

Enhancing Students' Mathematical Critical Thinking Skills through Ethnomathematics Digital Book STEM-PjBL

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Abstrak

Pembelajaran abad 21 menuntut siswa harus mampu berpikir kritis, kreatif, kolaboratif, dan berkomunikasi secara efektif. Akan tetapi, siswa SMP di Indonesia masih memiliki kemampuan berpikir kritis matematika yang relatif rendah. Penelitian ini bertujuan untuk mengembangkan digital book yang menggunakan etnomatematika dan PjBL STEM untuk meningkatkan kemampuan berpikir kritis siswa. Penelitian ini melibatkan Research and Development (R&D) menggunakan model pengembangan ASSURE yang memiliki enam tahapan dilanjutkan dengan metode penelitian kuantitatif dengan teknik pengumpulan data melalui tes. Hasil dari penelitian ini menunjukkan validitas buku digital berbasis PjBL STEM dengan pendekatan etnomatematika untuk meningkatkan kemampuan berpikir kritis matematis siswa pada materi teorema Pythagoras dinyatakan valid. Berdasarkan penelitian ini, kemampuan berpikir kritis siswa SMP pada materi teorema Pythagoras dapat ditingkatkan dengan buku digital berbasis PjBL STEM dengan etnomatematika. Karena implementasi proyek STEM dan etnomatematika untuk meningkatkan pembelajaran, temuan penelitian ini juga bermanfaat bagi guru dan sekolah dalam menciptakan lingkungan belajar baru.

Kata Kunci: Berpikir Kritis Matematis; Digital book; Etnomatematika; STEM- PjBL

Abstract

In the twenty-first century, students need to develop critical thinking, creativity, collaboration, and effective communication skills. However, junior high school students in Indonesia still exhibit relatively weak critical thinking abilities in mathematics. This study aims to create a digital book that integrates ethnomathematics with the PjBL STEM approach to enhance students' critical thinking skills. Using the ASSURE development model and quantitative methods, the research demonstrates that the STEM-based PjBL digital book, incorporating ethnomathematics and focusing on the Pythagorean theorem, effectively improves students' mathematical critical thinking abilities. Additionally, this approach can aid in the development of innovative learning environments in schools, benefiting both educators and students. Future research is recommended to explore in greater depth how digital book learning media and the STEM-PjBL approach based on ethnomathematics influence educational outcomes. Such investigations will provide a more nuanced understanding and help refine and enhance educational practices and results.

Keywords: Mathematical Critical Thinking; Digital book; Ethnomathematics; STEM- PjBL

I. INTRODUCTION

In the twenty-first century, Indonesia faces several challenges, including the need for students to develop critical thinking, effective oral and written communication, teamwork, creativity, research skills, and problem-solving abilities (Nabilah & Nana, 2020). Therefore, they must be able to respond to the demands of the times to meet the difficulties of the 21st century (Septikasari, 2018; Meilina, Mariana, & Rahmawati, 2023). The Framework Partnership of 21st Century Skills identified this capability or skill as one of "The 4C Skills" for the twenty-first century, of which critical thinking is one. Critical thinking is one of the few abilities that are crucial to develop in the 21st century because Indonesian students' critical thinking ability is now below international standards (Janah, Suyitno, & Rosyida, 2019). The low ability of students' critical thinking is also seen in the ability of students of SMP Negeri 2 Randublatung. Based on critical thinking indicators according to Kennedy, Fisher & Ennis (1991), According to a discussion between the research team and the mathematics teacher at SMP Negeri 2 Randublatung, the eighth-grade students' critical thinking skills still need to improve. The Pythagorean theorem learning outcomes also demonstrate a lack of critical thinking abilities among students; the majority of them remain below requirements in higher-order thinking activities, particularly on inference

indicators (Pritananda & Yusmin, 2016; Afriansyah et al., 2021).

