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Development of Ethnomathematics-Based Teaching Materials through Interactive Games to Improve Students' Mathematical Literacy

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Abstract

This research explores the development of ethnomathematics-based teaching materials through interactive games, and analyzes their effectiveness in increasing students' mathematical literacy. The ethnomathematics approach combines mathematical concepts with cultural contexts and daily life practices, while interactive games provide an interesting and interactive learning experience. By applying the 4D development model (Four D model), which consists of the stages of definition, design, development, and dissemination, this research produces ethnomathematics teaching material products through interactive games for geometric transformation material. The research was conducted on class XI students majoring in Office Administration at SMK Pasundan 3 Bandung, using test and non-test instruments such as questionnaires, observation sheets, and interview guides. The research results show that the quality of teaching materials, from the feasibility aspect, falls into the very feasible category. The product of this research is ethnomathematics teaching material through interactive games for geometric transformation material. The results of this development show: (1) The quality of teaching materials seen from the feasibility aspect is included in the very feasible category; (2) ethnomathematics-based teaching materials through interactive games have a high effect on students' mathematical literacy; (3) the majority of students have a habit of mind attitude in learning after using ethnomathematics-based teaching materials through interactive games; (4) There is a correlation between mathematical literacy and students' habits of mind after using ethnomathematics teaching materials through interactive games with a strong causal relationship.

Keywords: Teaching Materials, Culture, Interactive Games , Mathematical Literacy, Technology

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INTRODUCTION

Mathematical literacy is a student's ability to formulate, use, and interpret mathematics in various contexts (Yudiawati, et al, 2021). UAE grade 10 students' overall mathematical literacy performance is very low, with females excelling in all aspects, and performance is better on personal math problems than occupational, societal, or scientific problems (Almarashdi & Jarrah, 2023). Mathematical literacy is the ability of students to understand, apply, and evaluate mathematical concepts in various situations (Komarudin, et al, 2024). Mathematical literacy is related to knowledge and skills in using various numbers and symbols in mathematical problems

(Sani, 2021; Verner et al, 2019). Skills that include mathematical literacy involve applying mathematical concepts in real situations and finding multiple ways to solve them. In mathematics, mathematical literacy can be interpreted as an individual's ability to formulate, use, and describe mathematics in various conditions (Ekowati, 2019; Aulia & Prahmana, 2022). This helps individuals recognize the role of mathematics in everyday life and make informed judgments. Mathematical connection skills positively correlate with productive thinking in secondary school students, aiding in problem-solving, creativity, and decision-making (Jawad, 2022). Mathematics and mathematical literacy differ in terms of the concepts and skills used to develop knowledge. The scope of mathematical literacy is adapted to a wide range of environmental conditions. So it doesn't just focus on mathematics material and more on various other types of literacy. The process in mathematics of formulating problems and applying concepts includes several components of ability, namely: (a) formulating problems; (b) applying the concept; and (c) describing the results of the settlement (Purwanti et al., 2012). Based on the ANBK scores for the 2021-2022 academic year, students' mathematical literacy ability scores on a scale of 4 only got a score of 1.79, this shows competence below the minimum.

The learning process that occurs in schools so far shows that students act more as objects and teachers act as subjects. The teacher is the information or learning center, so it often happens that students learn only if the teacher teaches. Additionally, assessments still emphasize results rather than the learning process. The process of learning mathematics in schools is still limited to knowledge. This means that students only receive the materials without making any effort to explore the values and understanding contained therein. One of the factors causing students to be passive during learning is the teacher's monotonous and less innovative way of teaching which results in students not understand the material being presented (Hardianti, 2017). To achieve the goal of learning Mathematics, which is the internalization of students' understanding and their involvement in the learning process to avoid boredom, making learning more meaningful and relatable to everyday life. To support this, varied and rich teaching materials are needed in the learning process. One of the teaching materials that must be developed is ethnomathematics-based teaching materials.

Currently, the teaching materials used by teachers do not consider the condition of students and their environment due to the teacher's lack of ability to develop teaching materials (Mealings, 2023). Teachers have not adapted teaching materials to the conditions of students and their environment due to the limited ability of teachers to design teaching materials (Feng & Xiao, 2024). The learning process has been dominated by print media (books) and only a few use game applications (Nadeak, 2016). Meanwhile, each subject has different character with mathematics tending to require more teaching media besides books. Mathematics is linear and rigid, so the thinking process will become more if combined with something more adaptable such as culture (Tanti, 2018). To increase understanding of culture and mathematics, it is necessary to apply mathematical ethnomathematics (Pathuddin & Mariani, 2023).

