance students' problem-solving skills. Education should strengthen these aspects through strategies like project-based learning and resilience training, to better prepare students for real-world challenges.

1. Introduction

Adversity Quotient (AQ) is one of the key psychological factors in education, particularly in influencing students' mental resilience when facing challenges in the learning process (Hidayat et al., 2018; Safi'i et al., 2021). AQ, as proposed by Stoltz (1997), refers to an individual's capacity to face and overcome obstacles in life. In the context of education, AQ is closely related to students' ability to adapt to difficulties, such as complex mathematical problems that require critical

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thinking, focus, and perseverance (Putra et al., 2023; Qin et al., 2019).

Apart from AQ, another crucial factor in assessing students' ability to understand mathematics is learning independence. Learning independence refers to an individual's capacity to manage, plan, and take initiative in the learning process independently, without relying heavily on external support from teachers or peers (Zimmerman, 2002). Independent students tend to have high motivation, manage their time effectively, and seek the necessary resources to achieve their learning goals. Learning independence encompasses aspects of decision-making, planning, problem-solving, and self-evaluation within the educational context (Schunk, 2012; Zimmerman, 2002).

Problem-solving is one of the key elements in mathematics learning. It encompasses the ability to understand problems, formulate strategies, and identify as well as apply solutions (Kurnila et al., 2023). According to (Bariyyah, 2021; Franestian et al., 2020; Suparman et al., 2021), mathematical problem-solving ability involves an intelligent and rational cognitive process to identify problems and develop logical solutions. This process begins with problem recognition and concludes with achieving a solution, relying on sensory perception and critical thinking. Such ability is crucial for helping individuals effectively address everyday challenges.

To achieve excellence in mathematical problem-solving, individuals require a sufficient level of Adversity Quotient (AQ) and learning independence. AQ plays a vital role in building students' mental resilience when dealing with mathematical problems that require reasoning and strong analytical skills. This is supported by the findings of Lestari & Juandi (2023), who discovered that students with a high AQ demonstrate better problem-solving skills. Meanwhile, learning independence is essential, as self-reliant students can manage their learning processes more effectively, seek solutions independently, and overcome challenges with minimal external assistance. This aligns with the research conducted by Ismail et al. (2024), which states that students with high learning independence excel in communication and the utilization of mathematical tools, contributing to enhanced problem-solving abilities.

Social arithmetic in the mathematics curriculum is often a challenging topic for students. This area not only demands understanding of basic arithmetic concepts and linear programming but also their application in real-life contexts, such as financial problems, price comparisons, discounts, and interest rates. Research by (Hidayat et al., 2018; Naimnule et al., 2020; Pradika et al., 2019) indicates that students with higher mental endurance and positive attitudes toward difficulties tend to perform better in solving mathematical problems. Conversely, students with low AQ often feel overwhelmed or even avoid problems involving complex calculations in everyday contexts. Additionally, learning independence enables students to focus and stay consistent in solving problems while motivating them to keep learning and striving despite challenges. A combination of high AQ and good learning independence can significantly enhance students' efficiency and success in solving mathematical problems (Schunk, 2012; Zimmerman, 2002).

This study aims to analyze how Adversity Quotient (AQ) and learning independence influence students' ability to solve mathematical problems, particularly in the context of social arithmetic. The uniqueness of this research lies in combining two psychological variables—AQ and learning independence—

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within the domain of mathematical problem-solving, which are often studied separately. AQ, which focuses on an individual's ability to overcome obstacles and challenges, is expected to provide insights into how students manage cognitive and emotional difficulties when solving complex social arithmetic problems. Meanwhile, learning independence, encompassing self-management and initiative in the learning process, is seen as a crucial factor in enhancing problem-solving effectiveness, as independent students are better equipped to address challenges without relying on external assistance.

Another novelty of this study is the use of social arithmetic as a context for assessing mathematical problem-solving abilities, which is typically focused on other topics such as algebra or geometry. Social arithmetic involves the application of mathematical concepts to real-life scenarios, such as calculating discounts, profit, loss, taxes, or interest, requiring both analytical skills and practical understanding. Overall, this research contributes to the field of mathematics education by identifying psychological factors that enhance students' problem-solving skills and deepening our understanding of how AQ and learning independence interact in the context of social arithmetic.

Previous studies have shown that AQ is a key factor contributing to students' academic success across various domains, including mathematics (Safi'i et al., 2021). On the other hand, research by (Agoestanto & Masitoh, 2021) revealed that low AQ can pose significant barriers for students in developing the critical and analytical thinking skills needed to solve social arithmetic problems. Additionally, (Nuraini et al., 2023) demonstrated that learning independence also influences students' mathematical problem-solving abilities.

This study is expected to provide valuable insights for teachers and educators into the critical roles of AQ and learning independence in enhancing students' mathematical problem-solving abilities, particularly in social arithmetic. By leveraging these insights, teachers can design teaching strategies that focus on improving students' AQ and learning independence, helping them develop the skills needed to address various challenges in mathematics learning. Consequently, this research has the potential to make a practical impact on curriculum development and teaching approaches, promoting the reinforcement of AQ among students.

This study aims to enrich our understanding of the relationship between Adversity Quotient (AQ) and learning independence and their impact on students' mathematical problem-solving abilities, specifically in social arithmetic. The findings of this research can serve as a foundation for further studies exploring other psychological factors influencing problem-solving skills and evaluating the effectiveness of teaching strategies that emphasize the development of AQ and learning independence in mathematics education.

