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STEM-Based Learning Module Oriented Towards Balinese Ethnomathematics to Enhance Students' Creative Mathematical Thinking Abilities

Kadek Dwiki Juliantara[1*], I Wayan Puja Astawa[2], I Made Ardana[3]

[1,2,3]Departement of Master's Program in Mathematics Education, Ganesha Education University, Indonesia

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ABSTRAK

Saat ini terdapat tantangan dalam pembelajaran matematika yaitu berpikir kreatif. Banyak siswa yang ditemukan memiliki kemampuan berpikir kreatif matematis yang rendah. Oleh karena itu penelitian ini bertujuan untuk mengembangkan modul pembelajaran berbasis STEM dengan fokus etnomatematika Bali untuk meningkatkan berpikir kreatif matematis siswa. Penelitian ini menggunakan desain penelitian plomp, penelitian ini melibatkan 105 siswa SMA yang dilanjutkan melalui tahap penelitian pendahuluan, prototyping dan penilaian. Berbagai instrumen yang digunakan antara lain lembar validasi, penilaian praktikalitas, dan tes esai, dengan menggunakan analisis deskriptif. Penelitian ini menghasilkan terciptanya modul pembelajaran berbasis STEM yang berkualitas, tervalidasi efektivitas dan kepraktisannya. Modul ini mengintegrasikan unsur etnomatematika Bali, menampilkan video pembelajaran dan unsur GeoGebra interaktif. Penelitian ini mengidentifikasi lintasan pembelajaran yang melibatkan tiga kegiatan utama yang berkaitan dengan transformasi geometri sekolah menengah. Penerapan modul memberikan peningkatan kemampuan berpikir kreatif matematis siswa secara signifikan, dibuktikan dengan hasil post-test dan nilai n-gain yang dihitung. Kesimpulannya, modul yang dikembangkan merupakan alat yang valid, praktis dan efektif untuk meningkatkan berpikir kreatif matematis siswa, yang memadukan prinsip STEM dan etnomatematika Bali. Kajian tersebut menekankan pentingnya mengintegrasikan unsur budaya ke dalam materi pendidikan untuk menumbuhkan pemahaman konsep matematika yang lebih dalam. Temuan ini menggarisbawahi potensi pendekatan ini untuk memberikan kontribusi positif terhadap pendidikan matematika, khususnya dalam konteks relevansi budaya lokal.

ABSTRACT

Currently there is a challenge in learning mathematics, namely creative thinking. Many students were found to have low mathematical creative thinking abilities. Therefore, this study aims to develop STEM-based learning module with a focus on Balinese ethnomathematics to improve students' creative mathematical thinking. This research used a plomp research design, this research involved 105 high school students who continued through the preliminary research, prototyping and assessment stages. Various instruments are used, including validation sheets, practicality assessments, and essay tests, using descriptive analysis. This research resulted in the creation of quality STEM-based learning modules, validated for their effectiveness and practicality. This module integrates elements of Balinese ethnomathematics, featuring instructional videos and interactive GeoGebra elements. This study identified learning trajectories involving three main activities related to middle school geometric transformations. The implementation of the module provides a significant increase in students' mathematical creative thinking abilities, as evidenced by the post-test results and the calculated n-gain value. In conclusion, the module developed is a valid, practical and effective tool for improving students' creative mathematical thinking, which combines STEM principles and Balinese ethnomathematics. The study emphasizes the importance of integrating cultural elements into educational materials to foster a deeper understanding of mathematical concepts. These findings underscore the potential of this approach to make a positive contribution to mathematics education, particularly in the context of local cultural relevance.