One of the alternative materials in mathematics education is ethnomathematics which aims to explore various ways of understanding mathematics by considering academic mathematical knowledge developed by society through various cultures contexts including grouping, calculating, measuring, designing and so on (Rudyanto, 2019). Ethnomathematics is the result of various mathematical activities that are practiced or developed in society. Ethnomathematics also stems from the activities of a tribe where there are mathematical concepts

that are sometimes not recognized by the people themselves.

To evaluate the success of the teaching and learning process, all factors related to teachers and students must be taken into account. This includes the teacher's behavior in teaching and the students' behavior as a response to the outcomes. A student's behavior during the teaching and learning process can indicate whether the student is interested or uninterested in the lesson.

The latest PISA in 2018 shows that Indonesia's mathematical literacy score is still far below the international average, at 379 out of 489, therefore it is possible that students struggle withsolving contextual questions given explicitly with all the necessary data provided. Additionally, only 0.1 % of Indonesian students are able to develop and work on mathematical modeling that requires thinking and reasoning skills (Pranitasari, 2020). Based on my experience while teaching, quite a few students lack motivation when studying mathematics. High student motivation positively influences their perception of teaching practices and use of resources for study, with no gender differences observed (Hossein, 2023). Sometimes, I even find students sleeping in class, chatting, and showing no interest in the mathematics learning. They tend to lack enthusiasm for learning mathematics, if given practice questions only 20% of the students complete them. This is caused by a lack of effective strategies and approaches used by teachers in classroom learning. Classroom learning activities do not employ effective thinking strategies thus failing to develop students' abilities to think critically and systematically (Albaniah, 2014). The situation is that students struggle to solve mathematical problems, and their mathematical literacy skills tend to be low. In classroom activities, students are often only asked to solve problems after the teachers's explanation which leads to passive and silent participation. This results in poory constructed knowledge, understanding, and problem–solving skills.

One way to increase mathematical literacy is through innovation in mathematics learning. In this case, research and development of teaching materials that include cultural elements are needed to motivate students and overcome boredom in learning mathematics. By applying ethnomathematics one can bridge culture and mathematics learning (Pradhan, 2023). Culture-based mathematics learning will be an exciting and innovative alternative (Ota, 2019). Moreover, developing ethnomathematics-based teaching materials through interactive games is a response to the development of science and technology. In line with this, the present study aims (1) to analyze the development of ethnomathematics-based teaching material through interactive games on mathematical literacy (2) to analyze the effectiveness of students' mathematical literacy abilities.

Research into the development of ethnomathematics-based teaching materials through interactive games contributes to increasing mathematical literacy by connecting mathematical concepts with local culture, thereby helping students understand the relevance of mathematics in everyday life. This approach not only improves the ability to think logically, solve problems, and apply concepts, but also makes the learning process more interesting and fun through active interaction in games. In addition, ethnomathematics-based teaching materials also support the preservation of local culture by integrating cultural values into learning, creating students' awareness of the richness of their culture while learning mathematics contextually

METHOD

This research is a type of development research or Research and Development (R&D). This research design uses a 4D (four-D) development model. The 4D Model was developed by Thiagarajan et al (1974). As the name suggests, the 4D model consists of 4 main stages: : (1) definitions; front-end analysis by interviewing and observing learning tools, analyzing concepts by identifying important parts to be studied and arranging material systematically, (2) planning; designing draft teaching materials based on data obtained from the initial research stage, (3) development; is the main stage in creating or arranging teaching materials into a complete unit as well as carrying out expert reviews and (4) dissemination; At this stage, interactive game teaching material products are introduced individually and in groups, then distributed to all students in the school. The population in this study consisted of class XI students at SMK Pasundan 3 Bandung. The research sample included one class of class XI students majoring in Office Administration. Data collection uses non-test instruments in the form of questionnaires, observation sheets and interviews. The test consists of a pretest and posttest with 6 questions in the form of descriptions to measure students' mathematical literacy abilities.