2. Method

The research approach employed in this study is a sequential explanatory design with a mixed-methods approach. The instruments used include questionnaires and tests. The questionnaire was designed to measure students' Adversity Quotient (AQ) and learning independence, while the test assessed their mathematical problem-solving abilities. The study began with the collection and analysis of quantitative data, followed by the collection and analysis of qualitative data to derive comprehensive conclusions from the findings

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(Wahyuni et al., 2024).

In the initial phase, quantitative data were gathered to evaluate the influence of AQ and learning independence on students' mathematical problem-solving abilities. In the second phase, semi-structured interviews were conducted to gain deeper insights into the quantitative results.

The study sample consisted of 150 students. This research examined how AQ and learning independence contribute to students' mathematical problem-solving abilities. Data on AQ and learning independence were collected using a Likert scale questionnaire ranging from 1 ("never") to 4 ("very often"). The data were analyzed using multiple regression tests to determine the significance of the relationships between variables. Subsequently, AQ and learning independence data were categorized into several groups: high AQ, low AQ, high learning independence, and low learning independence. To deepen the analysis, two students were selected as research subjects based on these categories: one student with high AQ and low learning independence, and another student with low AQ and high learning independence. This selection was made to provide a more specific understanding of their strategies in solving mathematical problem-solving tests, which were explored through in-depth interviews.

The influence of AQ and learning independence on arithmetic problem-solving abilities was analyzed using multiple regression tests, with problem-solving test scores as the dependent variable. Qualitative data analysis, including test results and interview protocols, followed an analysis model (Hembree, 1990) comprising data reduction, data presentation, and conclusion drawing. The validity of the quantitative data was tested through instrument validation procedures, including content validity assessed by expert judgment and reliability analysis using Cronbach's alpha. For the qualitative data, triangulation was applied by comparing the results of interviews, problem-solving test results, and observation notes to ensure the credibility and consistency of the findings. The test results were then compared between students with high AQ and low learning independence and those with low AQ and high learning independence.

3. Results and Discussion

A total of 150 vocational high school students completed questionnaires on AQ and learning independence, followed by solving mathematical problem-solving tasks. The test results are presented in the following table:

Table 1. Statistical Descriptions for Adversity Quotient, Learning Independence, and Problem-Solving Ability

	Mean	**Standard Deviation**
Adversity Quotient	60.31	12.20
Learning Independence	60.93	12.43
Mathematical Problem-Solving Ability	79.64	6.89

Table 1 above presents the statistical descriptions for the variables Adversity Quotient, Learning Independence, and Problem-Solving Ability. The mean value for the Adversity Quotient is 60.31 with a standard deviation of 12.2, indicating a moderate variation in students' ability to endure challenges. The mean for Learning Independence is 60.93 with a standard deviation of 12.43, showing a relatively similar variation. Meanwhile, Problem-Solving Ability has a mean

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score of 79.64 with a standard deviation of 6.89, reflecting a good level of problem-solving ability among students with smaller variability compared to the other two variables.

Before applying multiple linear regression to address the research questions, prerequisite analysis or classical assumption tests were conducted, including tests for normality, linearity, multicollinearity, and heteroscedasticity. In this study, the normality test was performed using a Normal P-P Plot on regression residuals. The results of this analysis are presented in the following figure:

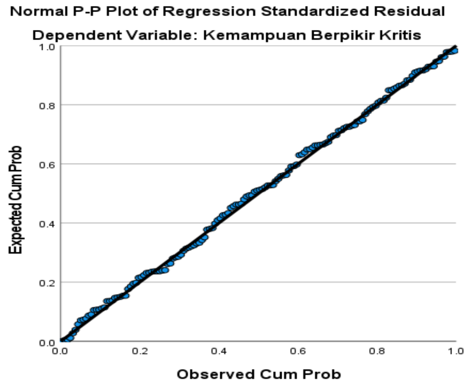

Figure 1. Normality Assumption Test P-Plot

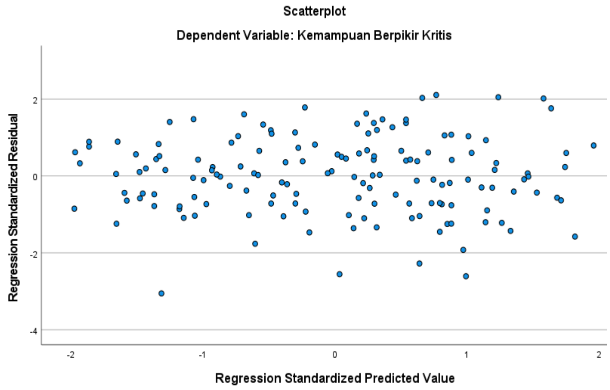

Figure 2. Heteroscedasticity Assumption Test Scatterplot

The plot above shows that the residual points are scattered around the diagonal line, indicating that the residual distribution is approximately normal. The deviation of the points from the diagonal line is minimal, leading to the conclusion that the data meets the normality assumption. This aligns with the statement by Purnomo (2017), who explained that the normality test in regression models is used to examine whether the residuals generated by the regression are normally distributed. One method for testing normality is by observing the distribution of data on the Normal P-P Plot; if the points are scattered around the line and follow the direction of the diagonal line, the residuals are considered normal (Lestari, et al., 2024). Therefore, the regression model used is deemed valid for further analysis. After confirming that normality is met, the next step is to conduct a heteroscedasticity test using a scatterplot.