Corresponding author
*E-mail addresses: kadekdwikijuliantara@gmail.com (Kadek Dwiki Juliantara)

1. INTRODUCTION

In the rapidly advancing landscape of science and technology, various innovations have emerged, creating implications across multiple sectors to guide humanity through the swift currents of disruption and 21st-century competition. The demands of the 21st century underscore the need for a competent workforce in the fields of science, technology, engineering, design, and mathematics (Piotrowska et al., 2022; Tytler & Prain, 2022). Previous study asserts that 21st-century skills require human resources proficient in learning and innovation skills; information, media, and technology skills; as well as life and career skills (Ratama et al., 2021; Sulistyaningsih et al., 2019). High school graduates must excel not only in one discipline but in various fields (Tentama & Riskiyana, 2020; Yassir et al., 2022). Education plays a crucial role in preparing the younger generation to compete in the future and cope with the developments of the 21st century. The dynamic changes in the education sector necessitate the ability and skills to generate new ideas, enabling teachers and students to tackle the complexity of problems. The importance of creative thinking abilities is highlighted by previous study emphasizing the need for individuals to provide unusual ideas, examine problems from various perspectives, and generate diverse ideas (Cindy & Silver, 2016). Creative thinking skills, therefore, become a vital competency in line with the requirements of 21st-century learning, encompassing critical thinking, creative thinking, communication, and collaboration skills (Priyatni & Martutik, 2020; Ulandari et al., 2019).

The ability of students to generate mathematical ideas and solve problems creatively is referred to as mathematical creative thinking ability (Muskitta & Djukri, 2016; Priyatni & Martutik, 2020). Creative thinking is a fundamental component embedded in mathematics learning, as acknowledged by previous study stating that creative thinking is a major part of mathematics learning and has been proposed as one of the essential components to be included (Dhayanti et al., 2018). In the realm of mathematics education, the essence of mathematics is creative thinking, signifying that creative thinking is a necessary skill for students in learning mathematics.

However, the mathematical creative thinking ability of students in Indonesia remains suboptimal, as evidenced by the results of the Programme for International Student Assessment (PISA) from 2014 to 2022, reflecting a decline in Indonesia's performance. Specifically focusing on the mathematics category, Indonesia obtained scores of 386 in 2014, 379 in 2018, and 366 in 2022. This decrease in PISA scores in Indonesia indicates a serious and sustained crisis in learning that needs to be addressed, especially considering the targeted mathematics scores in the National Medium-Term Development Plan (RPJMN) for 2024, set at 388. Notably, the PISA mathematics score in Indonesia dropped by 13 points from 2018 to 2022 (Tytler & Prain, 2022). The challenges in mathematical creative thinking are reinforced by real-world observations. During the researcher's observations and interviews with mathematics teachers at the research school, SMA Negeri 1 Singaraja, many students were found to have low mathematical creative thinking abilities. This deficiency could be attributed to the conventional teaching methods in schools, which generally focus on convergent thinking processes, limited to verbal reasoning and theoretical conceptual mastery. As a result, students become accustomed to convergent thinking, leading to difficulties in creatively solving problems and providing an uninteresting learning experience, especially in mathematics education.

To assess the current status of students' creative thinking abilities in mathematics, the researcher conducted a pre-test to gauge students' creative thinking abilities with questions directed toward creative thinking indicators. The provided sample answers illustrate the shortcomings in understanding mathematical concepts and applying them correctly, further highlighting the need for a comprehensive approach to foster creative thinking abilities. In light of these challenges, there is a crucial need for an effective learning environment that stimulates students' reasoning to enhance their motivation to solve various mathematical problems. The availability of learning materials or modules that align with the demands of the era is vital (Chuseri et al., 2021; Maziyah & Hidayati, 2022).

The rapid development of science and technology significantly influences the field of education, especially the use of teaching materials that must adapt to these advancements (Arsić & Milovanović, 2016; Englund et al., 2017). Previous study explain that students comprehend the material better when provided with teaching materials that guide their thinking patterns and foster self-reliance (Septianto & Hasan, 2017). Teachers must creatively develop resources and teaching materials to help students understand the taught material, and students benefit more from additional practice problems at home.