Low higher-order thinking is a result of a variety of factors, including repetitious learning, boring textbooks as learning material, and improper method choice (Azizah et al., 2022; Fitriyah & Ramadani, 2021; Siregar et al., 2021). Kristiyanto (2020) and Siregar et al. (2021) both stressed the necessity for engaging media that is appropriate for the times in order to address this issue, as well as a good strategy to develop students' capacity for higher-order thinking.

To be prepared for 21st-century learning, students must grasp the development and progress of information and communication technology (ICT). Many experts have recently discussed interactive digital books in light of ICT's quick development (Pearson, 2018; Siregar et al., 2023). By integrating electronic media, such as text, photos, music, video, and graphics, along with tools that may be used for interaction, creation, and communication tasks, digital books can promote the development of critical thinking skills (Hofstetter, 2001; Sarumaha & Kurniasih, 2022). Moreover, digital books are an efficient and useful form of electronic learning material that may help students learn, especially those with high levels of ability (Astutik et al, 2024; Pramasdyahsari, 2023; Buchori et al., 2022; Siregar et al., 2021). Digital books not only have a high degree of quality with an enjoyable category design but are also

practical and helpful in the learning process (Divayana et al., 2019; Pramasdyahsari, 2024).

One of the learning approaches, such as project-based learning that is integrated with STEM (Science, Technology, Engineering, and Mathematics), also known as STEM-PjBL (Sumarni & Kadarwati, 2020; Fauzan et al., 2023), is one way to develop critical thinking skills in addition to engaging digital media (Sumarni & Kadarwati, 2020; Pramasdyahsari, et al., 2022; Harun & Pramasdyahsari, 2023). Students are taught to think critically using the STEM method by employing innovative collaborative learning strategies and technical tools to solve and explore problems (Pramasdyahsari et al., 2021; Warsito et al., 2023). The STEM approach also provides various benefits that are by 21st-century learning, such as showcasing students' multidisciplinary viewpoints, developing 21st-century skills, fostering problem-solving abilities, and critical thinking, and boosting digital literacy (Morrison, 2006; Ricks, 2006; Bybee, 2010; Olivarez, 2012; Roberts, 2012; Kennedy & Odell, 2014; Sahin et al., 2014; Gulhan & Sahin, 2016). According to Oktavia and Ridlo (2020); Setyawati, Pramasdyahsari, Astutik, Nusuki, Aini, Arum, Widodo, Salmah and Zuliah (2022) students may be encouraged to communicate procedurally and develop their critical thinking abilities when using the STEM-PjBL learning approach.

On the other hand, critical thinking skills can also be improved through learning techniques based on ethnomathematics. It has a positive and useful effect on the educational process and raises students' motivation to learn (Aini et al, 2023; Aini et al, 2024; Mirnawati et al., 2020; Saesena et al., 2019; Winahyu et al., 2020). However, the previous findings have not been any attempt to foster students' critical thinking abilities through the use of digital books with an ethnomathematics-based PjBL STEM approach. For this reason, the goal of this study is to create digital books that foster students' critical thinking abilities.

II. METHOD

The ASSURE model, consists of systematic activity steps consisting of six sequences, including Analyze Learner, State Standards and Objectives, Select Strategic, Technology, Media and Materials, Utilize Resources, Require Learner Participation, Evaluate and Revise (Purwanti, 2015), was employed in this study continued by a quantitative method with a pre-experimental design (Creswell, 2014; Sugiyono, 2010, 2014). The research involved the students at SMP Negeri 2 Randublatung in the 2022 academic year.

Then the validation is carried out in two stages, namely media validation by experts and instrument validation based on the results of trials on students analyzed using the Rasch Model according to Bambang Sumintono and Wahyu Widhiarso (2015)

assisted by Winstep software. According to Bond and Fox (2015), the mathematical equation in Rasch's modelling on the partial credit model or polytomy grain form (because the form of the test is later described) is:

$$P_{i1}(\theta) = \frac{P_{i1}(\theta)}{P_{i0}(\theta) + P_{i1}(\theta)} = \frac{\exp(\theta_n - \delta_{i1})}{1 + \exp(\theta_n - \delta_{i1})}$$