In this research, we tested the effectiveness of ethnomathematics-based learning through interactive games by analyzing pre-test and post-test data. Pretest and posttest analysis was conducted by administering literacy ability test questions and measuring learning outcomes. This was done to determine the effectiveness of the developed interactive game-based teaching materials using effect size. Effect size measures the practical significance of research results by indicating the magnitude of one variable's correlation, difference, or effect on another. The following interpretation is presented for the effect size for a Single Group/One Group.

Table 1. Effect Size for Single Group/One Group

Effect Size	Interpretation
d <2	Weak effect (small effect)
0.21 – 0.50	Modest Effect (simple effect)
0.51 – 1.00	Moderate Effect (moderate effect)
$> 1,00$	Strong Effect (high effect)

Researchers also processed N-Gain data to measure the increase in students' mathematical literacy skills through interactive games before and after learning. Then, the gain index was calculated to determine the classification of increasing mathematical literacy skills in the classroom. The classification of gain achievement according to Hake (Tyson, et al., 2023) is presented in the following table.

Table 2. Classification of Normalized Gain Coefficients

Gain Index	Interpretation
$g \geq 0.7$	Tall
$0.3 \leq g < 0.7$	Currently
$g < 0.3$	Low

Next, the researcher tested the difference in the means of two paired samples in the N-Gain pretest and posttest scores in students' mathematical literacy abilities using the IMB 25.0 program using a non-parametric statistical test, namely the Wilcoxon signed-rank test

RESULTS AND DISCUSSION

1. Development of Ethnomathematics-Based Teaching Materials through Interactive Games

Based on the problems identified in the analysis stage explained in the research results, it is known that the student learning process needs more support from learning resources to help students with geometric transformation material. Therefore, the researcher developed a product in the form of interactive game teaching materials. The titles and indicators were determined based on the syllabus and adapted to the required competencies. The presentation of the development of teaching materials follows the steps (Fika, 2022), namely definition, design, development, and dissemination.

The first stage of developing teaching materials is the definition stage. The definition stage consists of four steps: Front-end Analysis, which involves conducting interviews and observing learning tools. Next, the concept is analyzed by identifying the important parts to be studied and arranging the material systematically. After that, the researcher carries out a task analysis by analyzing the tasks that students need to understand to obtain minimum competency. The final defining step is the formulation of learning objectives by arranging teaching materials as learning media.

The second stage of design. At the design stage, a draft of appropriate teaching materials is designed based on data obtained from the initial research stage or needs analysis. Preparing drafts and determining the appearance of teaching materials is adjusted to the characteristics of teaching materials that students can use independently.

This development research produced a product as an application for teaching materials based on interactive games for vocational school mathematics subjects on geometric transformations. Interactive game-based teaching materials are one of the learning media applications that can be used on Android-based cell phones. The process in the development stage includes developing the content contained in interactive game-based teaching materials so that they can be opened on Android cell phones. The main page is a menu to go to the contents of the teaching materials created.

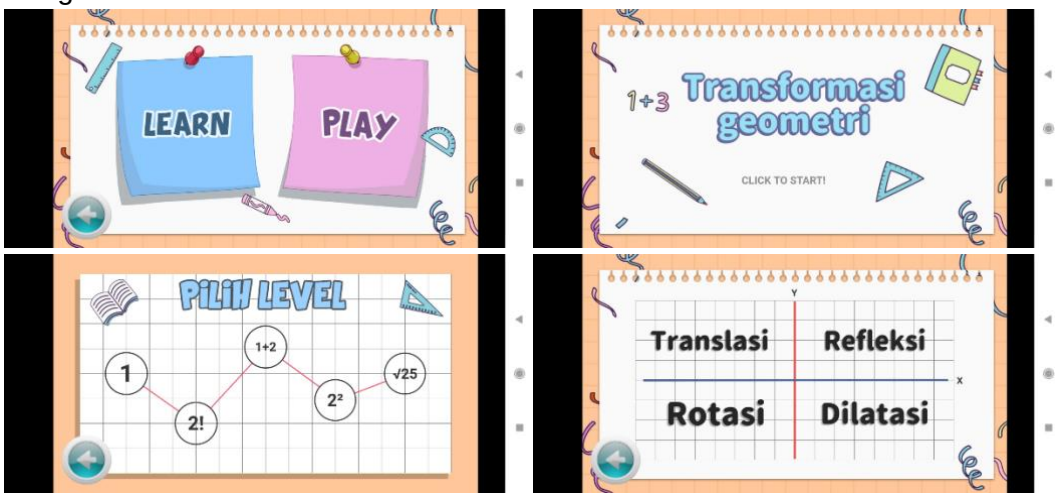


Figure 1. Cover page and main page

The material description contains contextual issues, text, images, and videos. The material is presented using simple language, making it easy for students to understand. Text presentation is equipped with color, bold, and italics. This teaching material product is also equipped with example questions and discussions, practice questions in each learning activity in the form of games.