One such teaching material that teachers can develop to facilitate students' understanding of the material is a module. Modules serve as instructional materials because they are systematically and engagingly structured, encompassing the content, methods, and evaluation that students can use independently. Module-based learning facilitates meaningful learning, allowing students to be active in the learning process (Pujiastuti et al., 2020; Winatha & Abubakar, 2018). The literature review explores key concepts related to learning modules, creative thinking skills assessment, STEM-based education, Balinese ethnomathematics, and relevant research studies. Learning modules, as instructional materials, are designed to facilitate independent learning with minimal guidance from teachers, emphasizing

characteristics such as self-instructional, self-contained, stand-alone, adaptive, and user-friendly (Castronovo et al., 2022; Fotiadou et al., 2017). The structure of a module includes essential components like subject review, introduction, learning activities, exercises, answer guidelines, summaries, formative tests, and their answer keys (Dini et al., 2023; McKown, 2019).

STEM education, integrating science, technology, engineering, and mathematics, is considered a multidisciplinary approach exploring real-world issues. Balinese ethnomathematics, the connection between culture and mathematics, involves specific mathematical activities within a cultural context (Darmayanti et al., 2022; Sirate, 2011). The integration of STEM education with Balinese ethnomathematics, using Project-Based Learning (PjBL), enhances student creativity. Creative thinking in mathematics involves generating new ideas, combining logical and divergent thinking based on intuition, and providing varied solutions to problems (Handayani et al., 2019; Nurhikmayati & Sunendar, 2020; Saputra & Sujarwanta, 2021). Indicators for creative thinking include fluency, flexibility, elaboration, and originality. Learning trajectory, viewed as a sequence of steps in a specific topic, guides the development of cognitive and learning style-appropriate teaching models and strategies (Jamal, 2020; Palupi & Septiana, 2018). The review concludes with an overview of relevant research studies, each providing insights into the development and effectiveness of STEM-based learning tools, emphasizing the need for incorporating ethnomathematics and cultural elements in educational materials (Lampropoulos et al., 2019; Saputra & Sujarwanta, 2021).

The central focus of this research is the enhancement of students' mathematical creative thinking abilities, with a primary objective centered on the development and implementation of a module-based learning approach. this study aims to develop STEM-based learning module with a focus on Balinese ethnomathematics to improve students' creative mathematical thinking. This research seeks to employ a comprehensive strategy to not only augment creative thinking skills but also to evaluate the effectiveness of the chosen approach. This structured evaluation will provide valuable insights into the efficacy of the module-based learning approach in fostering creative thinking skills. The novelty of this study provide nuanced examination of the impact of the module-based learning strategy on the mathematical creative thinking abilities of the participating students, offering a robust foundation for drawing informed conclusions about the effectiveness of the proposed intervention.

2. METHOD

The research utilizes an educational design research methodology, specifically the model proposed by (Tjeerd Plomp, 2013). This systematic analysis, design, and evaluation approach aim to provide research-based solutions to complex educational problems, contributing to knowledge advancement in intervention characteristics and design processes. There are three key aspects for the quality of a developed learning product: validity, practicality, and effectiveness. These criteria are vital for evaluating the quality of the developed learning module. The criteria for assessing the quality of the learning module, covering aspects such as content validity, construct validity, practicality, and effectiveness. The research follows the three-phase model including: Preliminary Research, Prototyping, and Assessment. Each phase involves specific activities, providing a structured approach to designing and developing the STEM-oriented ethnomathematics Bali-based learning module. Plomp development model is show in Figure 1.

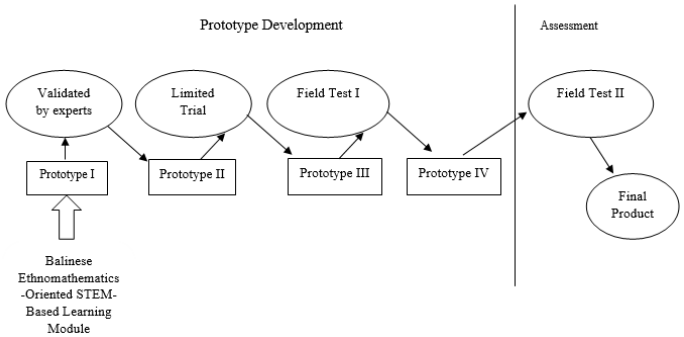

Figure 1. Plomp Development Model

The subjects of the study include experts, students, and teachers. The selection rationale is purposeful, considering the heterogeneity of students in Grade X, where the newly implemented curriculum allows for unique insights into the practicality of the module. The research adopts the educational design research model, focusing on designing and developing the STEM-oriented ethnomathematics Bali-based learning module. The study employs various instruments for evaluation, including a module validity sheet,

practicality assessment questionnaires for students and teachers, and a test of students' mathematical creative thinking abilities.