Figure 2 presents the scatterplot for the heteroscedasticity test, utilizing residuals and standardized predicted values from the Problem-Solving Ability variable. The scatterplot shows that the residual points are randomly distributed around the horizontal line (axis 0) without displaying any particular pattern. The distribution does not form any widening (fan-shaped), narrowing, or curved patterns. Based on this pattern, it can be concluded that there is no indication of heteroscedasticity in the regression model. This conclusion is supported by Olvera Astivia & Zumbo (2019), who state that heteroscedasticity is usually defined as "non-constant error variance," indicating that the residual variability changes as a function of something not included in the model. They suggest that a scatter plot of residuals versus fitted values can be used to explore heteroscedasticity; a non-random pattern, such as a wedge-shaped (fan-shaped) pattern, can be indicative of heteroscedasticity. Similarly, Cho, et al. (2022) explains that in the context of linear mixed models, a scatter plot of residuals

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versus fitted values can reveal heteroscedasticity if patterns like a wedge shape are present. The absence of such patterns suggests homoscedasticity, meaning the variance of residuals is constant. Therefore, the random distribution of residuals around the horizontal axis without specific patterns in the scatterplot indicates that the assumption of homoscedasticity is met, and there is no evidence of heteroscedasticity in the regression model.

This study also involved a multicollinearity test to ensure that the independent variables, AQ and learning independence, do not have strong correlations with each other. Multicollinearity occurs when there is a significant relationship between independent variables. Since this study uses multiple linear regression analysis, it is important to avoid multicollinearity. Data is considered free from multicollinearity if the tolerance value exceeds 0.8 and the Variance Inflation Factor (VIF) is less than 10. The results of the multicollinearity test are presented as follows:

Table 2. Multiple Linear Regression Analysis

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	54.459	3.155		17.260	.000		
	Adversity Quotient	.142	.038	.251	3.700	.000	.993	1.007
	Learning Independence	.273	.038	.492	7.237	.000	.993	1.007

a. Dependent Variable: Mathematical Problem-Solving Ability

Based on the Coefficients Table above, the analysis results indicate no multicollinearity between the independent variables, AQ and learning independence. This is evidenced by a tolerance value of 0.993, which exceeds the minimum threshold of 0.1, and a Variance Inflation Factor (VIF) value of 1.007, which is below the upper limit of 10. Therefore, the regression model is free from indications of multicollinearity and can be used for further analysis. This conclusion is supported by O'Brien (2007), who stated that a VIF value above 10 is often considered indicative of serious multicollinearity; however, this threshold should be evaluated in the context of other factors influencing the variance of regression coefficients. Hence, the VIF value of 1.007 in this analysis indicates that multicollinearity is not a significant issue in the regression model used.

To evaluate the influence of each independent variable on the dependent variable, a partial t-test was conducted using multiple regression analysis. This study examines how AQ and learning independence individually affect mathematical problem-solving ability, as detailed in Table 2. The resulting multiple linear regression equation is:

$$y = 54.459 + 0.142X_1 + 0.273X_2 \quad (1)$$

where X_1 represents AQ, X_2 represents learning independence, and y denotes mathematical problem-solving ability.

The regression analysis results indicate that both independent variables, AQ and learning independence, have a significant influence on the dependent variable. This is supported by the significance value (Sig.) of 0.000 (< 0.05) for

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AQ, indicating that its influence on problem-solving ability is statistically significant. The regression coefficient (B) of 0.142 shows that a 1% increase in AQ contributes to a 0.142% increase in problem-solving ability, assuming other variables remain constant. Similarly, the significance value (Sig.) of 0.000 (< 0.05) for learning independence demonstrates a significant impact on problem-solving ability, with a regression coefficient (B) of 0.273. This implies that a 1% increase in learning independence improves problem-solving ability by 0.273%, assuming other variables are held constant.

From Table 2, it can be observed that the t-values for AQ (3.7) and learning independence (7.237) exceed the critical t-value (1.655), indicating that AQ and learning independence are good predictors in the multiple linear regression model. Therefore, this model demonstrates that AQ and learning independence significantly contribute to enhancing students' problem-solving abilities.

After evaluating the partial effects of each variable, the simultaneous influence of AQ and learning independence on problem-solving ability was analyzed using the F-test. If the significance value (Sig.) is below 0.05, it can be concluded that AQ and learning independence jointly influence problem-solving ability, as shown in Table 3 below.

Table 3. ANOVA Test Results

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2307.957	2	1153.979	35.548	.000[b]
	Residual	4771.939	147	32.462		
	Total	7079.896	149			

a. Dependent Variable: Mathematical Problem-Solving Ability
b. Predictors: (Constant), Learning Independence, Adversity Quotient

Based on Table 3, the results of the ANOVA test indicate that the overall regression model is significant in predicting problem-solving ability based on Adversity Quotient (AQ) and learning independence. The calculated F-value (35.548) is greater than the critical F-value (3.058), with a significance value (Sig.) of 0.000, which is less than 0.05. This demonstrates that AQ and learning independence simultaneously have a significant effect on students' mathematical problem-solving ability. This conclusion is supported by studies showing that AQ plays an essential role in mathematics learning, particularly in problem-solving, reasoning, and creativity. Students with high AQ exhibit superior abilities in understanding, planning, executing, and evaluating problem solutions and possess strong semiotic reasoning (Putra, et al., 2023). Moreover, the analysis of variance (ANOVA) is commonly used to test the overall significance of a regression model. The F-test in ANOVA evaluates whether the regression model provides a better fit to the data compared to a model without predictor variables. An F-value greater than the critical F-value indicates that the regression model is statistically significant (O'Brien, 2007). Thus, the significant ANOVA results suggest that the regression model, which includes AQ and learning independence, has a meaningful influence on students' mathematical problem-solving ability.