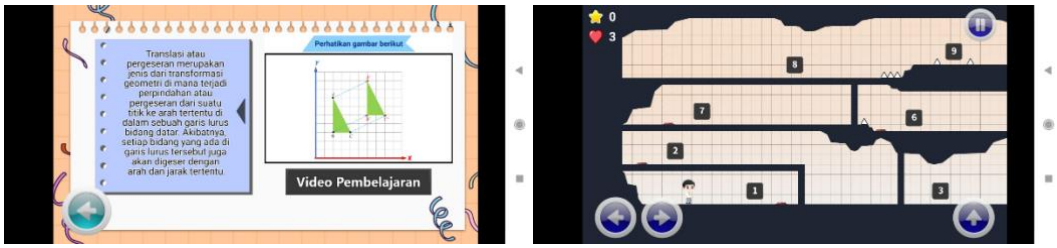
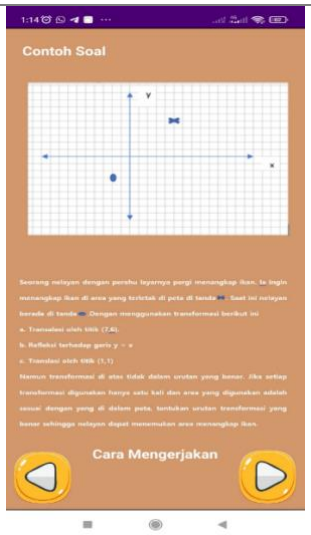
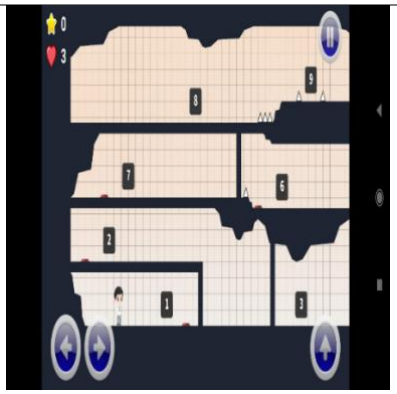


Figure 2. Description of material and practice questions in the form of games

Before being used, the teaching materials are validated by material and media experts. In addition to validating ethnomathematics teaching materials, the validators also provide comments and suggestions on them as input for development.

Table 3. Material and Media Expert Revision

No	Before Revision	After Revision
1		

2	There are no example questions	
3		

The third stage is the development stage, which is the main stage in creating or arranging teaching materials into a unified whole and carrying out expert reviews. The aim of conducting reviews by experts is to obtain input, criticism, and suggestions for improvements to perfect the teaching materials being developed. Expert input is used as a reference for revision, apart from that, filling out a validation questionnaire will determine the suitability of the teaching material to be tested on students. This revision was carried out as a step to create a viable product. The product being developed underwent several revisions regarding components that had to be improved in the teaching materials, such as changing the text and image display to make it more proportional and adding learning materials by embedding learning videos.

Game teaching materials are introduced individually and in groups and then distributed to all students in the school. This research is supported by a statement (Nurdyansyah, 2018) that one of the functions of teaching materials for students is to help students learn independently without having educators or other students help them.

Quantitative data were obtained from the validation of this teaching material, which shows that the teaching material developed from the results of material validation received the very

appropriate category. Thus, material and media experts can conclude that ethnomathematics-based teaching materials through interactive games are worth trying.

Researchers carried out the research by creating ethnomathematics-based teaching materials through interactive games. This aligns with research conducted by Suryani (2018), indicating that interactive games can be used as an easy and effective learning tool in completing students' learning process. One of the advantages of interactive games is that students can be given ease in carrying out learning activities that are not limited by area (Panjaitan, 2020). Another advantage of interactive games is the use of sophisticated, practical, and light tools; hence, students can learn anywhere and anytime.