Data collection methods include observation, interviews, questionnaires, and tests to assess the validity, practicality, and effectiveness of the developed learning module. Descriptive data analysis is employed, focusing on the validation, practicality, and effectiveness of the learning module. Validity is determined through expert validation, practicality through response questionnaires, and effectiveness through the test of students' mathematical creative thinking abilities. The steps involve obtaining scores from validators, calculating average scores, and converting them into qualitative values based on predefined criteria. The learning module must achieve a minimum valid category for classroom use. Additionally, the validation of an instrument for testing creative thinking skills is performed using the Gregory technique, with a calculation of content validity. The practicality of the developed module is assessed through responses from teachers and students, categorized into practicality criteria. The observance of the module's implementation is measured through an observation sheet. Finally, the effectiveness of the learning module is evaluated based on the achievement of research objectives, using descriptive analysis for creative thinking skills test data. The criteria for effectiveness are determined by the scores on the creative thinking skills test.

3. RESULT AND DISCUSSION

Result

The research outcomes reveal various challenges in the current mathematics learning process, primarily focused on teacher-centered approaches, a lack of diverse learning resources, and insufficient use of technology. The study identifies the need for innovative solutions to enhance students' creative thinking abilities in mathematics. Several obstacles, including the dominance of lecture-style teaching, limited learning materials, and low enthusiasm among students, hinder the optimal execution of mathematics education. Moreover, the lack of exposure to STEM-based approaches, ethnomathematics orientation, and the utilization of applications like GeoGebra further contribute to the less-than-ideal learning environment.

Base on the need in the field the researcher interested to develop STEM-based module with a Balinese ethnomathematics orientation to address the identified challenges. The chosen topic for module development is Transformation Geometry, considering its complexity and the students' struggles with understanding and finding relevance in real-life situations. The display of product is show in Figure 2.

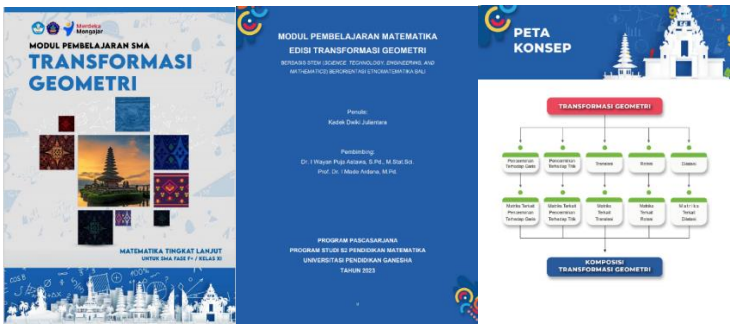

Figure 2. Display of Product

The product is a STEM-based Etnomathematics-oriented learning module on Geometric Transformations, created using Canva and Adobe Illustrator. It includes components tailored to students' needs: introductory material (text and video), material explanations (text and video), example problems, discovery of geometric transformation concepts in traditional Balinese motifs (endek), summary, GeoGebra usage, exercises, and evaluations with explanations.

The learning module encompasses several vital components. Firstly, the Module Identity section incorporates details such as the module title, intended educational level, and the designated time for in-class utilization. Subsequently, the Learning Outcomes section aligns the material structure with the objectives outlined in the Merdeka curriculum. A succinct overview of the geometric transformation material, enriched with STEM and Balinese Ethnomathematics, is provided in the Brief Material Description segment. The module also integrates a straightforward self-assessment feature at the end of each learning activity. This self-assessment proves beneficial by promoting reflection, instigating learning responsibility and independence, fostering ownership of the learning process, and motivating students to continue their educational journey. Furthermore, project-based learning is encouraged when utilizing this STEM-oriented Etnomatematika Bali-based module. Clear instructions for assigning projects are outlined, specifically focusing on designing endek motifs using GeoGebra and applying learned Geometric Transformation

concepts. The detailed explanation of these module components substantiates that the developed module being easily digestible for independent learning, containing comprehensive competencies, functioning as a stand-alone resource, adapting to current technological needs, and presenting visually appealing, user-friendly language within the module.