$P_{i1}(\theta)$ = Probability of respondent I in point 1

θ_n = level trait individual

δ_{i1} = parameter lokasi butir

At this stage, the instrument will be evaluated based on tests of validity, reliability, level of difficulty and differentiating power. Here are the criteria for each test:

Table 1.
Validity Criteria

Criterion	Interval	Information
Meet the MNSQ outfit	0.5 < MNSQ < 1.5	Minimum meets one criterion declared Valid
Meet the ZSTD outfit	2 < ZSTD < +2	
Meet PT Measure Correlation	0.4 < PMC < 0.85	

(Sumintono and Widhiarso, 2015)

Before the test was tested, the validity of the instrument was based on the validation sheet calculated using Aiken's formula according to Crocer (2015) as follows:

$$V = \sum \frac{S}{[n(c - 1)]}$$

Table 2.
Reliability Criteria

Criterion	Interval
Bad	< 0.5
Ugly	0.5 to 0.6
Enough	0.6 to 0.7
Good	0.7 to 0.8
Very good	>0.8

Sumintono and Widhiarso (2015)

Table 3.
Criteria for Difficulty

Criterion	Interval
Difficult	0 to 1
Very difficult	>1
Easy	0 to -1
It's easy	< -1

Sumintono and Widhiarso (2015)

Table 4.
Differentiating Power Criteria

Criterion	Interval
Excellent	>4
Good	0.3 to 0.39
Enough	0.2 to 0.29
Less	0.1 to 0.19
Rejected	<0

Sumintono and Widhiarso (2015)

In addition to analyzing the items, to determine the effectiveness of learning media using criteria according to Saadi (2013) and Wahid, Handayanto & Purwosetiyono (2020), namely (a) learning completeness, it is said to be complete if at least 75% of the total students obtain a score of more than or equal to 60, (b) the average learning outcomes of classes with better treatment than classes without treatment with right-party t tests (c) interest and Student learning motivation is said to increase and learn in a pleasant state if the average score of the response

questionnaire criteria is above 75%. The formulation of the right t-test according to Budiyo (2016) is as follows:

$$t = \frac{(\bar{X}_1 - \bar{X}_2) - d_0}{s_p \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \sim t(n_1 + n_2 - 2)$$

III. RESULT AND DISCUSSION

The development model used by researchers in this study is the ASSURE model which consists of 6 stages including Analyze Learner, State Standards and Objectives, Select Strategic, Technology, Media and Materials, Utilize Resources, Require Learner Participation, and Evaluate and Revise (Purwanti, 2015).

The type of learning needs information containing student needs in the learning process such as learning styles. In this case, based on the results obtained in the interview, students of the second stage is state standards and objectives or determining standards and objectives. At this stage, researchers formulate core competencies and basic competencies based on Permendikbud Number 37 of 2018 and indicators of critical thinking ability according to Robert Ennis (1991) known as FRISCO (Focus, Reasons, Inference, Situation, Clarity, Overview). In addition, formulating standards and goals is also based on the scores of grade VIII B students of SMP Negeri 2 Randublatung which are still below average in mathematics subjects. So because these factors are formulated learning objectives, namely through the learning process by

applying digital books with an ethnomathematics-based PjBL STEM approach, students are expected to be able to think critically in analyzing, proving and solving problems related to the Pythagorean theorem and Pythagorean triple. In this study, the PjBL syntax used is based on the syntax proposed by Laboy Rush (2010).