Therefore, AQ and learning independence can be considered important factors influencing students' problem-solving skills. The percentage contribution of AQ and learning independence to problem-solving ability is presented in the

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following table:

Tabel 4. Model Summary AQ, Kemandirian Belajar dan Kemampuan pemecahan masalah

Model Summary[b]

Model	**R**	**R Square**	**Adjusted R Square**	**Std. Error of the Estimate**
1	.571[a]	.326	.317	5.69756

a. Predictors: (Constant), Learning Independence, Adversity Quotient
b. Dependent Variable: Mathematical Problem-Solving Ability

Referring to Table 5, it is evident that Adversity Quotient (AQ) and learning independence contribute **32.6%** to the problem-solving ability of vocational high school students, as indicated by the R-square value.

3.1. Description of Student Responses Based on AQ and Learning Independence Levels Subject with Low AQ and High Learning Independence (CEA)

In solving this problem, the first step taken by the CEA subject is to identify the variables needed to solve the problem. Next, the subject states and writes down all information about the problem comprehensively and sequentially, as shown in Figure 3 below:

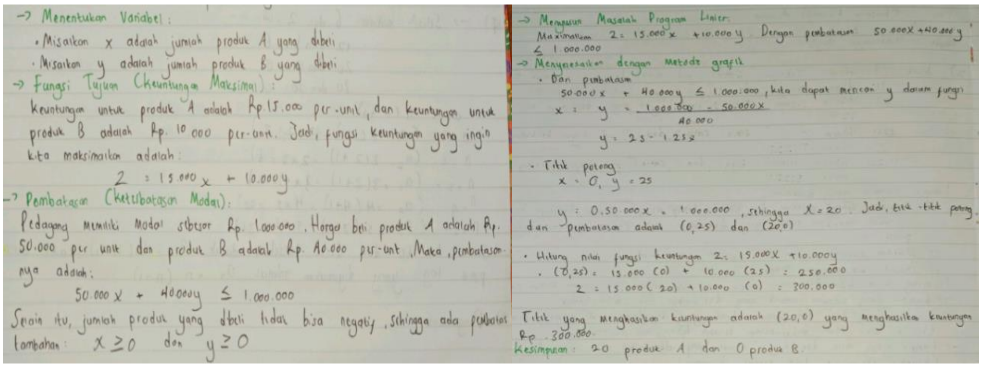
-> Menentukan Variabel :
• Misalkan x adalah jumlah produk A yang dibeli
• Misalkan y adalah jumlah produk B yang dibeli
-> Fungsi Tujuan (Keuntungan Maksimal) :
keuntungan untuk produk A adalah Rp.15.000 per-unit, dan keuntungan untuk produk B adalah Rp. 10 000 per-unit. Jadi, fungsi keuntungan yang ingin kita maksimalkan adalah :
Z = 15.000x + 10.000y
-> Pembatasan (Keterbatasan Modal) :
Pedagang memiliki modal sebesar Rp. 1000.000, Harga beli produk A adalah Rp. 50.000 per unit dan produk B adalah Rp. 40.000 per-unit, Maka, pembatasannya adalah :
50.000x + 40000y ≤ 1.000.000
Selain itu, jumlah produk yang dibeli tidak bisa negatif, sehingga ada pembatasan tambahan : x ≥ 0 dan y ≥ 0
-> Menyusun Masalah Program Linier
Maximalkan Z = 15.000x + 10.000y Dengan pembatasan 50.000x + 40.000y ≤ 1.000.000
-> Menyelesaikan dengan Metode grafik
• Dari pembatasan
50.000x + 40.000y ≤ 1.000.000, kita dapat mencari y dalam fungsi x : y = (1.000.000 - 50.000x) / 40.000
y = 25 - 1.25x
• Titik potong
x = 0, y = 25
y = 0, 50.000x = 1.000.000, sehingga x = 20. Jadi, titik-titik potong dan pembatasan adalah (0,25) dan (20,0)
• Hitung nilai fungsi keuntungan Z = 15.000x + 10.000y
• (0,25) = 15.000 (0) + 10.000 (25) = 250.000
Z = 15.000 (20) + 10.000 (0) = 300.000
Titik yang menghasilkan keuntungan adalah (20,0) yang menghasilkan keuntungan Rp. 300.000
Kesimpulan : 20 produk A dan 0 produk B.

Figure 3. CEA Subject's Answer Sheet

Based on Figure 3, it can be observed that the CEA subject understands the step-by-step process to solve the problem. This includes defining variables, formulating the objective function, determining constraints for profit, identifying test points, and evaluating the objective function to arrive at the total products to be purchased to maximize the trader's profit.

