MALAYSIAN JOURNAL OF LEARNING AND INSTRUCTION
https://e-journal.uum.edu.my/index.php/mjli

How to cite this article:
Edi Supriyadi, T. Turmudi, Jarnawi Afgani Dahlan & Dadang Juandi. (2024). Development of Sundanese gamelan ethnomathematics e-module for junior high school mathematics learning. *Malaysian Journal of Learning and Instruction, 21*(2), 147-186. https://doi.org/10.32890/mjli2024.21.2.6

DEVELOPMENT OF SUNDANESE GAMELAN ETHNOMATHEMATICS E-MODULE FOR JUNIOR HIGH SCHOOL MATHEMATICS LEARNING

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Received: 3/9/2023 Revised: 5/1/2024 Accepted: 10/3/2024 Published: 14/8/2024

ABSTRACT

Purpose – This study aimed to conduct a needs analysis for developing the ethnomathematics e-module based on Sundanese Gamelan to facilitate mathematics learning in junior high school. Specifically, this study identified crucial components for module development and to gather feedback from both students and teachers regarding the learning material.

Methodology – The Research and Development (R&D) method was used, specifically the Plomp model, to create e-module for mathematics learning. Qualitative data were collected from ethnomathematics experts, a mathematics teacher, and five students via purposive sampling. The instruments used for this data collection included expert validation sheets, student interview recordings, teacher questionnaires, and small group observations.

Findings – The results indicated that the integration of Sundanese Gamelan ethnomathematics into junior high school mathematics e-module significantly improved students' understanding and interest in the subject. This culturally infused approach increased students' motivation and engagement, indicating a potential shift towards more inclusive and culturally responsive educational practices.

Significance – The integration of Sundanese Gamelan ethnomathematics into mathematics curriculum is known for the unique blend of cultural elements with academic content, contributing to enhanced students' understanding and cultural awareness. In addition, this method offered benefits for students, teachers, curriculum developers, and ethnomathematics researchers, presenting a holistic model that combined educational innovation with cultural appreciation.

Keywords: Atlas.ti, ethnomathematics e-module, Plomp, research and development, Sundanese Gamelan, Tessmer, qualitative.

INTRODUCTION

The lack of awareness and understanding of ethnomathematics among curriculum experts, designers, and teachers is a critical issue that needs exploration (Weldeana, 2016), which could adversely affect the integration of ethnomathematics into mathematics curriculum. Further investigation is needed into the development and implementation of realistic mathematics learning models and teaching modules in elementary and junior high schools (Sari et al., 2022; Yuliana et al., 2022). As a result, several studies showed the potential of ethnomathematics-based teaching modules in achieving 21st-century learning goals and enhancing students' mathematical literacy. Moreover, further exploration is needed as a bridge between education, culture, and mathematics as well as the potential to enhance students' understanding of contextual mathematics material (Fredy et al., 2020; Gusvarini et al., 2022). Investigating the impact of ethnomathematics-based learning media on students' critical thinking ability, particularly in geometry learning, is an important issue (Sumiyati et al., 2018). To offer insights for educators, there is a need to understand how ethnomathematics influences students' critical thinking ability.

The integration of local wisdom and cultural values into ethnomathematics learning for character building in elementary and junior high schools is also an area that requires further exploration (Fredy et al., 2020). This issue is crucial for comprehending the way ethnomathematics can contribute to holistic student development. Additionally, exploring the local wisdom of different ethnic tribes related to mathematics education and implementing the results in geometry learning is an important study area (Aminah & Syamsuri, 2022; Yustinaningrum et al., 2018). This investigation can show the potential of integrating diverse cultural perspectives into mathematics education.

Addressing the historical and critical framework related to mathematical experiences of black teachers and students is a crucial issue that needs attention (Joseph et al., 2021), as understanding the historical and structural barriers, as well as the dehumanization experienced in mathematics education, is essential for promoting inclusivity and equity in the classroom. In addition, exploring the role of language diversity and investigating the latest characteristics of mathematics education reform in various cultural contexts, such as China, are important areas that need further exploration (Guo et al., 2018; Phakeng & Moschkovich, 2013).

The development of Sundanese Gamelan ethnomathematics e-module for junior high school mathematics education is a significant study that integrates culture into mathematics. Previous studies examined the manner in which ethnomathematics impacted mathematics learning (Lidinillah et al., 2022). Furthermore, e-module enhances mathematical logical thinking and cognitive variables associated with mathematics courses (Setiyani et al., 2022; Yaniawati et al., 2021). Ethnomathematics-based electronic modules have shown validity, effectiveness, and practicality, making them suitable for students (Milenia et al., 2022). Additionally, open-ended mathematics e-module aims to enhance critical thinking, potentially improving students' ability (Purwoko et al., 2023). To produce online interactive learning media, tutoring e-module, and mathematics e-encyclopedia, ADDIE model was applied, showing its importance in educational module development (Agustin, 2020; Pebrianti & Handayani, 2022; Yuniarti & Astuti, 2022). By using the ADDIE paradigm, the feasibility and efficacy of e-module have been tested, confirming the quality and suitability for educational use (Agustin, 2020; Fahmi et al., 2022).

There are various gaps in the integration of Sundanese Gamelan into ethnomathematics and mathematics education. Limited investigation exists on using Sundanese Gamelan as a cultural and mathematical resource in mathematics education (Abdullah, 2016; Supriadi & Arisetyawan, 2020), highlighting the need for a study to enhance mathematical and creative thinking ability. The lack of didactical designs and learning apps that incorporate Sundanese Gamelan into mathematics education suggests the need to develop effective pedagogical methods (Rahayu et al., 2022; Supriadi, 2022). Therefore, integrating Sundanese Gamelan into mathematics teaching is crucial for cultural diversity and students' learning.

Furthermore, the lack of research into Sundanese Gamelan's significance in character education and the potential to enhance reading ability calls for further investigation. Examining Sundanese Gamelan effects on character and literacy could provide more clarity on the comprehensive educational benefits. Yet, there is a significant gap in researching early childhood mathematics learning and the development of mathematical competencies (Jankvist & Kjeldsen, 2010). This means that incorporating e-module into early childhood mathematics education can inspire unique and culturally appropriate methods.

Further investigation is needed on the inclusion of Sundanese Gamelan in mathematics curriculum and the impact on students' mathematical resilience and motivation (Duggan et al., 2017). Understanding how e-module can enhance academic resilience and motivation is crucial for promoting positive attitudes toward mathematics learning. Additional exploration is required on the application of Sundanese Gamelan in cross-cultural music education and the potential challenges in non-STEM subjects (Duggan et al., 2017; Goldsworthy, 1997). Examining the challenges and benefits of integrating the e-module into cross-disciplinary education can provide valuable insights for educators and curriculum developers. The integration into ethnomathematics and mathematical education necessitates studies on pedagogical methods, character education, early childhood learning, and cross-disciplinary education. Therefore, addressing these gaps can contribute to the development of culturally inclusive and effective mathematics education.

In line with these considerations, the objective of this study was to conduct a needs analysis for developing ethnomathematics e-module

based on Sundanese Gamelan to facilitate mathematics learning in junior high schools. Specifically, the exploration aimed to identify crucial components for module development and gather feedback from both students and teachers regarding the learning material.

Ethnomathematics

Ethnomathematics has received attention for its potential to integrate cultural diversity into mathematics education. The term "ethnomathematics" has faced criticism and contradictions, particularly concerning the epistemological and pedagogical positioning (Pais, 2010). However, it has also been acknowledged for the potential to develop mathematical thinking through the integration of ethnomathematical folklore games in mathematics instruction (Fouze & Amit, 2017). Ethnomathematics is defined as the study of mathematical concepts in small-scale or indigenous cultures (Eglash, 1997). This concept has been explored in various cultural contexts, such as Javanese culture (Risdiyanti & Prahmana, 2017), Sundanese culture (Supriyadi et al., 2022), and the culture of Baduy tribe (Arisetyawan & Supriadi, 2020). The integration of ethnomathematics into the curriculum has shown the potential to promote the growth of students' nationalism (Zaenuri et al., 2019) and improve mathematical ability (Payadnya & Jayantika, 2022). Furthermore, it has been suggested that ethnomathematics can be used to enhance students' mathematical literacy ability (Runtu et al., 2023).