The third stage is to select strategic, technology, media and materials or choose strategy, technology, media and teaching materials. In improving critical thinking skills in this study, researchers chose digital book media with an ethnomathematics-based PjBL STEM approach as teaching material that is adapted to the times and interactive because it is a student center because student-oriented learning can make students learn actively, besides digital books is also preferred by students because it is interesting in the learning process (Priatna & Lorenzia, 2018; Pixyoriza, 2018; Sugiharni, 2018). The choice of the PjBL STEM approach is because it is an approach that provides positive assistance in improving critical thinking skills (Setyawati, Pramasdyasari, Astutik, Nusuki, Aini, Arum, Widodo, Salmah and Zuliah, 2022; Setyawati et al, 2023). This PjBL STEM syntax uses the syntax proposed by Laboy Rush (2010) which consists of five stages in learning PjBL STEM, namely Reflection, Research, Discovery, Application, and the last is Communication. Figure 1 shows the

particular design of the digital book developed by the author:

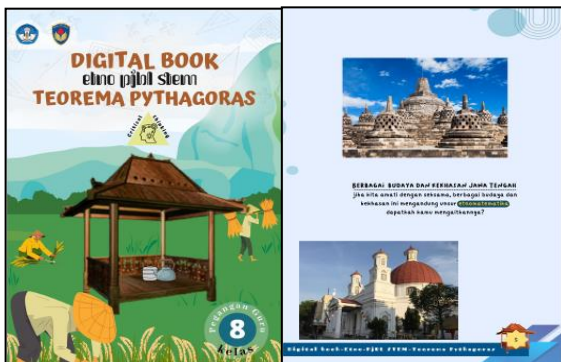


Figure 1. The design of digital book Ethnomathematics STEM-PjBL based.

After the digital book has been completed, the media enters the media expert validation stage which gets the following values:

Table 5. Validation Media

Aspects	Score (Max = 120)	
	Validator	Validator
	1	2
Learning	62	56
Critical thinking	16	16
Ethnomathematics	14	13
Evaluation	13	12
Total Score	105	97
Percentage	87,5%	80%

Based on the data in Table 5, the final percentage results were 87.5% for the first validator who was classified into the "Very Good" category and 80% for the second validator classified in the "Good" category. However, there are several suggestions for improvement from validators, namely (1) the cover title is included in the table of contents, (2) the concept map display is changed not to rotate. The results of this

validation make the media feasible to be tested in the trial class even though there are several revisions based on suggestions and input from validators so that digital book media products are better in the future.

In addition to media validation, critical thinking test instruments are also validated by experts and evaluated based on the results of trials with tests of validity, reliability or consistency, level of difficulty and differentiating power. For the validity of the instrument experts who use Aiken's formulation get results including: (1) aspects of the compatibility of question items with FRISCO indicators, (2) construction and (3) language. The three aspects get the "medium" category because they are in the interval 0.4 to 0.9, namely 0.8 for the first aspect, 0.79 for the second aspect and 0.81 for the third aspect.

Then the analysis of validity, reliability, level of difficulty and differentiating power with the Rasch Model using Winstep analysis can be seen in Table 6:

Table 6. Results of Rasch Model analysis using Winstep

Group	Criterion	Level
Person reliability	More than 0.8 is great	0.81 (Very good)
Cronbach Alpha	More than 0.8 is great	0.86 very good)
Difficulty level	0 to 1 difficult	0.18 to 0.67 for 3B to 4E (hard)
	0 to -1 easy	-0.14 to -0.95 for grains 1A to 3A (easy)
Differentia	More than	0.54 to

Group	Criterion	Level
ting power	0.4 Very good	0.822A to 4E (excellent)
	0.3 – 0.39 Good	0.32 grain 1D (good)
	0.2 – 0.29 is enough	0.22 to 0.29 grains 1A,1B,1C (sufficient)
Outfit MNSQ	0.5 – 1.5 valid	invalid 1D, 2A, 3C, 4B-E
Outfit ZSTD	-2.0 – 2.0 valid	All valid
PT Measure Correlation	0.4 to 0.85	Invalid 1A to 1D are in the interval 0.22 – 0.32

Based on the Table 6, all items are said to be valid according to Sumintono and Widhiarso (2015) because they meet at least one of the three criteria mentioned. Then for consistency, differentiating power and level of difficulty also get a good value which means that the instrument is suitable for use because a good instrument that can be used in decision-making is an instrument that meets several criteria including validity tests, consistency, differentiating power and level of difficulty (Pramasdyahsari, et al., 2022). Table 8 presents the instrument test of mathematical critical thinking skills.