To confirm the subject's AQ, learning independence, and problem-solving ability, the researcher conducted an interview with the subject. The results of the interview can be seen in the following transcript:

R : What do you usually do when faced with a very difficult problem that you cannot solve immediately?
S : Usually, ma'am, if the problem is difficult and I can't solve it, I often feel frustrated and confused.
R : How do you feel when you try to solve the problem but fail several times?
S : Hehe, usually if I fail several times, I feel hopeless, ma'am. It feels like

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all my efforts are in vain, and I lose the motivation to try solving it again.
R : Do you often study independently?
S : Yes, ma'am, I do.
R : What do you usually do to understand new material independently?
S : When there is new material, I prefer rereading the material in the book or looking for explanation videos online. I also try to solve practice problems on my own to understand the concepts better.
R : Do you have a study schedule outside school hours?
S : Yes, ma'am, I do. At home, after dinner, I usually set aside one or two hours for studying. During this time, I usually finish my assignments or just work on practice problems.
R : Okay, now let's look at solving this problem. How do you determine the first step when solving a problem involving several steps or concepts like this one?
S : Usually, ma'am, I read the problem carefully and write down the given information and what is being asked. Then, I think about the most logical step to take first. Like in this problem, I started by reading the question, writing down the information, and solving it step by step based on what I understood.
R : Do you usually recheck your work?
S : Yes, ma'am, I do. Especially when I understand the concept well, I make sure to do it properly and double-check to see if my work is correct.
R : If you find two different ways to solve a problem, how do you decide which one is better?
S : I usually choose the method I understand best—one that is simpler or faster to give the answer, as long as the result is still correct.

Based on the interview results above, it has been confirmed that this subject possesses a low Adversity Quotient (AQ), as indicated by their tendency to feel easily frustrated and discouraged when facing difficulties. However, they demonstrate a high level of independent learning through their initiative in self-study and maintaining a regular study schedule. Additionally, the student exhibits strong problem-solving skills, as evidenced by their systematic approach to understanding, solving, and analyzing mathematical problems.

3.2. Subject with High AQ and Low Independent Learning (YGAM)

In solving this problem, the initial step taken by this subject was to write down the information they understood related to the problem. Subsequently, they proceeded to solve the problem based on their understanding. The problem-solving process of the YGAM subject can be seen in the following figure:

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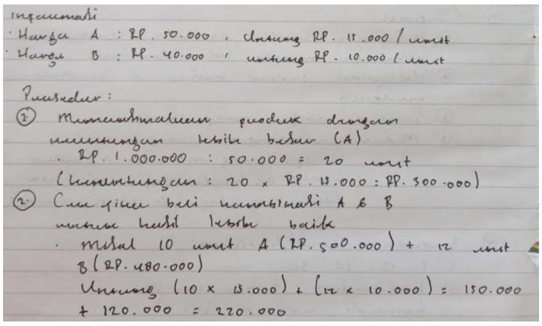

Figure 4. Answer Sheet of Subject YGAM

Based on Figure 4 above, the student's work shows that they have a basic understanding of the initial information in the problem but face difficulties in planning and devising a systematic solution strategy. YGAM correctly listed the purchase price of products A and B, as well as the profit per unit for each product. The subject's understanding of the basic information in this problem is quite good. Additionally, the subject tried to calculate the maximum number of units of product A that could be bought with the available capital. However, YGAM focused only on one product (product A) without considering the combination of products A and B to maximize profit. This indicates that YGAM did not understand that the goal of the problem was to find the optimal combination of products A and B. In the next step, YGAM tried to calculate the profit from purchasing product A and part of product B randomly (10 units of A and 12 units of B). This step shows that YGAM has not used a systematic approach (such as a system of linear equations or a combination table) to find the combination that maximizes profit. The main mistake made by YGAM was not considering all possible combinations of units of A and B within the budget constraint of Rp1,000,000. The subject also did not check if the total capital matched the number of units selected.

To confirm the AQ, learning independence, and problem-solving abilities of the student, the researcher conducted an unstructured interview with YGAM. The results of the interview can be seen in the following interview transcript:

R : What do you usually do when you encounter a very difficult problem or one that cannot be solved immediately?
S : Usually, ma’am, when I find a difficult problem and can't solve it, I often ask a friend sitting next to me or someone I'm close to for help in solving the problem together.
R : How do you feel when you try to solve the problem but fail several times?
S : Hehe, honestly ma’am, I usually think, 'Maybe there's something wrong with my steps.' So, I try again with a different approach. Or if not, I immediately ask a friend whom I think can help.
R : Do you often study independently?
S : Not often, ma’am. I usually prefer learning when someone explains, like a teacher in class or a friend. When I study alone, I often get confused about where to start, so I tend to wait for an explanation or help from someone else.
R : I see. Ok, now let’s look at how you solved this problem. How do you

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determine the first step when solving a problem that involves multiple steps or concepts, like this one?

S : I usually read the problem carefully first, ma'am, then write down the information I know, like the prices of the products or the profits. After that, I try to calculate the maximum number of one product that can be bought with the available capital. If there are further steps, I try to solve them as I understand, for example, calculating the total profit from the number of products I've selected.

R : Okay, in this solution, you first calculated the profit for one product. Can you tell me why?

S : I think, ma'am, it's easier to focus on one product first because if I try to calculate both products at once, I'm afraid I'll get confused and make mistakes. So, I try to solve one at a time first.

R : Alright, then why did you end up using 10 units of product A and 12 units of product B in this solution?

S : Actually, ma'am, I don't quite understand the right way to solve this problem. I don't know the correct combination for the number of products A and B, so I just randomly tried the numbers 10 for product A and 12 for product B. At that time, I thought the result was close to the available capital, so I used that for the number of products A and B.