During the research, students' responses were seen when learning ethnomathematics-based teaching materials through interactive game applications who looked more motivated and enthusiastic to access the material in interactive games. Game-based learning positively impacts computational thinking, but non-significantly affects certain elements due to limited time and students' preferences (Wang, et al., 2023). Gamification and game-based learning, when combined with cooperative learning, enhance academic, personal, and social skills in playful spaces that foster emotions and creativity (Fonseca, et al., 2023). The developed project-based mathematics learning model, integrated with ethnomathematics and technology, effectively improves problem-solving skills, creative thinking, collaboration, and learning motivation in Indonesian students (Wawan, et al., 2023). This is also shown by the students' activeness during learning, where they are enthusiastic about accessing every learning activity in interactive games, they are motivated to solve all the questions contained in each question stage every day, and they try to complete all the challenges contained in the game. This results in them being active in discussion activities to complete practice questions in learning activities, as well as being active in presenting the results of discussions. Students become more active when learning using games (Mulyati, 2020). When students learn with interactive game applications, students become more motivated to study the material more deeply. Students' learning motivation increases by using interactive games media (Rosidah, 2022). Learning through interactive games creates an effective learning climate (Suryani, 2018).

The use of interactive games as a learning medium is easy, cheap, and affordable but effectively complements the learning process. This can increase students' attention and interest in the process, which makes them more active. Learning resources are not limited to printed books only; they can also be taken from the Internet. Using interactive games as a learning medium can create more interesting learning and interest students, potentially increasing mathematical literacy.

2. Effectiveness of Ethnomathematics Teaching Materials through Interactive Games on Mathematical Literacy Ability

The pretest and posttest are designed to determine the effectiveness of the interactive games teaching material products developed in increasing students' mathematical literacy, namely by comparing scores before and after using ethnomathematics teaching material products through interactive games.

The test instruments (pretest and posttest) were carried out on all class XI students at SMK Pasundan 3 Bandung, which consists of one class. The pretest and posttest were carried

out with a total of 24 students. In mathematics learning, interactive game teaching materials provide six descriptive questions that have previously been tested and validated. Complete data on pretest and posttest results can be seen in the attachment. The overall effect size calculation results are shown in the following table.

Table 4. Overall Effect Size Calculation Results

Group	Pretest Mean	Posttest Mean	Effect Size	Criteria
	11,11	66.47	6.58	Strong effect
Standard Deviation	5.78	8.42		

Table 3 shows that the effect size for the application of ethnomathematics-based teaching materials through interactive games on students' mathematical literacy abilities obtained a value of 6.58. Based on the percentile position criteria for the effectiveness of Cohen's actions, it is included in the large category, so it is found that the application of ethnomathematics-based teaching materials through interactive games on geometric transformation material is effectively oriented towards the mathematical literacy abilities of class XI students.

The average percentage of students' mathematical literacy posttest results after using ethnomathematics teaching materials through interactive games applications is 66.47% with sufficient criteria (55%≤C<75%). Below is a bar chart comparing each item's average pretest and posttest scores with no questions.

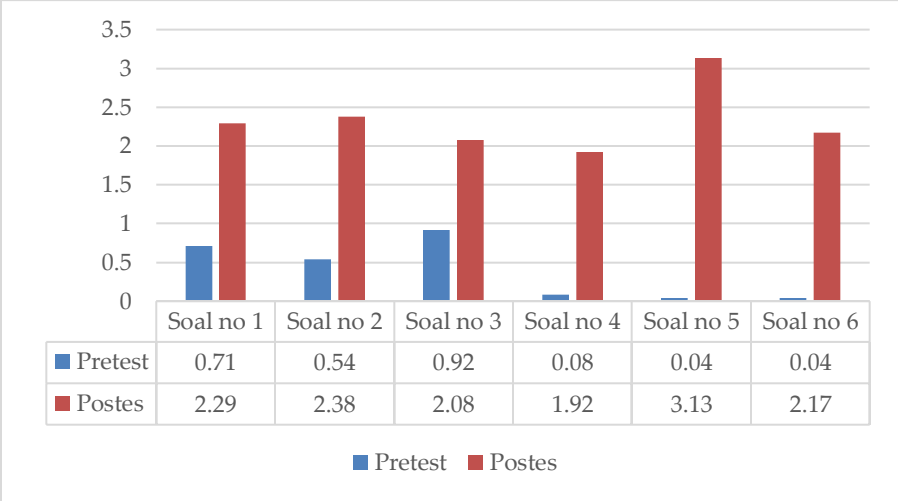


Figure 3. Comparison of Pretest and Posttest Average Scores

Next, tests will be carried out on two paired samples. This sample is defined as a sample with the same subject but carried out with different measurements; the subject will receive treatment I before using ethnomathematics teaching material products through interactive games applications, then treatment II after using mathematics teaching materials through interactive

games applications on geometric transformation material in Pasundan 3 Vocational School Bandung.