The potential of ethnomathematics to connect mathematics with students' lives through the local culture has been discussed (Deswita & Muslim, 2021). It has also been recognized as a means to improve the quality of learning by providing a context commonly found in students' daily lives (Yuliana et al., 2022). Moreover, ethnomathematics has been identified as a manifestation of the evolution of culture and human thought, justifying its integration into mathematics education (Hendriyanto et al., 2023). Ethnomathematics has been explored in elementary school as a means of building students' character (Fredy et al., 2020). Additionally, applying ideas from critical mathematics education to ethnomathematics is productive for both methods (Andersson & Barwell, 2021).

E-module

The creation and application of e-module in mathematics education have become increasingly important, specifically in response to the

challenges caused by the COVID-19 pandemic. Ramadhani and Fitri (2021) investigated the use of EPUB3-based mathematical e-module using the Sigil application as a solution for teaching and learning during the pandemic. The study recognized the potential of digital solutions in adapting to the new educational landscape. Aulia and Prahmana (2022) focused on developing interactive e-module based on the realistic mathematics education method and mathematical literacy ability. The exploration described the practicality of e-module in assessing student responses with good criteria. Similarly, Marsitin and Sesanti (2023) addressed the potential of e-module based on mathematical literacy to improve students' mathematical reasoning. The investigation found significant differences and increases in mathematical reasoning ability. Additionally, Kurnianto et al. (2022) showed the effectiveness of e-module developed through Professional Flip PDF application assisted by React strategy. The module proved successful in enhancing the problem-solving ability of vocational middle school students. Murdikah et al. (2021) also discussed the potential of e-module based on Vee's heuristic strategy to train students' mathematical representation ability. This method provided an alternative for students to independently construct new knowledge. Collectively, these studies describe the potential of e-module in addressing the challenges of mathematics education, specifically in the context of the COVID-19 pandemic, and in improving mathematical and problem-solving ability. The development and use of e-modules have shown promise in adapting to the new normal in education and in providing effective and engaging learning experiences for students.

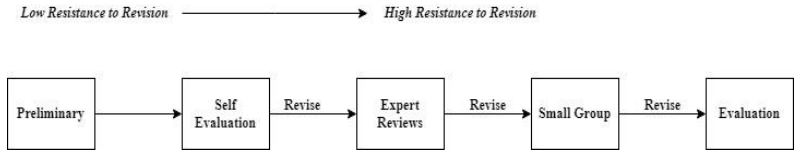
METHODOLOGY

This study used the Research and Development (R&D) method, specifically the Plomp model (Plomp & Nieveen, 2013) through a condensed three-stage process. In the preliminary phase, needs analysis tasks were conducted to analyze the requirements and expectations of development. Data were obtained through interviews conducted with mathematics teachers at SMP Negeri 30 Bandung, and the existing educational curriculum in school was examined to incorporate Sundanese cultural content. In the development phase, results from the initial analysis were used to create educational resources in the form of an e-module. The design outcomes, referred to as prototype 1, they were assessed using the modified Tessmer development formative evaluation as shown in Figure 1. In particular,

it describes the continual feedback and assessment during educational material and program creation (Uzunboylu, 2018). This method is consistent with educational study trends in curriculum and teaching, educational technology, learner needs, and instructional design (Uzunboylu, 2019).

Figure 1

The Modified Tessmer Framework Used in this Study



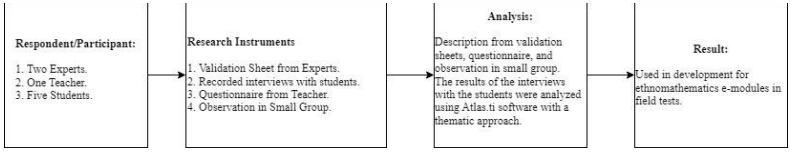
To ensure thoroughness, mathematics education lecturers conducted self-evaluation, incorporating consultations with professors. Prototype 1, which was refined into Prototype 2, it went through evaluation, observation, and feedback from validators—who have mathematics education PhDs with expertise in the ethnomathematics and learning media. A small group test of Prototype 3 was conducted with five students and a mathematics teacher, based on students' ability levels, use of the e-module, and the integration of mathematics and the Sundanese Gamelan. Education professionals also provided feedback during product development compactness tests, with plans for further field trials to be discussed in a subsequent article.

Data Analysis and Collection

This study used qualitative data and two ethnomathematics and learning media experts, a mathematics teacher, and five students with varying mathematical abilities as shown in Figure 2, based on purposive sampling for relevance, and depth. Multiple methods, including the semi-structured interviews, e-module validation sheets, questionnaires, and observation sheets in small groups, were used for data acquisition. Descriptive analysis of validation sheets, questionnaires, and group observations, focusing on e-module effectiveness and applicability, provided a comprehensive view of replies and interactions. Atlas.ti 23 was used for thematic analysis of student interviews, enabling the exploration of qualitative data themes and patterns, shaping the ethnomathematics e-module, and preparing for small-group testing.

Figure 2

Flow in Collecting and Analyzing Data in this Study



Participant

In this study, purposive sampling was used to investigate phenomena at the study site, a method that selected the respondents with relevant features (Creswell & Poth, 2016; Bhardwaj, 2019). After obtaining consent from SMP Negeri 30 Bandung's principal, a teacher, and five students were purposefully selected for the investigation, requiring respondents to have five years of mathematics teaching experience using the Merdeka curriculum. The selection process aimed to ensure the inclusion of knowledgeable individuals that are capable of providing in-depth information on the issue (Merriam & Tisdell, 2015).

Study Instruments

This study relied on tools for collecting and analyzing data to assess integrity and validity. Initially, an expert validation sheet obtained from [source] was used for reliability testing of the e-module prototype. The study focused on the perspectives of PhDs in mathematics education regarding ethnomathematics and the use of instructional media. Subjective judgments from recorded student interviews and semi-structured discussions provided valuable insights. Additionally, transcription of these interviews unveiled themes, reasons, and information that quantitative tools could not capture. Teacher questionnaire contributed essential insights into teaching methods and students' interactions with e-module learning materials. Manual data gathering was facilitated through the small-group observation, allowing for an examination of students' interactions with each other and the e-module learning contents. This setting enabled the observation of non-verbal cues such as body language, facial emotions, and social dynamics, which could not be conveyed through writing alone. Recorded and evaluated observations conducted by [researchers/ observers] offered a holistic understanding of the learning process.

In small-group interviews with students who used the Sundanese Gamelan ethnomathematics e-module, thematic analysis proved instrumental in identifying and analyzing major data topics. Thematic analysis, a qualitative method, helped reveal data themes and patterns (Dawadi, 2021). This method, utilized in interviews, transcription, and theme identification by Rice and Ezzy (1999), provided precision, particularly when using tools such as Atlas.ti (McMullin, 2023) . The process included coding significant topics and subsequently analyzing them within the context of relevant literature (Creswell & Poth, 2016). Thematic analysis provided a systematic method to organizing and comprehending the qualitative data. The transcription process played a crucial role in ensuring accuracy and precision in capturing participants' responses, with the assistance of software namely, Atlas.ti. Consequently, the coded topics were examined in the context of existing literature to gain deeper insights and generate meaningful results.

ANALYSIS AND DISCUSSION

Preliminary

This preliminary stage consisted of the students' analysis and curriculum analysis.