Based on the interview results, it has been confirmed that the respondent shows a fairly good AQ, as seen from their willingness to keep trying and not giving up easily, even after failing several times while solving the problem. They are able to learn from their failures and try different approaches to solve the problem. However, this respondent lacks independence in learning, which suggests that they need more external support or guidance in the learning process. Their learning independence could be improved through practice, such as starting to study without relying on others or more frequently overcoming difficulties on their own. The respondent's problem-solving ability is still lacking. Although they attempt to approach the problem in a structured way, they do not apply the correct concepts to find the solution, instead resorting to trial and error to arrive at a solution. This indicates a lack of confidence in determining the correct steps.

Based on the summary of the research data, it was found that the average Adversity Quotient (AQ) of students was 60.31 with a standard deviation of 12.20, indicating that most students have a moderate level of resilience when facing difficulties. According to (Erza et al., 2024), an AQ in the moderate category reflects that students tend to be able to persevere in difficult situations, although they are not yet optimal in overcoming challenges independently. In addition, the average learning independence score was 60.93 with a standard deviation of 12.43, showing a similar distribution to AQ. Zimmerman (1990) emphasizes that learning independence is an important predictor of academic success, where students with high independence tend to have greater intrinsic motivation. The mathematical problem-solving ability, with an average of 79.64 and a standard deviation of 6.89, indicates that students generally have good skills in solving complex problems. This finding is in line with research by (Agustin et al., 2024), which states that mathematical problem-solving ability is influenced by experience and repeated problem-solving practice.

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In this study, the multiple linear regression analysis showed that AQ and learning independence contribute positively to mathematical problem-solving ability. The regression coefficient for AQ was 0.142, confirming that an increase in AQ directly improves problem-solving ability. Research by (Pratiwi & Mudrikah, 2024) supports this finding, where high AQ is positively correlated with perseverance in solving complex problems. Meanwhile, the regression coefficient for learning independence was 0.273, indicating that this variable has a greater influence. This is in line with research by Karlen et al. (2021), which found that students with high learning independence are more likely to seek innovative solutions. Since learning independence has a more significant influence than AQ, it can be concluded that even if a student has low AQ (like subject CEA), this does not preclude them from demonstrating good problem-solving skills, as explained in the findings of this study. Conversely, students with low learning independence (like subject YGAM) tend to struggle in solving problem-solving tasks, especially due to a lack of independent practice and learning outside the school environment.

Based on the simultaneous test results (F Test), the calculated F value of 35.548, which is greater than the F table value, indicates that AQ and learning independence together have a significant effect on problem-solving ability. This finding is consistent with research by (Code, 2020; Dadandii, 2023), which shows that psychological factors and self-learning skills have a synergistic impact on academic achievement. The coefficient of determination (R Square) value of 0.326 indicates that 32.6% of the variability in problem-solving ability is explained by AQ and learning independence. The remaining variability is explained by other factors, such as learning experience and environmental support. Although the R Square value is not very high, it is sufficient to show that the model is relevant in the context of education.

The integration of quantitative and qualitative research results provides deeper insights into the relationship between AQ, learning independence, and mathematical problem-solving ability. Quantitatively, the regression analysis highlights that both AQ and learning independence significantly influence problem-solving ability, with learning independence showing a greater effect. This aligns with the qualitative findings, where students with high learning independence (e.g., subject CEA) demonstrated systematic and effective problem-solving strategies despite having low AQ. Conversely, students with high AQ but low learning independence (e.g., subject YGAM) struggled to independently develop structured solutions, highlighting their reliance on external guidance. These findings suggest a complementary relationship: while AQ supports persistence and resilience, learning independence plays a more prominent role in fostering autonomy and innovation in problem-solving. The combined results emphasize that enhancing both traits simultaneously can lead to more robust improvements in students' academic performance.

The implications and conclusions of these findings emphasize the importance of improving AQ and learning independence as key factors in developing mathematical problem-solving ability. An educational approach that integrates mental resilience training and the development of learning independence will yield more optimal results. Therefore, schools and educators are encouraged to design programs that encourage students to enhance AQ and learning independence through challenging activities and self-reflection.

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4. Conclusions

Based on the findings of this study, it can be concluded that Adversity Quotient (AQ) and learning independence significantly contribute to students' mathematical problem-solving abilities. Although the average AQ of students falls within the moderate category, indicating that they are capable of persevering in the face of difficulties, learning independence has a greater impact in enhancing their problem-solving skills. The regression analysis reveals that learning independence has a stronger influence than AQ on mathematical problem-solving ability, aligning with literature that links learning independence to better academic achievement. Furthermore, this study emphasizes that even students with low AQ can still demonstrate strong problem-solving skills, as long as they have high levels of learning independence.

The importance of psychological factors and self-learning skills as synergistic influences on academic performance is emphasized, consistent with the findings of the simultaneous test (F Test), which shows a significant effect of AQ and learning independence on problem-solving ability. Therefore, schools and educators need to design learning programs that integrate the development of AQ and learning independence, providing challenges that encourage students to practice and engage in self-reflection. This approach is expected to result in optimal improvements in mathematical problem-solving skills and overall academic achievement.

Author Contributions

This article was prepared by the first and second authors. Theoretical analysis and result interpretation were conducted by all three authors. Each author provided thorough feedback and contributed to the development of the study, analysis, and manuscript. The corresponding author, who is also the first author, revised the manuscript based on feedback from journal editors and reviewers.

Declaration of Competing Interest

No potential conflict of interest was reported by the author(s).