Learning results before (pretest) and after (posttest) using mathematics teaching materials through interactive games will be tested for normality using Kolmogorov-Smirnov (for Significance Correction) or Shapiro Wilk in the IMB 25.0 program and obtained values, sig<(α=0,05), the pretest and posttest score data were not normally distributed. For homogeneity of variance in students' pretest and posttest mathematical literacy scores using the Levene test in the IMB 25.0 program, the Based Mean sig value was <0.05, so the variance was not homogeneous.

A non-parametric test was carried out using the test ranking marked from Wilcoxon since the two samples' data come from a population that is not normally distributed. The results obtained are presented in the following table.

Table 5. Wilcoxon Signed Rank Test

Test Statistics [a]	
	Posttest – Pretest
Z	-5,240 [b]
Asymp. Sig. (2-tailed)	,000
a. Wilcoxon Signed Ranks Test	
b. Based on negative ranks.	

Because the probability value Asym. Sig (2 – tailed) < 0.05, then there is a difference in mathematical literacy before and after using ethnomathematics-based teaching materials through interactive mobile game applications.

N-gain analysis is taken from the pretest and posttest scores; the average pretest score is 11.11, and the average posttest score is 66.47. Based on the calculations obtained a gain score of 0.62 in the “Currently” category (0.3≤g<0.7). The increase in the average posttest score shows that, in general, ethnomathematics-based teaching materials through interactive games increase mathematical literacy after students use the product in learning.

Ethnomathematics-based teaching materials through interactive games are considered effective and greatly impact students' mathematical literacy. This is in line with the research results of Malasari et.al (2019) that teaching materials developed through ethnomathematics learning make a positive contribution to students' mathematical literacy abilities. Ethnomathematics, a problem-based learning model, improves students' understanding of linear equations by incorporating real-world context and context-sensitive teaching methods (Sari, et al., 2023)

Applying ethnomathematics-based teaching materials through interactive games dramatically influences the learning process of geometric transformation material. Ethnomathematics learning approaches positively impact students' spatial abilities in non-Euclidean geometry compared to conventional learning approaches (Sukestiyarno, et al., 2023). The proposed framework and tools like GTVisualizer and GTCards effectively support self-learning geometric transformations, achieving comparable results to classroom learning and improving students' visual-spatial abilities (González, et al., 2022). In this ethnomathematics-based teaching material, mathematical literacy questions linked to local culture are presented with the aim of getting students used to working on literacy questions so that students' mathematical

literacy can increase. The habit of working on mathematical literacy questions increases students' understanding of mathematics (Malasari et al., 2019). According to Nurmasari et al. (2023), frequently practicing mathematical literacy questions can improve students' understanding of mathematical material. Elementary education teacher candidates can effectively elicit students' mathematical thinking through various question types in a practice-based education course (Colonnese, et al., 2022)

By using ethnomathematics-based teaching materials through interactive games, students show interest in understanding geometric transformation material because this teaching material is designed with students' characters and needs in mind and is linked to the surrounding culture. The developed Android-based AR learning media effectively improves students' creative thinking skills in geometry learning in the ethnomathematical context of Yogyakarta, Indonesia (Richardo, et al., 2023). Manipulative materials, such as blocks and paperclips, play a crucial role in elementary school students' understanding of geometric figures, promoting their exploration, construction, and differentiation of shapes (Ponte, et al., 2023). This aligns with previous research that ethnomathematics provides a learning environment that creates good motivation, is fun, and is free from the assumption that mathematics is scary (Kusumaningsih, 2018). In addition, culture-based mathematics learning will also be an enjoyable, fun, and innovative alternative because it allows for contextual meaning-making based on students' experiences (Hardianti, 2023). According to Saaudallah et al. (2024), mathematics learning that integrates cultural elements can be an interesting, fun and creative choice, because it allows students to understand concepts through contexts that are relevant to their experiences. Culturally responsive practices can enhance mathematics instruction for culturally and linguistically diverse students with mathematics learning disabilities (Tran & Schepers, 2023). Integrating self-regulated learning and culturally responsive pedagogical practices in complex tasks can improve student engagement in multicultural classrooms (Anyichie, et al., 2023).