Student Analysis

This examination focused on assessing students' knowledge and characteristics, including their mathematics abilities through knowledge analysis. Information from interviews with mathematics teachers showed that students struggled to connect real-world situations with mathematical principles, particularly the cultural aspects in classroom arithmetic instruction. In this study, the teaching module of Sundanese Gamelan ethnomathematics e-module for learning methodologies was grounded in the autonomous curriculum. Each session prioritized achieving learning outcomes by utilizing training modules and incorporating real-world challenges into assessment sheets in the e-module. The planned e-module comprised two sets of two 40-minute sessions, covering Phase-D comparison and geometry teaching modules in line with the Merdeka Curriculum ideas and qualities. After analysis and consultation with mathematics teacher, Grade VIII students were selected for small group testing, and the

identified concerns were addressed by developing an e-module based on Sundanese Gamelan ethnomathematics, comprising comparison and geometry modules aligned with the Merdeka Phase-D curriculum.

The development of e-module based on Sundanese Gamelan ethnomathematics aimed to address concerns related to mathematics education. As a pedagogical innovation, the e-module focused on nurturing students' love for mathematics, motivation, and creativity in learning (Prahmana et al., 2021). This method successfully established a connection between mathematics and the reality of society, bridging gaps arising from rigid and non-contextual formal education (Prahmana & D'Ambrosio, 2020). Additionally, teachers perceived the use of ethnomathematics was a positive contribution to addressing gaps in mathematics education (Mania & Alam, 2021). Systematic reviews on the integration of Sundanese ethnomathematics into the curriculum suggested various methods such as problem-posing, problem-solving, open-ended, and realistic mathematics education (Lidinillah et al., 2022). Studies found that ethnomathematics showed positive impacts on students' academic development, enhancing creative thinking, understanding of geometry, and algebraic abilities (Supriyadi et al., 2022).

The inclusion of ethnomathematics in e-module was in line with the goal of making mathematics more intuitive and relevant to students' lives. By integrating cultural elements such as Sundanese Gamelan, the module aimed to enhance students' understanding and appreciation of mathematics through the local culture. This method improved students' mathematical literacy and also contributed to the meta-awareness of mathematics' role in society and culture (Kurniawan & Hidayati, 2020; Yuliana et al., 2022). In line with previous studies, the e-module focuses on comparison and geometry in ethnomathematics in the context of learning and the exploration of cultural patterns (Aminah & Syamsuri, 2022; Prahmana & D'Ambrosio, 2020). Therefore, the e-module based on Sundanese Gamelan ethnomathematics represented a promising initiative to enhance mathematics education by integrating cultural elements and promoting a deeper understanding of mathematical concepts in the local context.

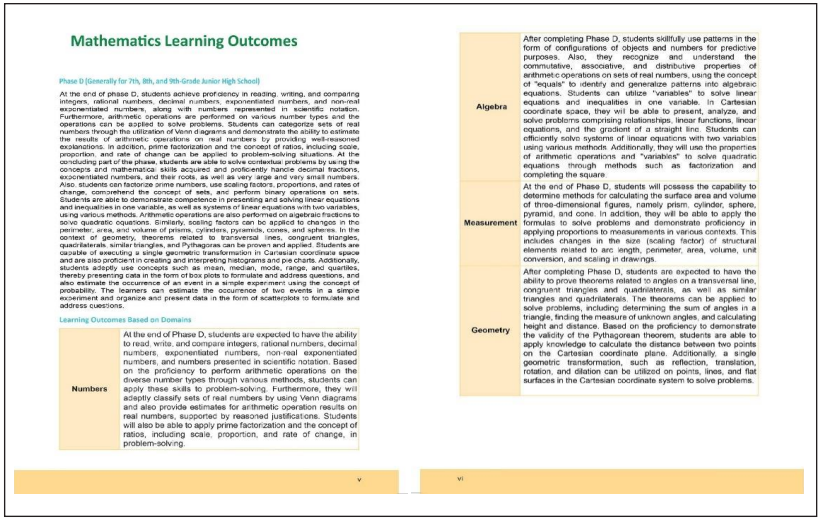
Curriculum Analysis

During the analysis stage, various activities were performed, including scrutinizing the Phase-D mathematics curriculum in line with the

Merdeka curriculum for junior high school. The focus of this analysis was on the topics of comparison and geometry, and also included an examination of the Merdeka curriculum package books shown in Figure 3. Additionally, interviews between examiners and teachers were conducted and the mathematics Learning Outcomes section outlined the ability and knowledge that students were expected to master by the end of this phase. These included fractions, decimals, prime factorization, proportions, set theory, linear equations and inequalities, algebraic fractions, quadratic equations, scale factors, geometry, and statistics. The competencies comprised the ability to solve contextual problems using learned mathematical concepts and ability, master various mathematical operations, comprehend and apply geometry theorems, and use statistical methods for data presentation and analysis. This comprehensive method aimed to establish a robust mathematical foundation for students at this educational stage.

Figure 3

Analysis of the Merdeka Curriculum for Phase-D or Junior High School Level



Mathematics Learning Outcomes

Phase D (Generally for 7th, 8th, and 9th-Grade Junior High School)

At the end of phase D, students achieve proficiency in reading, writing, and comparing integers, rational numbers, decimal numbers, exponentiated numbers, and non-real exponentiated numbers, along with numbers represented in scientific notation. Furthermore, arithmetic operations are performed on various number types and the operations can be applied to solve problems. Students can categorize sets of real numbers through the utilization of Venn diagrams and demonstrate the ability to estimate the results of arithmetic operations on real numbers by providing well-reasoned explanations. In addition, prime factorization and the concept of ratios, including scale, proportion, and rate of change can be applied to problem-solving situations. At the concluding part of the phase, students are able to solve contextual problems by using the concepts and mathematical skills acquired and proficiently handle decimal fractions, exponentiated numbers, and their roots, as well as very large and very small numbers. Also, students can factorize prime numbers, use scaling factors, proportions, and rates of change, comprehend the concept of sets, and perform binary operations on sets. Students are able to demonstrate competence in presenting and solving linear equations and inequalities in one variable, as well as systems of linear equations with two variables, using various methods. Arithmetic operations are also performed on algebraic fractions to solve quadratic equations. Similarly, scaling factors can be applied to changes in the perimeter, area, and volume of prisms, cylinders, pyramids, cones, and spheres. In the context of geometry, theorems related to transversal lines, congruent triangles, quadrilaterals, similar triangles, and Pythagoras can be proven and applied. Students are capable of executing a single geometric transformation in Cartesian coordinate space and are also proficient in creating and interpreting histograms and pie charts. Additionally, students adeptly use concepts such as mean, median, mode, range, and quartiles, thereby presenting data in the form of box plots to formulate and address questions, and also estimate the occurrence of an event in a simple experiment using the concept of probability. The learners can estimate the occurrence of two events in a simple experiment and organize and present data in the form of scatterplots to formulate and address questions.

Learning Outcomes Based on Domains

Numbers	At the end of Phase D, students are expected to have the ability to read, write, and compare integers, rational numbers, decimal numbers, exponentiated numbers, non-real exponentiated numbers, and numbers presented in scientific notation. Based on the proficiency to perform arithmetic operations on the diverse number types through various methods, students can apply these skills to problem-solving. Furthermore, they will adeptly classify sets of real numbers by using Venn diagrams and also provide estimates for arithmetic operation results on real numbers, supported by reasoned justifications. Students will also be able to apply prime factorization and the concept of ratios, including scale, proportion, and rate of change, in problem-solving.
Algebra	After completing Phase D, students skillfully use patterns in the form of configurations of objects and numbers for predictive purposes. Also, they recognize and understand the commutative, associative, and distributive properties of arithmetic operations on sets of real numbers, using the concept of "equals" to identify and generalize patterns into algebraic equations. Students can utilize "variables" to solve linear equations and inequalities in one variable. In Cartesian coordinate space, they will be able to present, analyze, and solve problems comprising relationships, linear functions, linear equations, and the gradient of a straight line. Students can efficiently solve systems of linear equations with two variables using various methods. Additionally, they will use the properties of arithmetic operations and "variables" to solve quadratic equations through methods such as factorization and completing the square.
Measurement	At the end of Phase D, students will possess the capability to determine methods for calculating the surface area and volume of three-dimensional figures, namely prism, cylinder, sphere, pyramid, and cone. In addition, they will be able to apply the formulas to solve problems and demonstrate proficiency in applying proportions to measurements in various contexts. This includes changes in the size (scaling factor) of structural elements related to arc length, perimeter, area, volume, unit conversion, and scaling in drawings.
Geometry	After completing Phase D, students are expected to have the ability to prove theorems related to angles on a transversal line, congruent triangles and quadrilaterals, as well as similar triangles and quadrilaterals. The theorems can be applied to solve problems, including: determining the sum of angles in a triangle, finding the measure of unknown angles, and calculating height and distance. Based on the proficiency to demonstrate the validity of the Pythagorean theorem, students are able to apply knowledge to calculate the distance between two points on the Cartesian coordinate plane. Additionally, a single geometric transformation, such as reflection, translation, rotation, and dilation can be utilized on points, lines, and flat surfaces in the Cartesian coordinate system to solve problems.