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The Effect of Bamboo Dacing Learning Model to Improve Mathematics Learning Outcomes

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ABSTRACT

This study aims to determine the learning outcomes of mathematics in class VIII MTS Ponpes Darus Sholihin before and after using the Bamboo Dancing learning model. This research was a quasi-experiment involving two classes, each with 25 students. Data were collected through observation and tests. The results showed that the control class had an average pretest score of 67.72, while the experimental class, after treatment, had a posttest average of 85.76. Statistical analysis (sig = 0.000 < 0.05) confirmed a significant effect, meaning the Bamboo Dancing model improved learning outcomes. This model enhances engagement, understanding, and social skills, making it effective in mathematics learning.

1. Introduction

Education is a conscious and planned effort to create a learning atmosphere and learning process so that students actively develop their potential to have religious spiritual strength, self-control, personality, intelligence, noble character, and skills needed by themselves and society. Education has an important role in individual progress and nation building. Today's education is designed to produce a generation that is able to face the challenges of the information age and the development of communication technology, in accordance with the objectives of national education. As the main pillar in the development of quality human resources, learning mathematics plays a very significant role.

Mathematics is a subject studied by students in *Madrasah Tsanawiyah* (MTs).

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However, researchers found that students often struggle to receive and process learning materials. Observations conducted with class VIII teachers at MTs Darus Sholihin revealed that students' understanding of mathematical concepts was still low. This was evident when teachers introduced learning models, yet students continued to rely on memorizing formulas from textbooks rather than grasping underlying concepts. Additionally, monotonous teaching methods made students passive and less enthusiastic about learning. The lack of variation in instructional approaches, which remained predominantly teacher-centered, further contributed to this issue. Students merely absorbed what was presented without active engagement, limiting their conceptual understanding.

Many factors cause low student ability, including many students who are afraid (phobia of mathematics), not used to expressing opinions, lack of ability to analyse the meaning of the problem, and lack of student interest in the material being taught. Students receive material delivered by the teacher actively by taking notes and without a single student expressing an opinion or asking questions verbally related to the material. The learning method used is still limited to the lecture method so that students appear passive during the learning process. According to Setiawan in Pangestu & Fathani (2024) states that mathematics learning must begin by introducing problems or proposing real-world problems. Therefore, it is necessary to design a lesson that accustoms students to construct their own knowledge and can understand mathematical concepts that affect the improvement of learning outcomes.

According to Sudijono (2012), learning outcomes serve as an evaluation tool encompassing cognitive (thinking processes), affective (attitudes and values), and psychomotor (skills) domains. In other words, they help assess student achievement after the learning process. Hidayat (2017) noted that teacher-centered learning often leads students to focus on memorization rather than conceptual understanding. Similarly, Rahmawati (2015) emphasized that conventional models, such as lecture-based teaching without student involvement, result in passive learning. To improve mathematical comprehension, it is essential to implement engaging and varied instructional strategies that encourage active student participation.

One of the main challenges in learning mathematics is how to overcome fear and boredom that can hinder students understanding of the material. Therefore, an innovative and fun approach is needed to improve student learning outcomes. One method that can be applied is the Bamboo Dancing learning model. This model, which is originally a traditional game that relies on body coordination and co-operation, can be adapted for the educational environment, especially in learning mathematics. By integrating active, creative and collaborative elements, it is expected that this model can attract students' interest and improve their learning outcomes, especially in mathematics (Julianti, 2016).

Bamboo Dancing learning model is a type of cooperative learning model, this learning model is relevant to mathematics learning. In this learning, students will learn in heterogeneous groups. The teacher will act as a facilitator and students will play a full role in this learning. According to Anita Lie as cited in Zuraida (2015), the Bamboo Dancing Learning Model begins with listening to the presentation of mathematics material information

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from the teacher, then students learn in groups in pairs or face to face. The material that has been discussed is then taught to members of other groups, by shifting in a clockwise direction and returning to the original pair. The Bamboo Dance learning model aims for students to share information together with different partners in a short time regularly. The selection of this model is felt to make students more active and improve students' understanding of concepts

Based on previous research, the Bamboo Dance learning model can provide information evenly. This strategy is suitable for teaching materials that require exchange and experience between students. The syntax is that some students stand in a line at the front of the class or between the benches of the table and some others stand opposite the first group of students, students who face each other share experiences and knowledge, students who stand at the end of one line move to the other end of the line, and return to sharing information (Ana, 2019).

2. Method

This research uses a quantitative approach with the type of quasi experiment (quasy experiment). The variables in the study were the independent variable (Bamboo dancing learning model) and the dependent variable (Mathematics Learning Outcomes). The design used in this research is Nonequivalent control group design. This study divides the class into two, namely the experimental class and the control class. The experimental group is the group that gets treatment. In this study, class VIII A was the experimental class that used the bamboo dancing learning model. And class VIII B which became the control class using a conventional learning model.

The population in this study were all students of class VIII MTs Darus Sholihin. In this study, Non Probability Sampling technique was used. The sample was taken using saturated sampling technique, which means that all members of the population were used as samples. Arikunto (Arifani et al., 2023) said that if the subject is less than 100, it is better to take all so that the research is population research. In this study, the research was conducted twice, namely before the experiment and after the experiment. The assessment before the experiment is called the pre-test and the assessment after the experiment is called the post-test. Then the data analysis technique in this study uses a Comparative Hypothesis Test, namely the Parametric Test in the form of the Independent Sample t-Test and Paired Sample t-Test tests using SPSS version 22.

3. Results and Discussion

This research is a quantitative study with an experimental design that aims to determine the effect of the Bamboo Dancing learning model to improve the mathematics learning outcomes of 8th grade students of MTs Ponpes Darus Sholihin. This research was conducted with different treatments between the experimental class using the Bamboo Dancing learning model and the control class using the conventional learning model.