Table 7.
Instruments Test of Mathematical Critical Thinking Skills

No.	Problems
1	Pak Bowo and his team are a group of builders who are in great demand by people in the Randublatung District. He is renowned for his meticulousness in constructing well-measured houses or buildings. Once Pak

No.	Problems
	<p>Bowo and his team got a project to build the Joglo Sinom Hall. Every time you build a building, you will certainly make an initial foundation first to support the building. In making the square-shaped foundation, Pak Bowo and his team always use three numbers that they do not know where they came from because only a group of village builders with experience form right angles on the foundation.</p> <ol style="list-style-type: none"> What are the three numbers in the information on the question so that they can form a right angle? Give your reasons If you meet Mr. Bowo and the team, how do you explain the origin of the 3 numbers? Explain Help Mr. Bowo and his team find some other three round numbers that can be used if you are going to make a foundation measuring 15 x 10 m and explain your answer! In addition to measuring the foundation, can you give other examples in making Joglo Houses that can use this concept? Explain.
2	<p>The height of a 2nd floor window in a Blora Regent Office is approximately 4 meters. In front of the office there is a Barong Park with a width of 3 m. From the office, the regent wanted to make stairs from the 2nd floor to the front of Taman Barong without damaging the park.</p> <ol style="list-style-type: none"> Simple sketch of the above problem What problems should be solved? And what are the steps? What is the minimum staircase length needed so that the stair legs do not damage the garden? Explain
3	<p>A diver from the Search and Rescue Team hooked himself to a 25 m rope to search for the remains of the wreckage on the seabed. The sea is dived to a depth of 20 meters and the bottom is flat. Because it is linked to a rope, a diver is only able to swim in areas that can be reached.</p> <ol style="list-style-type: none"> Sketch the problem above and what information did you get? What problems do you think are in the

No.	Problems
	above problem? And mention the steps in solving the problem! c. Is it true that the area that can be reached by divers is 605 m ² ? Check it out and give your reasons
4	A rectangular plot of rice field owned by Pak Fajar measuring (16x12) m along the perimeter and both diagonals will be made a fence for Rp15,000.00 per meter. Help Mr. Fajar estimate the costs involved! a. Sketch the fence track to be made by Mr. Fajar! b. What problem should be solved in the problem? c. After knowing the problem, what are the steps to solve the problem? Give your answer d. Help Mr. Fajar to calculate the required length of the fence! e. If Pak Fajar's capital is Rp1,500,000.00, is it left or less for the installation of the fence? Check it out and explain your reasoning

The fourth stage is utilizing resources or utilizing learning resources. In this step, researchers discussed with mathematics subject teachers there about the application of digital book media with an ethnomathematics-based PjBL STEM approach, namely by using tablets which are school facilities because they are not allowed to bring mobile phones and in groups due to the limited availability of tablets. Then the researcher also provided a learning experience in the form of project-based assignments by making a miniature Joglo Sinom Gazebo with ice cream sticks associated with the Pythagorean theorem problem. Making projects cannot be separated from cultural aspects, namely by using Central Javanese

traditional houses in the form of Joglo Sinom Gazebo to increase students' appreciation of culture and become an efficient approach used in learning, this is in line with research conducted by Kencanawati and Irawan (2017) and Rosa and Orey (2011). Along with making the assignment, they are also equipped with an Engineering Design Process (EDP) as a step in completing the project. According to Anne Jolly (2017) there are seven stages in EDP, namely problem identification, solutions or sources of information, solution design, activity processes, trials, revisions and communication.

Based on the EDP answers from each group, it shows an increase in critical thinking such as being able to identify problems, being able to explain with logical reasons, and deciding to give conclusions. The following PjBL STEM learning designs are used:

Table 8.
PjBL STEM Learning Design

Learning design
A group of builders want to build a Joglo Gazebo with the type of Joglo Sinom. The first step that will be done is to make a square-shaped foundation. The builders ensure that the four corners of the building foundation are right elbows by using a right triangle so that the building does not tilt to the top. Help the handyman to find the length of the three sides of the triangle so that it becomes a right triangle angle if the scale is 1:100 m with the actual size of the building which is likened to a miniature Joglo Sinom Gazebo if only 10 ice cream sticks are available to make seats at the Joglo Sinom Gazebo which are each 1 cm wide and 11 cm long! Do you think the problem can be solved by which mathematical connections can be applied to the problem?