v vi

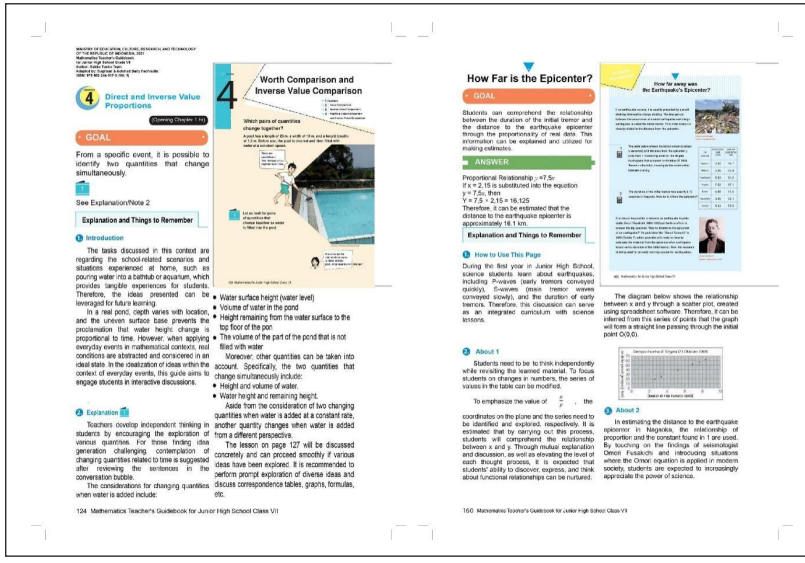
Source: Tim Gakko Tosho, 2021.

The Merdeka curriculum for junior high school Grade VII focused on ratio, scale, proportion, and the rate of change in problem-solving and other scenarios as illustrated in Figure 4. The geometry section

described transversal lines, triangles, quadrilaterals, and proofs and applications of the Pythagorean theorem. Students were also introduced to Cartesian coordinate plane geometric transformations, including reflecting, translating, rotating, and dilation. This material cultivated analytical and problem-solving abilities in students, while the chapter on comparison in Mathematics curriculum for junior high school Grade VII incorporated information, puzzles, and activities to assist students in learning about comparison. In addition, it explained value comparison and inverse value comparison through daily situations, such as filling a pond. Students were able to apply these concepts in various contexts, while simultaneously exploring variable relationships. The material served as a guide through a practical and interactive idea-discovery process to promote critical thinking and autonomous exploration.

Figure 4

Analysis of Comparison Materials in Mathematics Lessons in the Merdeka Curriculum



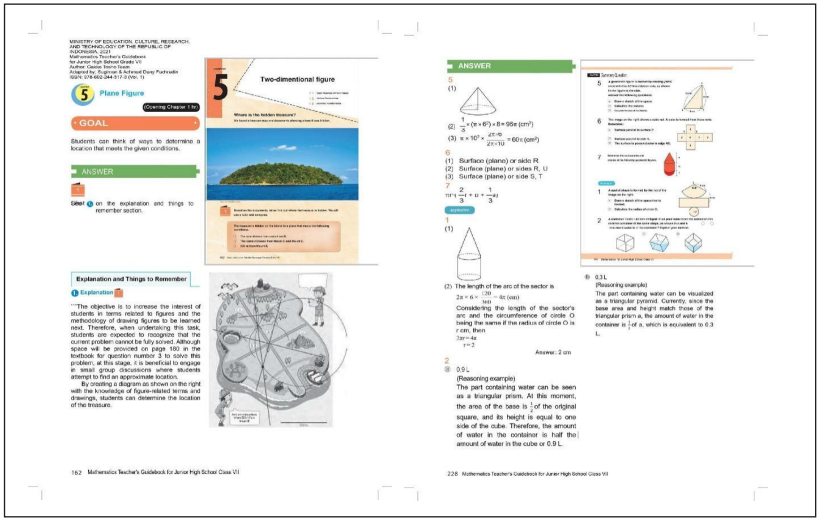
Source: Tim Gakko Tosho, 2021.

The comparison chapter explored Eco Cap Movement recycling initiatives, using Indonesian daily life and culture as examples. A task created by the curriculum challenged students to estimate the

number of caps collected at a school for recycling without counting. This example applied arithmetic to real-life circumstances, teaching students about recycling and social welfare programs, such as immunizations in impoverished countries. It should be noted that this document did not include references to Sundanese Gamelan or other cultural or ethnomathematical materials. The main focus was on comparing Eco Cap Movement efforts and calculations. Neither Sundanese Gamelan nor other Indonesian cultural components were mentioned in a mathematical setting. Chapters 5 and 6 of Mathematics for Junior High School Grade VII extensively covered building space geometry. Specifically, Chapter 5 taught the surface area of spatial forms, including prisms, tubes, cones, and spheres, using questions and exercises created by the curriculum that challenged students to apply formulas in real-world settings. Chapter 6 covered space volume, teaching students how to determine the volume of prisms, tubes, cones, and spheres through practical exercises and exploration. Both chapters were identified as assisting students in building critical thinking and problem-solving abilities related to geometry, which are essential for middle school arithmetic, as shown in Figure 5.

Figure 5

Analysis of Geometry Materials in Mathematics Lessons in the Merdeka Curriculum



Source: Tim Gakko Tosho, 2021.

Chapter 6 explored spatial shapes and also focused on Indonesian culture and daily life. Furthermore, it showcased images of various structures, including images of various structures, such as the pyramid building in Rowosari (representing a pyramid), the chimney of a power plant (representing a tube), the Mbaru Niang Traditional House in Wae Rebo Village, NTT (representing a cone), and the Bank Building (representing a rectangular prism). These visuals were found to aid students in understanding geometry in the context of Indonesian culture and the environment by associating architectural space with both physical and cultural structures. However, the materials reviewed did not address ethnomathematics or Sundanese Gamelan. Chapters 5 and 6 focused on spatial geometry using examples from Indonesian architecture. Meanwhile, these materials did not mention Indonesian culture or local traditions such as Sundanese Gamelan in mathematics. SMP Negeri 30 Bandung needs study yielded several critical conclusions. The school initially adopted the Merdeka curriculum, and teachers used the Learning Implementation Plan (RPP) or Teaching Module to develop curriculum-aligned learning materials based on learning outcomes and assessment indicators. It should be noted that modern teaching materials lacked cultural components. According to observations, teaching resources that actively engaged students in learning activities, aside from teacher-centered methods, fostered students' autonomy. Additionally, there has been an increase in demand for smartphone-accessible educational materials, including e-modules for individual study, which is considered a crucial aspect in the post-COVID-19 for both teachers and students.

The preliminary stage of this study focused on examining the Merdeka curriculum and students' ability, with a specific emphasis on integrating ethnomathematics. After the analysis, Sundanese Gamelan ethnomathematics e-module, developed in line with an autonomous curriculum, was created. The decision to create this module was prompted by the findings that students faced challenges in connecting real-world events with mathematical concepts, especially those related to cultural factors in mathematics training. The evaluation sheets for Grade VIII module, created for this study, incorporated real-world situations, geometry, and comparison. The Merdeka Phase-D mathematics curriculum covered various topics including fractions, decimals, proportions, algebra, and geometry. Specifically, it described ratios, proportions, geometric transformations, and spatial geometry in context, using examples such as Eco Cap Movement and Indonesian architecture. This study conducted by [researchers] showed the

necessity for engaging teaching resources and smartphone-accessible materials such as e-module, particularly in the post-COVID-19 era. However, it acknowledged the absence of cultural elements namely Sundanese Gamelan in current teaching materials.