Then questionnaires on teacher and student responses are distributed during the limited field testing to gauge practicality of the product. The average scores for teacher and student responses indicate high practicality. Feedback from teachers and students is also used for further revisions, resulting in Prototype III. Prototype III undergoes field testing (Field Test I) to evaluate its quality in terms of effectiveness and practicality. The testing involves class XI-A, with 35 students participating. Pre-test and post-test assessments are conducted to measure the effectiveness of the learning module, revealing a significant improvement in students' creative thinking ability after using the module. The practicality is assessed through observation scores, teacher response questionnaires, and student response questionnaires. The results indicate that Prototype III is practical and effective, with improvements seen in both practicality and effectiveness scores in subsequent sessions. Post-test scores show a substantial increase, indicating enhanced creative thinking ability. Teacher and student response questionnaires also highlight the high practicality of the module. The feedback obtained from the field test is used for further revisions, leading to the development of Prototype IV.

The assessment phase involved conducting field trial II using prototype IV with 35 students from class XI-B. The focus was on obtaining a high-quality, valid, practical, and effective final product. Similar to field trial I, field trial II comprised three stages: implementation, observation, and reflection/evaluation, conducted over 5 sessions. A pre-test was administered before implementation to assess students' initial creative thinking abilities. The average score was 52.00, with only 4 students passing. During implementation, researchers, teachers, and students followed the schedule, and observations were made by two observers. The results of the implementation score sheet are summarized as show in Table 1.

Table 1. Summary of Scores for the Learning Module Implementation Sheet in Field Trial II

Meeting	Average Score (Sr)		Total	Total Sr Each Meeting	Remarks
	Observer 1	Observer 2			
1	3.08	3.33	6.42	3.21	Practical
2	3.42	3.67	7.08	3.54	Very Practical
3	3.67	3.50	7.17	3.58	Very Practical
4	3.75	3.42	7.17	3.58	Very Practical
5	3.58	3.75	7.33	3.67	Very Practical
Overall Average Score (SR)				**3.52**	**Very Practical**

Table 1 shows an improvement in scores at each meeting, attributed to initial student adaptation and encountered challenges. However, regular evaluations at the end of each meeting led to solutions for the challenges, optimizing subsequent meetings. The evaluation phase involved collecting data through student response questionnaires, teacher feedback surveys, and a post-test measuring students' creative thinking ability in mathematics. The post-test results indicated an average score increase to 80.51, with 31 students passing and 4 not passing. Interviews with the four students revealed their unfamiliarity with providing more than one answer in a math test. Despite this, the overall results demonstrated an improvement from pre-test scores, with increased student proficiency. The student response questionnaire scored 3.57, indicating "Very Practical," while the teacher feedback survey scored 3.93, also classified as "Very Practical."

The STEM-based ethnomathematics-oriented Bali learning module is rigorously evaluated in terms of validity, practicality, and effectiveness. The learning module undergoes a meticulous validation process involving two experts – a Mathematics Education Master's degree lecturer and an active STEM educator practitioner. The validity assessment includes content validity, ensuring adherence to the Plomp development model, and construct validity, examining the interrelation and consistency of module components. The module achieves a highly valid status with an average score of 3.61. Specific aspects of validity, such as rationality (3.33), objectives (3.75), module content (3.45), layout (3.90), language (4.00), and special features (3.50), collectively establish the module as highly valid and suitable for implementation.

The practicality evaluation involves observations of module implementation, student responses, and teacher feedback. The limited trial yields a practicality score of 3.305, indicating a practical category. Subsequent field trials show consistent improvements, reaching scores of 3.36 and 3.52, categorizing the module as highly practical in both instances. This progression signifies the module's increasing practicality, culminating in a highly practical status during the final field trial. The effectiveness is gauged by assessing the enhancement in students' mathematical creative thinking abilities. Pre-tests and post-tests, analyzed using the gain-score test, reveal gain scores of 0.72 (Moderately Effective) and 0.62 (Moderately Effective)

in the first and second field trials, respectively. The overall effectiveness suggests that the developed module is moderately effective in fostering students' mathematical creative thinking abilities.