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Table 1. Descriptive Analysis Results

Desciptive Statistics					
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**
Experimental Pretest	25	56	77	68.12	6.566
Experimental Posttest	25	80	92	85.76	3.455
Control Pretest	25	55	84	67.72	7.492
Control Posttest	25	67	89	78.00	5.212
Valid N (listwise)	25				

Based on table 1, the results of descriptive statistics obtained the average value of the control class prestest of 67.72, the control class posttest of 78.00 and the average value of the experimental class pretest of 68.12 while the experimental class posttest of 85.76. these results indicate that there is an effect of the bamboo dancing learning model to improve the learning outcomes of mathematics students in class VIII MTs Darus Sholihin. After descriptive analysis is carried out, the data analysis prerequisite test is carried out which consists of normality test and homogeneity test.

3.1. Normality Test

The normality test is used to determine whether the data under study is normally distributed or not. The normality test was calculated using SPSS 22 for windows with the Kolmogrov-Smirnov test and the Shapiro-Wilk test. If the significance (sig) obtained is greater than α = 0.05, then the data is normally distributed or vice versa. Based on table 2 below shows> 0.05, the data is normally distributed.

Table 2. Tests of Normality

		Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Learning Outcomes	Experimental Pretest	.112	25	.200	.927	25	.073
	Experimental Posttest	.133	25	.200	.951	25	.261
	Control Pretest	.124	25	.200	.966	25	.543
	Control Posttest	.151	25	.147	.960	25	.409

3.2. Homogeneity Test

Homogeneity test is used to determine whether the data studied comes from a normally distributed population. The normality test of student data was calculated using SPSS 22 for windows with one way ANOVA analysis. with testing criteria; if the significance value (Sig) obtained is greater than α = 0.05, then the data is homogeneous. Based on table 3, it can be seen well the results of the homogeneity test obtained a significance value of 0.243. this shows that the significance> 0.05, so it can be concluded that it comes from the same or homogeneous population

Table 3. Test of Homogeneity of Variances

	Levene Statistic	**df1**	**df2**	**Sig.**
Learning Outcomes	1.398	1	48	.243

3.3. Hypothesis Test

Hypothesis testing using the Paired Sample t Test is a test used to compare the

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difference in mean data from two paired samples with the assumption that the data is normally distributed. Paired samples come from the same subjects, each variable is taken during different situations and circumstances. This test is also called the t test.

Table 4. Independent Samples Test for Learning Outcomes

	Levene's Test Equality of Variances		t-test for Equality of Means						
								95% Confidence Interval of the Difference	
	F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**Lower**	**Upper**
Equal Variances Assumed	1.398	.243	6.204	48	.000	7.760	1.251	5.245	10.275
Equal Variances not Assumed			6.204	41.681	.000	7.760	1.251	5.235	10.285

The analysis results in table 4. show that the sig. (2-tailed) value of 0.000, which is smaller than 0.05. This indicates that H_0 is rejected and H_a is accepted. Thus, it can be concluded that there is a significant influence between the application of the Bamboo Dancing learning model on students' mathematics learning outcomes in class VIII MTs Darus Sholihin.

This finding is in line with previous research which shows that collaborative learning, such as the Bamboo Dancing model, can improve student learning outcomes. For example, research conducted by (Sahlan, et al., 2024) found that the Bamboo Dancing model encourages students to be more active in the learning process, increases. interaction between students, and strengthens concept understanding through group discussions. Students' involvement in collaborative activities in the Bamboo Dancing model allows them to share ideas, discuss material, and solve problems together. This provides a more in-depth learning experience compared to conventional learning methods. Therefore, the results of the analysis showing the significant effect of applying the Bamboo Dancing model support previous findings that interactive and collaborative learning approaches are effective in improving student learning outcomes, especially in mathematics subjects that require strong conceptual understanding.

4. Conclusion

The Bamboo Dancing learning model is proven to have a positive influence in improving the learning outcomes of mathematics class VIII students at MTs Ponpes Darus Sholihin. The research data shows that the average post-test score in the experimental class (using the Bamboo Dancing model) is higher (85.76) than the pre- test average (68.12), and better than the average value of the control class which only uses conventional learning methods. The results of hypothesis testing with paired samples test showed

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a significance value of 0.000 (<0.05), which indicates that there is a significant difference in student learning outcomes between the use of the Bamboo Dancing model and conventional learning methods. Thus, it can be concluded that learning with the Bamboo Dancing model is able to increase students' activeness and understanding of mathematical concepts compared to conventional methods.

This model contributes to creating a more active, collaborative, and fun learning atmosphere, thus becoming an innovative alternative to improve mathematics learning outcomes. Some recommendations from the Bamboo Dancing learning model for the development of science are This study shows that the Bamboo Dancing model is effective in improving mathematics learning outcomes. Further research could be conducted to apply this model to other subjects, such as social science or language, to measure its impact on concept understanding and student engagement. This research underlines the importance of innovation in learning. It is recommended to develop more activity-based learning methods that involve students' active participation, such as project-based methods or simulations, to reduce the fear of certain subjects.

Author Contributions

The first author focuses on collecting, processing and analysing data and presenting it in the form of scientific work, the second and third authors as mentors in the process of forming this article.

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Declaration of Competing Interest

As the author, I hereby declare that I have no conflict of interest or competing interests related to this research. All results of this research were prepared with objectivity and without influence from any party that could affect the validity and independence of the findings.

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