Ethnomathematics in the Merdeka curriculum adjusted students' real-world experiences with mathematical principles, particularly through cultural features in mathematics teaching (Himmah et al., 2019). Culturally responsive teaching, which incorporated students' cultural knowledge into the learning process, made mathematics relevant to daily life (Gradini & Firmansyah, 2020). According to Acharya et al. (2021) current instructional materials lacked cultural inclusion amidst the demand for technology-driven resources after Covid-19. The transformation required an egalitarian educational framework that incorporated cultural experiences into arithmetic instruction. According to the curriculum, the focus on practical mathematical ability was consistent with Chevallard's Anthropological Theory of Didactics and was applied to Eco Cap Movement and Indonesian architecture (Páez et al., 2022). To improve pre-university education, this study described innovative teaching strategies, such as didactic engineering and the use of counterexamples in mathematics courses, which were based on didactic situations and methodological elements (Ramirez et al., 2020). The development of a didactic proposal for geometry practices, within the frameworks of the Didactic Situations Theory and the Anthropological Theory of the Didactic, indicated the importance of these theoretical frameworks, in designing inclusive and resonant teaching practices, that reflected students' diverse cultural backgrounds, creating a more inclusive and effective mathematics education environment (Olmos et al., 2022).

Formative Evaluation

The formative evaluation process consisted of several sequential stages, including self-evaluation, expert review, and small groups.

Self-Evaluation

Sundanese Gamelan ethnomathematics e-module integrated geometry and comparison with Gamelan culture. Applying mathematical concepts to real life and culture, served the Merdeka Phase-D or Junior High School curriculum. The e-module engaged students with simple language and relevant assignments. It also applied mathematics

to Sundanese Gamelan culture through activity sheets and practice problems. For example, students practice calculating the saron blade area. Consequently, this enhanced arithmetic comprehension and made learning fun.

Expert Review

The developed e-module was validated by two mathematics education teachers. Only one round of validation was conducted based on comments and suggestions provided by the validators. In the fourth validation stage, three validators considered Prototype 1 valid. During this stage, the e-module was deemed valid based on a validation sheet designed for small-group testing. The validators approved these questions and focused on Prototype 1 product validation during expert evaluation. Dr. Sudirman, M.Pd, and Dr. Muhamad Galang Isnawan, M.Pd, specialists in the mathematics education, reviewed this process. Prototype 1 underwent online validation on August 24, 2023, using WhatsApp to facilitate more flexible communication. Table 1 shows the reviews of these two experts and their comments/ suggestions on content correctness, ethnomathematics relevance, e-module interactive design, and curricular fit. Their feedback helped refine the prototype to meet academic requirements and educational goals.

Table 1

Comments and Suggestions from Experts' Review

No.	Comments and Suggestions	
	Dr. Sudirman M.Pd (Validator 1)	Dr. Muhamad Galang Isnawan, M.Pd (Validator 2)
1	For applicable aspects, figures depicting ethnomathematics were suggested to be used as points or contexts that successively form the concept of iceberg.	Adjust KD and GPA with Merdeka Curriculum.
2	In terms of language use, the sentences in module need to be reread to make it easier for students to understand, some parts of the sentences need to be clarified.	Divide module into three main activities, namely initial, core, and final activities.

(continued)

No.	Comments and Suggestions	
	Dr. Sudirman M.Pd (Validator 1)	Dr. Muhamad Galang Isnawan, M.Pd (Validator 2)
3	For student-centered activities, module should be integrated with specific learning designs and sections that allow for student interaction and understanding of the material.	Include learning objectives in each material.
4	Finally, for student worksheet questions as an evaluation tool, it is recommended that the questions aim to develop certain ability, such as problem-solving.	Clarify the activities in module according to the learning steps.
5	-	Pay attention to the proper use of mathematical signs.
6	-	Avoid typos, such as typos on the cover.

Dr. Sudirman, M.Pd., found the module usable with some suggestions for improvement. For example, Dr Sudirman emphasized the importance of using simpler language, implementing student-centered activities, and including targeted evaluation questions on ability development to enhance the module's practicality. Dr Sudirman and Dr Muhamad Galang Isnawan concluded that with a few tweaks, the module could be more effective for junior high arithmetic students. The Junior High School Comparison and Field Geometry Teaching Module, based on Ethnomathematics Approach of Traditional Musical Instruments (Sundanese Gamelan) was approved. However, Dr. Muhamad Galang Isnawan, M.Pd., suggested some changes to improve module quality and efficacy for Junior High School learning. Furthermore, it was determined that the Sundanese Gamelan ethnomathematics e-module required a complete overhaul to incorporate Dr. Sudirman and Dr. Muhamad Galang Isnawan's recommendations. Dr. Sudirman proposed using ethnomathematics visuals to show Sundanese Gamelan mathematical principles using the iceberg model. Simplified language was recommended for students' comprehension, incorporating engaging, student-centered activities to promote independent learning, and creating problem-solving evaluation questions. However, Dr. Muhamad Galang Isnawan

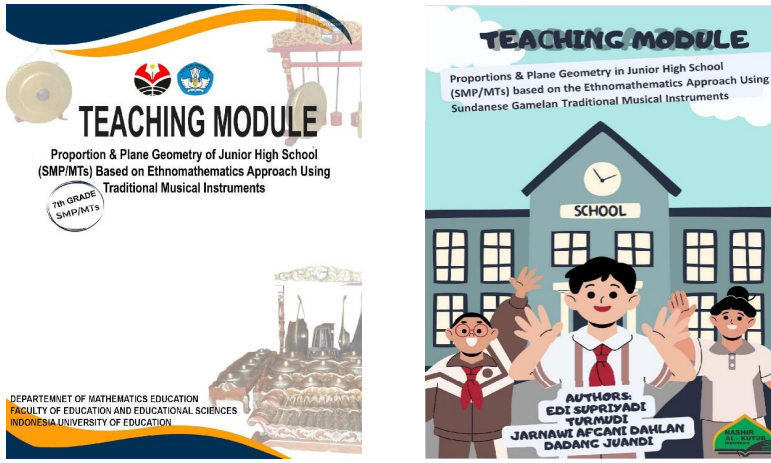
recommended adjusting the module with the Merdeka Curriculum, structuring it into initial, core, and final activities, clearly stating learning objectives, ensuring module clarity, using mathematical signs correctly, and avoiding typographical errors, specifically on the cover.

The suggestion by Dr. Sudirman and Dr. Muhamad Galang Isnawan to incorporate Sundanese ethnomathematics into mathematics curriculum aligns with the broader exploration of ethnomathematics in modern education (Lidinillah et al., 2022). The challenges in integrating ethnomathematics, particularly in complex subjects such as geometry, were identified, revealing the intricacies included in melding cultural elements with mathematical concepts (Sunzuma & Maharaj, 2019). This highlights the necessity of a meticulously planned implementation strategy, outlining specific activities and learning objectives. Additionally, the literature underscores the transformative potential of an ethnomathematical curriculum in enhancing students' abilities and talents (Fouze & Amit, 2017), suggesting a paradigm shift in educational methods. The exploration of ethnomathematics in specific cultural settings, such as the study of the House of Using Banyuwangi (Hariastuti et al., 2019), further elucidates the significance of cultural integration in mathematics education. This integration provides a richer, more relatable context for learning mathematics and also fosters a deeper appreciation of cultural diversity and its intellectual heritage. Therefore, the integration of Sundanese ethnomathematics in education represents a confluence of traditional wisdom and contemporary pedagogy, potentially leading to a more holistic and engaging learning experience.