The fifth stage requires learner participation or involves students in the learning process. The learning process in this study began with the provision of pretests for both classes. Then after the pretest, the next meeting is learning with the lecture method for the control class and project-based methods for the experimental class. The experimental class uses digital book media with an ethnomathematics-based PjBL STEM approach as a solution in learning, including improving critical thinking skills. At this stage, digital books with an ethnomathematics-based PjBL STEM approach stimulate students to be fully involved in the learning process commonly called the student center. This is by research conducted by integrating students as a whole in the learning process and teaching them how to think critically while solving challenges by Kristiyanto (2020). After the learning is complete, the author provides a posttest to determine whether or not students' critical thinking skills increase after the learning. Here is some documentation of activities involving students:



Figure 2. Group of students understanding the material with digital books and start planning the project to be developed.

The next stage, the sixth stage, is to evaluate and revise. At this last stage, researchers evaluate and revise based on questionnaire responses given to the experimental class and obtain results that can attract students in the learning process.

Table 9.
Right t-test Result

Class	n	t	t-table count	conclusion
Experiment	22	10,31	1,7201	The average critical thinking ability of the experimental class is better than that of the control class

Digital book media with an ethnomathematics-based PjBL STEM approach is considered practical throughout the learning process, especially those related to Pythagorean theorem material, because it is easy to access and easy to operate because it is equipped with instructions for use. In addition, digital book media with an ethnomathematics-based PjBL STEM approach is also said to be more effective in use than conventional learning. This is evidenced by the results of classical student learning completeness in experimental classes where 83% of students get scores above 60 in line with

research conducted by Sariyanti (2018) which also gets a percentage of 80% by applying digital book table $t_{hitung} > t_{tabel}$ in improving student learning outcomes, then because, the average posttest results Classes with better treatment compared to classes without treatment, as well as increased interest in student learning shown by their positive responses based on the percentage of questionnaires distributed that received an average overall percentage of 83%. With the category "excellent". This is reinforced by the results of research by Buchori et al (2022), Siregar (2021), Pixyoriza (2018), and Sugiharni which stated that digital book as electronic media is effectively applied to improve students' critical thinking skills.

IV. CONCLUSION

According to the findings and discussion above, digital book learning media using a PjBL STEM method that is based on ethnomathematics is effective for teaching students in junior high school how to develop their critical thinking abilities. This is demonstrated by the expert validation results, which on average fall into the "very good" category with an inclusion rate of 83.75%, compared to an inclusion rate of 88% for materials and learning tools. Additionally, digital books with a STEM-PjBL approach based on ethnomathematics are beneficial in the learning process to develop junior high school students' critical thinking abilities.

This is demonstrated by the 83% of student response questionnaire findings that fall into the "very good" category. Junior high school students' critical thinking abilities can be effectively enhanced by combining a STEM-PjBL approach with digital book learning resources. This is demonstrated by the results of the critical thinking ability test, which reveal that 83% of students completed it and received scores over 60. Compared to classes without treatment (control), students receiving treatment perform higher on average on tests of critical thinking skills. Results of student questionnaires with a percentage above 75%, which is 85% and is categorized as "very good," also demonstrate the increase in student excitement and motivation. We may therefore conclude that the usage of learning material in the form of digital books combined with a STEM-PjBL approach that is based on ethnomathematics can be beneficial in enhancing students' critical thinking abilities. Future research is recommended to explore in greater depth how digital book learning media and the STEM-PjBL approach based on ethnomathematics influence educational outcomes. Such investigations will provide a more nuanced understanding and help refine and enhance educational practices and results.

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