Discussion

The STEM-based learning module with a focus on Balinese Ethnomathematics in the Geometry Transformation material was developed based on the Plomp development stages, starting with needs analysis and learning analysis. After identifying the real learning needs and conditions in the field, the learning module was developed based on the established development steps. This module was created due to the absence of current high school mathematics modules based on STEM with a Balinese ethnomathematics orientation. Existing mathematics modules are limited in contextual problem-solving, and students' creative thinking abilities are perceived as low based on PISA and TIMSS results.

The integration of various components in STEM-based learning can stimulate students to engage in creative thinking processes. Research findings indicate that STEM-based learning can enhance students' creative thinking in mathematics (Pramesti et al., 2022). Strong support for the relevance of STEM to creative thinking in real-world applications, enriched by ethnomathematics, as highlighted by other study (Oschepkov et al., 2022). The incorporation of ethnomathematics in STEM-based learning, as explained by previous study can transform mathematics education by applying mathematical ideas to solve everyday problems (Fouze & Amit, 2023). From an ethnomathematics perspective, STEM disciplines can be connected to local culture, society, and the environment, allowing students to think holistically.

The developed product excels in its content, particularly in addressing the limited availability of STEM-related math modules and the absence of high school math modules incorporating Balinese ethnomathematics (Putri et al., 2023; Winandari et al., 2022). The module focuses on Bali's cultural aspect, specifically Bali fabric, as the focal point for learning Geometric Transformations. Clear instructions are provided at the beginning to guide students through difficulties. Various learning styles are accommodated through video explanations, GeoGebra usage, and evaluative questions with instant feedback accessible via barcodes and links (Del Cerro Velázquez & Méndez, 2021; Rohmitawati, 2018). The module offers diverse and varied math exercises aligned with national assessments and 21st-century skill requirements, each with comprehensive explanations. Its flexibility allows students to access it anywhere, anytime, with an attractive design featuring everyday objects for a student-friendly experience (Krelová et al., 2021; Octafianellis et al., 2021).

However, limitations include the focus on a specific Balinese ethnomathematical object – Lubeng motif woven fabric. The module has the potential for further development, exploring other Balinese ethnomathematical objects like different fabric motifs, Balinese carvings, and traditional dances. It is not electronic, aiming for easy storage and accessibility. Implementing the module requires collaboration with subject teachers for effective learning. The non-electronic nature and text-heavy content may pose challenges, requiring motivated and self-directed learners with a high awareness of their needs. Overcoming these challenges necessitates motivation and the right strategies for students.

Building on these findings, it is recommended that educators and practitioners develop similar STEM-based ethnomathematics-oriented modules with broader content coverage, considering the limited scope of transformation geometry content for grade XI in the Merdeka curriculum. Teachers are encouraged to use the module as a reference for innovative and technology-driven mathematics teaching, tailoring it to meet students' needs and enhancing the learning experience. Further research on similar module development is encouraged, extending the study to a broader range of research subjects. For researchers interested in this field, exploring alternative formats like electronic modules and adjusting content to align with students' characteristics and chosen pedagogical approaches could contribute to more interactive and effective learning experiences.

4. CONCLUSION

In conclusion, the developed STEM-based ethnomathematics-oriented module, focusing on Balinese culture and specifically Bali fabric, has proven to be valid, practical, and effective in enhancing students' creative mathematical thinking. The module's high validity, practicality, and effectiveness were evident in scores and feedback from limited trials and field tests, expanding the definition of learning modules to include videos and ensuring quality characteristics. The content, incorporating STEM and Balinese ethnomathematics, provides students with a diverse knowledge base, fostering positive collaboration and discussion through project-based learning. Moreover, the module, designed to enhance creative thinking, includes varied problem-solving scenarios and accommodates various learning styles.

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