The changes involved simplifying terminology, incorporating culturally relevant imagery to explain math concepts, and adding interactive features to engage children. The module was organized according to learning objectives, with activities carefully selected and aligned with these goals. Precise mathematical symbols and language were utilized throughout the model. Furthermore, thorough proofreading ensured clear presentation and maintained a professional tone. These revisions aimed to enhance the program's engagement, accessibility, and educational robustness, in line with Merdeka standards and culture. Prototype 1 underwent improvements based on expert feedback following validation as shown in the following figure showing the enhancements.

Figure 6

The Revision Process of E-Module Covers



Before Revision **After Revision**

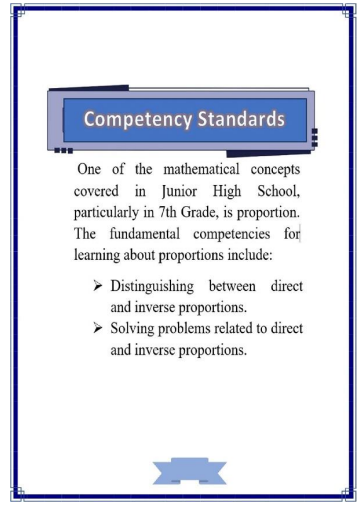
Figure 6 presents the original and updated covers of the e-module. Initially, the description was more detailed, featuring gamelan and traditional settings, along with text about the teaching module and an Indonesian university mathematics education curriculum. After the modification, the version became simpler, showcasing cartoon characters representing students in a school setting. The module title was presented with a sleeker layout and reduced content, with the authors' names at the bottom of the cover. These changes, including reduced graphic density and emphasis on the title and authors, aimed to make the material more appealing and accessible to students. It is worth noting that module title in Prototype 1 had typographical errors.

Figure 7 shows two pages of teaching material that served as the introductory pages for two sections, before and after editing. After the revision, Basic Competencies were prioritized. In education, basic competencies represent the fundamental knowledge and ability students should acquire. The foundational ability in Junior High School mathematics, specifically for Grade VII, focuses on the concept of comparison. The main topics comprise understanding basic and inverse value comparisons and solving related problems. The objective is to simplify and explain the competencies students needed to identify the primary learning outcomes of the comparative material.

Figure 7

The Process of Change as a Result of Revision in the E-Module Teaching Materials Section

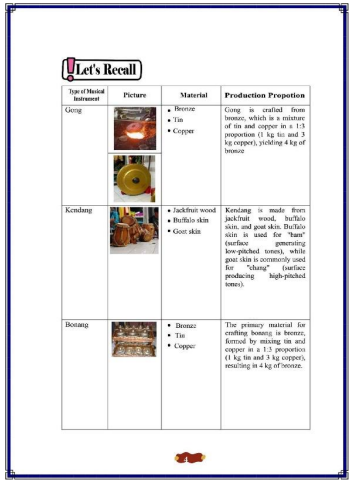
Before Revision



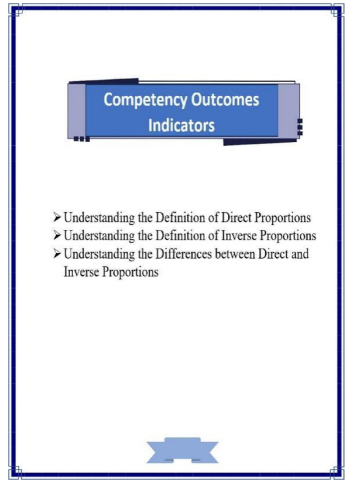
After Revision

Figure 8

The Process of Change as a Result of Revision in the E-Module Learning Activities Section



Before Revision

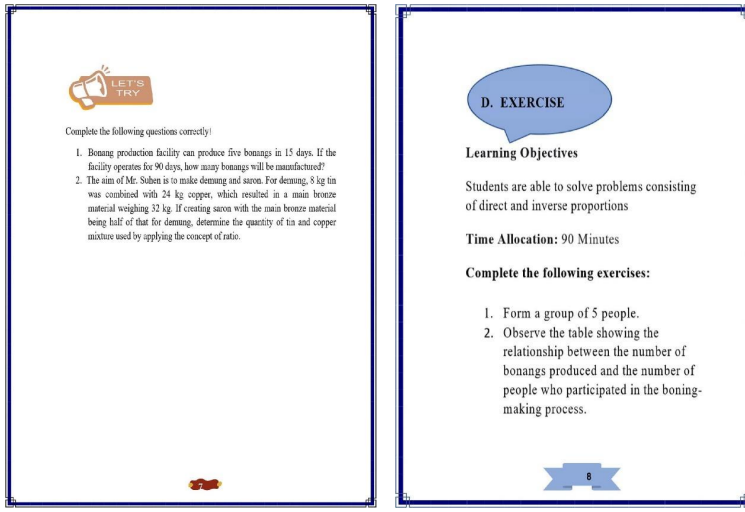


After Revision

Figure 8 shows two educational e-module pages with learning activities before and after revision. The "Mathematics Teaching Tools" on the pre-revision page featured photos and explanations of ethnomathematics learning resources using traditional tools. A table presented the tool type, a picture, and a caption or description of how to use it in mathematics learning, describing the way to set up and use objects for teaching math. On the other hand, the post-revision page used a narrative method to engage students in mathematical problem-solving. It encouraged students to use comparison in gamelan-making, a strategy used by mathematics teachers to help students apply abstract concepts. The transition from physical tools to narratives and case studies aimed to enhance conceptual understanding and problem-solving abilities.

Figure 9

The Process of Change as a Result of Revision in the E-Module Assessment Sheet Section

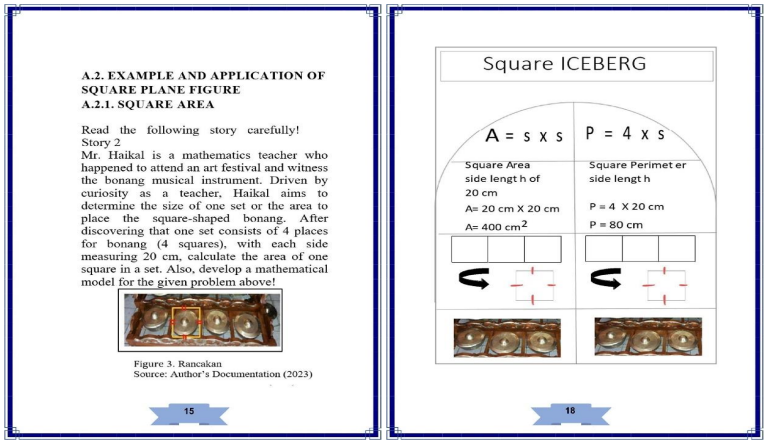


Before Revision **After Revision**

Figure 9 shows a student assessment sheet for ethnomathematics-based mathematics learning activities. The pre-revision section assigned tasks to students but lacked order and structure. However, the post-revision page organized the document and explained practice questions for assessment. This section included clear learning objectives, time constraints, and well-organized instructions.

Figure 10

Addition of Content Based on Experts' Suggestions in E-Module



In Figure 10, two pages from a classroom module show the practical application of mathematics in daily life. The iceberg metaphor stated that only a small part of the subject matter was visible, while the deeper comprehension and application of the topic might not always have been apparent. The following page described real-world square footage applications. Students were tasked with using area calculations to determine the number and placement of square sound boxes for an arts and music festival. By modeling the problem mathematically, students integrated mathematics with real-world issues. The inclusion of information about icebergs on the first page and language on the second page enhanced module background, combining explanations to effectively convey mathematical ideas in accessible language. Understanding the formula and its application in daily life helped enhance students' conceptual knowledge and problem-solving abilities.