After measuring the increase in students' mathematical literacy using ethnomathematics-based teaching materials through interactive games, it shows that these materials generally increase students' mathematical literacy. Gamification-based mathematics teaching materials are valid, practical, and effective in improving junior high school students' problem-solving abilities and critical mathematical thinking (Lukman, et al., 2023). Both shallow and deep gamification techniques can improve computational thinking skills in young students, with deep gamification having a stronger impact on motivation (Olmo, et al., 2023). Based on the analysis of research results, students' mathematical literacy in geometric transformation material after using ethnomathematics-based teaching materials through interactive games increased compared to before using ethnomathematics-based teaching materials through interactive games. After using teaching materials in the learning process optimally, students have a strong concept in geometric transformation material so they are able to develop their mathematical literacy. In line with previous research, interactive game- based learning can be used as a learning medium that can help improve students' mathematical literacy (Ramdani et al., 2018). This is also in line with research by Amorim, et al (2023) that interactive game-based learning is used as an effective medium to improve students' mathematical literacy.

Interactive game-based teaching materials on geometric transformations, this is due to the use of interactive game-based teaching materials which makes it easier for students to

understand mathematical concepts presented in each problem. Research conducted by Cuturi et al. (2023) shows that using interactive educational games significantly increases students' understanding of mathematical concepts. Interactive educational games significantly help improve students' understanding of mathematical concepts (Chue, et al, 2021). Students who used interactive educational games obtained higher scores on tests of understanding mathematical concepts compared to students who used traditional learning methods. In line with this, a study by Sari et al. (2021) concluded that using interactive game-based learning media positively impacts students' ability to understand mathematical concepts. Students become more interested and motivated to learn mathematics through interactive games. Game-based learning positively impacts students' cognitive and affective domains in mathematics education, improving knowledge, skills, and engagement (Hui & Mahmud, 2023)

In this research, there is an obstacle, namely at the stage of developing interactive games applications, there are problems in terms of the completion time for creating interactive games applications by IT teachers at schools. This occurs because IT teachers at schools are busy with a series of exam activities at school, the teaching materials created do not contain student identity because the software used does not have features to create it, some students do not participate in learning activities optimally either independently or in groups so they have difficulty solving mathematical literacy questions. However, these obstacles can be overcome with routine solutions in coordinating with the IT team to assist in creating interactive game applications so that the creation of teaching materials can be completed immediately, teachers continue to provide guidance and supervision, especially for students who have not yet maximized their learning through approach and communication active with the student. A co-design framework and four tools can enhance the design process for industrial engineering games, resulting in a playful learning experience for players (Ma, et al., 2023). Game-based learning using teacher-authored games in computer science education is as effective as traditional teaching in knowledge acquisition but significantly increases student motivation and enjoyment (López-fernández et al., 2021)

CONCLUSIONS

The development of ethnomathematics-based teaching materials in interactive game applications follows the stages outlined in the 4D development model: define, design, develop, and disseminate. Ethnomathematics-based teaching materials in interactive games effectively improve students' mathematical literacy with a moderate improvement category. These teaching materials are designed with the character and needs of students and are associated with the culture around the students' environment so that contextual meaning can occur based on students' experiences. This is able to increase students' motivation, attention, interest, and interests in the learning process so that it has the potential to improve mathematical literacy. The indicator with the highest percentage is interdependent thinking and the indicator that is lacking and needs to be improved is flexible thinking. This is because students are accustomed to routines

and mindsets that have been formed which make students avoid change and find it difficult to adapt to new situations, the traditional education system that emphasizes memorization and repetition of information rather than encouraging creativity and critical thinking, as a result students are not used to flexible thinking and innovation and some students are afraid of failure which can hinder their ability to try new things. There is a correlation between mathematical literacy and students' habit of minds after using ethnomathematics teaching materials through interactive games with a strong causal relationship and a positive (unidirectional) relationship between the two variables, which means that if students' mathematical literacy increases, students' habit of minds will increase, and vice versa.

For further research, it is recommended to focus on developing teaching materials that emphasize local cultural themes and are tailored to students' needs. Additionally, this research can serve as a foundation for similar studies to enhance cognitive and affective abilities.

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