Small Group

To assess the feasibility, practicality, and efficacy of e-module, Prototype 3 was tested with a small group of students with diverse abilities. In this phase, teachers were instructed to implement the module according to the authors' guidance, while an observer monitored the process. During the small-group stage, students accessed the e-module through smartphones using the link https://bit.

ly/etnosunda, shared by teacher following improvements based on expert suggestions. This link was also used for field trials including a larger number of students from this small group stage. Data was collected through semi-structured interviews, observation sheets, and teacher response questionnaires. Thematic analysis was applied to semi-structured interviews for qualitative analysis, whereby participants shared their insights. The results were instrumental in developing the Sundanese Gamelan ethnomathematics e-module, examining three themes related to e-module development demands. Data analysis, conducted with Atlas.ti 23, focused on content analysis and extensive textual data processing, making it suitable for qualitative studies (Gulsia & Yadav, 2023). This data analysis led to the revision of Prototype 3 to Prototype 4, which underwent field testing.

Figure 11

Activities for Using Sundanese Gamelan Ethnomathematics E-Module in Small Groups

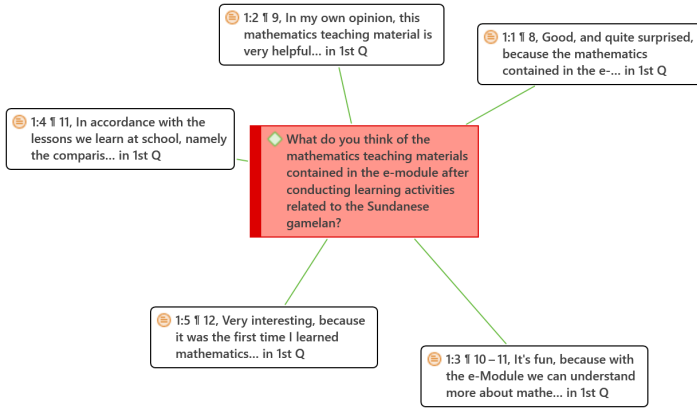
Selected responses from each respondent were shown in Figures 12–14, describing the manner in which the code was formed using Atlas.ti analysis tool. Overall feedback indicated positive reactions from students regarding the e-module.

Integration of Mathematics Materials with Sundanese Gamelan in e-module

This theme explored the way mathematics teaching materials integrated into the e-module related to Sundanese Gamelan impacted students' understanding and interest. Aspects covered in this theme included the suitability of materials to the curriculum, the clarity of mathematical concepts, and the effectiveness of Sundanese Gamelan as a tool to reinforce mathematical understanding. Qualitative data from student responses were analyzed to understand the way this integration effectively enriched the teaching and learning process.

Figure 12

Integration of Mathematics Materials with Sundanese Gamelan in E-Module



The individuals interviewed shared various insights on the mathematics teaching materials in e-module related to Sundanese Gamelan. The first participant appreciated the quality of the material but experienced initial surprise and mild confusion due to the mathematics content connected to Sundanese Gamelan. Furthermore, the second participant viewed the material as highly advantageous for students, enhancing eagerness for learning, specifically with Sundanese Gamelan. The third participant found the learning process enjoyable, valuing the deeper comprehension of mathematics and the connection to Sundanese Gamelan offered by the e-module. Additionally, the fourth participant described material's congruence with the school curriculum, comprising topics such as number comparisons, shapes,

area, perimeter, volume, and surface area. Finally, the fifth participant expressed particular interest, stating that it was the first time engaging with mathematics through an e-module.

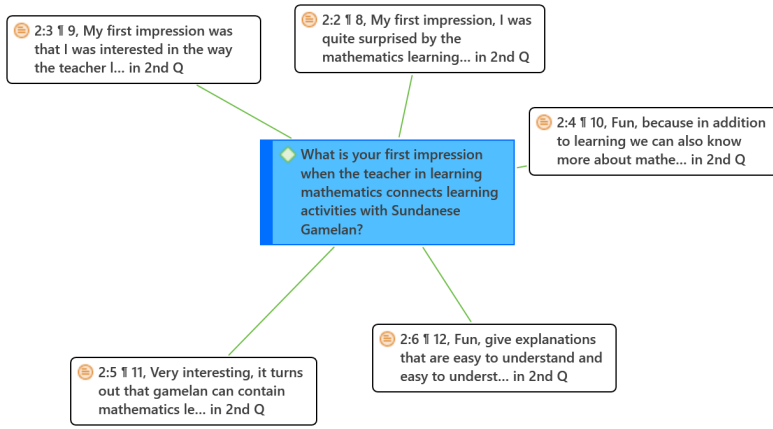
The fusion of Sundanese Gamelan with mathematics education has been shown to boost students' enthusiasm and deepen their mathematical understanding (Muhtadi et al., 2017; Supriyadi et al., 2022). This synergy aligns with increasing exploration in ethnomathematics and the infusion of cultural elements in mathematics education, showcasing the rich potential of cultural context in enhancing learning. The integration of Sundanese culture in educational materials reflects congruence with the school curriculum and also summarizes the essence of local wisdom (Lidinillah et al., 2022; Nugraha et al., 2020). However, the initial surprise and confusion expressed by some individuals indicate the crucial need for more in-depth investigation (Imswatama & Lukman, 2018; Purwoko et al., 2023). This investigation should examine the effective integration of cultural elements into mathematics education and ensure a seamless and enriching learning experience for students. Such exploration would ideally bridge the gap between traditional cultural practices and contemporary educational methods, forging a path that honors cultural heritage while simultaneously enhancing mathematical literacy and understanding.

Student Learning Experience with Ethnomathematics Method

This theme focused on students' first impressions and their overall learning experience when teachers integrate mathematics learning with local cultural elements such as Sundanese Gamelan. It encompasses aspects such as learning motivation, student engagement in the learning process, and how the method aids in understanding mathematics within a broader cultural context. An analysis of students' responses aims to identify the strengths and weaknesses of the method.

Figure 13

Student Learning Experience with Ethnomathematics Method



The interviewees shared varied yet positive impressions of the unique integration of mathematics learning with Sundanese Gamelan. A respondent was surprised by this innovative method, while another found it intriguing and beneficial for enhancing their abilities. Additionally, a respondent described the experience as enjoyable, stating that it improved understanding in both subjects. Another individual found the mathematical aspects inherent in gamelan form and construction fascinating. Finally, a participant appreciated the way this method made mathematics formulas simpler and more fun to learn, indicating the ease of understanding provided.

The use of an e-module incorporating Sundanese Gamelan in mathematics teaching provided the opportunity to evaluate the impact of culturally enriched educational tools. This method aligns with the development of STEM-based e-modules aimed at promoting critical thinking ability, particularly in trigonometry, suggesting a deeper engagement with the subject matter (Maziyah & Hidayati, 2022). The reported enhancement of students' eagerness and deeper comprehension of mathematics through the e-module shows the efficacy of problem-solving-oriented digital tools in cultivating critical thinking ability (Suarsana & Mahayukti, 2013). Furthermore, the practical application of the e-module by both teachers and students supported the integration of digital and culturally relevant content in educational settings (Utama & Zulyusri, 2022). This

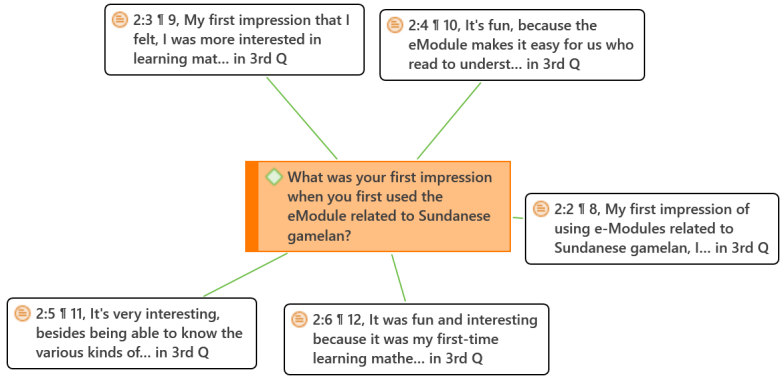
integration reflects an adaptive learning methodology and also calls for a nuanced understanding of how the digital tool, instilled with cultural elements, could revolutionize traditional teaching methods. Additionally, it incorporates a critical examination of how the module effectively bridges the gap between cultural relevance and modern pedagogical needs, potentially setting a precedent for future educational innovations.

Use of Ethnomathematics e-module

The theme of this analysis was the first impression and general experience of students when using the ethnomathematics e-module related to Sundanese Gamelan. This included technical aspects of the e-module, namely interface design, ease of use, and the content presented, as well as its impact on the mathematics learning process. Students' responses were analyzed to evaluate the effectiveness of the e-module in facilitating interesting and meaningful learning.

Figure 14

Use of the Ethnomathematics E-Module



The interviewees provided varied responses regarding their initial experiences with the e-module related to Sundanese Gamelan. The first participant was unfamiliar with the e-module in this context, but the second participant expressed increased interest in learning mathematics due to the incorporation of Sundanese Gamelan, which added an engaging element to the studies. Furthermore, the third participant found the e-module both fun and easy to understand, appreciating the connection to Sundanese Gamelan, which made the

learning process more enjoyable. The fourth participant described the experience as very interesting, particularly valuing the opportunity to learn about different types of gamelan and the mathematical concepts embedded in instruments such as *gong, drum, bonang, saron*, and *demung*. Finally, the fifth participant also found the experience fun and intriguing, stating that it was their first encounter with learning mathematics through an e-module.

The diverse reactions to the Sundanese Gamelan e-module, as recounted by interviewees, resonate with scholarly results on the relationship between cultural elements and digital learning tools. The integration piqued interest in mathematics and also indicated the potent blend of culture and education in stimulating students' engagement (Syahrial et al., 2019). Furthermore, Sundanese ethnomathematics can catalyze creative thinking and refine geometric and algebraic understanding, showing the multidimensional impact of a culturally infused curriculum (Supriadi, 2019). Moreover, interactive e-modules based on realistic mathematics education methods reinforce the positive influence of digital tools on mathematical literacy (Aulia & Prahmana, 2022). These scholarly insights are consistent with the interviewees' experiences, where the e-module's cultural relevance made learning more enjoyable and effective. Consequently, this synthesis requires a critical examination of how integrating cultural dimensions in e-learning could transform the educational landscape, enhancing both cognitive understanding and cultural appreciation and engagement in the learning process.

Observation Report

During the observations, students' reactions ranged from astonishment to appreciation before fully accepting and enjoying the new way of learning. The combination of mathematics with local cultural components such as Sundanese Gamelan made studying more interesting and improved their ability and comprehension of both topics, which increased motivation and engagement. The ethnomathematics method assisted students in understanding mathematics in a cultural context, making abstract concepts more real and relatable. As a result, positive feedback was received concerning the ethnomathematics e-module. The design and content made arithmetic fun and accessible. While some students were unfamiliar with e-modules, others enjoyed it, specifically Sundanese Gamelan. It is important to note that the

e-module was easy to use and enhanced student learning. Therefore, integrating cultural components such as Sundanese Gamelan into mathematics education through e-modules was a novel and effective method.

The integration of ethnomathematics with e-modules was shown to enhance students' engagement and motivation in learning educational methodologies. This blending made learning more enjoyable and significantly strengthened students' mathematical ability and comprehension by weaving in local cultural narratives (Fouze & Amit, 2023). This method, connecting mathematics with cultural context, was a pedagogical choice as well as a paradigm shift in educational practices. Specifically, it sparked a deeper interest in mathematics by anchoring abstract concepts in tangible cultural experiences. The effectiveness of ethnomathematics-based e-modules further corroborated the role in transforming mathematics from a traditionally abstract subject into an engaging, culturally enriched discourse (Sutarto et al., 2022). This positive reception showed the potential of such innovative teaching strategies in reshaping educational landscapes. The integration of culturally resonant elements, namely Sundanese Gamelan, into mathematics e-modules exemplified an educational renaissance, blending the rigor of mathematics with the richness of cultural heritage, thereby promoting a holistic and immersive learning experience.

Teacher Response

Teachers commended Sundanese Gamelan Ethnomathematics e-module for helping students understand comparison and geometry more easily. They found that the e-module's straightforward instructions and terminology facilitated teaching these topics effectively. Moreover, it was crucial to acknowledge that the e-module met the developmental needs of both students and teachers by promoting engagement and supported social and collaborative learning. Students' independence relied on the guidance provided by the e-module to understand the subject, meet learning objectives and improve problem-solving ability. Additionally, the e-module promoted student excitement for learning, which ultimately improved motivation and engagement. It also helped in instilling character values, reflecting focus on character growth in addition to cognition. Overall, the e-module was deemed an effective educational tool by

86% of teachers. Consequently, teachers advised including story problems comprising inverse ratios in the curriculum to enhance student comprehension, particularly in comparison materials, and provide a deeper understanding of more complicated mathematical topics.

The acclaim for the Sundanese Gamelan Ethnomathematics e-module, particularly in enhancing student comprehension in comparison and geometry, warrants a more nuanced analytical and critical examination (Faisyal et al., 2023). It is crucial to examine how the Sundanese Gamelan context enriches understanding and incorporate the significance of culturally relevant teaching tools in mathematics. While the e-module instructions and language were straightforward and user-friendly, a deeper inquiry should address whether this simplicity sufficiently challenges students to develop higher-order thinking abilities. The e-module's facilitation of social interaction and collaborative learning (Yuliana et al., 2022), as well as its alignment with learning objectives (Mutaqin et al., 2021), suggests robustness in promoting independent and comprehensive learning. However, these aspects require a closer examination to measure effectiveness in nuanced problem-solving scenarios. The e-module's role in improving student enthusiasm also calls for exploration of the specific elements that trigger this engagement, considering how they might be diversified to suit various learning styles (Latif, 2022). The proposed inclusion of story problems incorporating inverse ratios opens avenues for further enhancement, necessitating a discussion on the potential to accomodate diverse learning abilities while adhering to educational standards (Faisyal et al., 2023). The contribution of e-module to the broader ethnomathematics discourse highlights the need to evaluate the challenges and opportunities in adapting these educational tools to different contexts, thereby enriching the educational landscape with culturally responsive teaching methods.

CONCLUSION

In conclusion, the integration of Sundanese Gamelan ethnomathematics into e-modules for junior high school mathematics significantly enhanced students' understanding and interest in mathematics. This method successfully connected mathematics with cultural elements, making abstract mathematical concepts more

relatable and comprehensible for students. The study also showed that this culturally infused educational tool was well-received by both students and teachers, leading to increased motivation and engagement in the learning process. Moreover, the e-modules effectively bridged gaps in mathematics education by incorporating real-world challenges and cultural relevance, promoting a deeper appreciation and understanding of mathematics in the context of local culture and society. The implications of the results are substantial for the field of education, suggesting that integrating cultural elements into the curriculum could significantly enhance learning outcomes and students' engagement. This method enriched the educational experience and also promoted cultural awareness and appreciation, indicating a potential shift towards more culturally responsive and inclusive educational practices.

This pioneering study method in integrating Sundanese Gamelan ethnomathematics into mathematics offers a unique blend of cultural heritage with academic content. This innovative method significantly benefits students by making mathematics more tangible and relevant, enhances teachers' teaching strategies with culturally responsive tools, and provides curriculum developers with insights for future inclusive curriculum design. Additionally, it contributes valuable empirical evidence to ethnomathematics exploration. The novelty of this method is evident in its specific application of Sundanese cultural elements to teach mathematical concepts, both in increasing mathematical comprehension and promoting cultural awareness and appreciation, thereby presenting a holistic educational paradigm.

ACKNOWLEDGMENT

The authors acknowledge Dr. Sudirman M.Pd, and Dr. Muhamad Galang Isnawan, M.Pd, for validating the e-module. They also express gratitude to SMP Negeri 30 Bandung, particularly Mrs. Novia Heryanti, S.Pd, for her assistance in implementing this study.

CONFLICT OF INTEREST

The authors declare no conflict of interest regarding the publication of this manuscript.

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