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Development of interactive e-comics based on ethnomathematics oriented towards students' numeracy skills

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Abstract

The current mathematics learning process is often conducted in a blended manner, combining offline and online learning. Therefore, online learning requires instructional media that support the learning process and are appealing to students. However, the instructional media currently used to support online learning are limited and less relevant. This study aims to develop interactive mathematics learning media in the form of ethnomathematics-based e-comics that are valid, practical, and effective for middle school students. The research method employed is development research using the ADDIE model. The research subjects included middle school teachers and students. In the limited trial phase, 2 teacher and 32 students participated, while the large-scale trial involved 3 teachers and 57 students. Data collection instruments consisted of validation sheets for material and media experts, student response questionnaires, as well as pre-test and post-test questions validated by experts. Data analysis was conducted descriptively to assess the feasibility of the product. The research findings indicate that the ethnomathematics-based e-comic learning media are valid and practical. Furthermore, the e-comics meet the effectiveness criteria, as they enhance students' numeracy skills after the learning process. Therefore, the e-comics developed in this study can serve as a reference for mathematics learning media that meet current student needs.

Keywords: E-comics interactive, Ethnomathematics, Numeracy skills

Introduction

Technology plays a crucial role in education as it can transform learning and teaching, making them more effective and relevant to contemporary needs. With technology, students can access diverse and interactive learning resources, allowing for a deeper understanding of the material. Furthermore, technology supports personalized learning, enabling students to learn at their own pace and according to their learning styles (Nuryadi et al., 2023). For teachers, technology serves as a tool to create innovative, efficient, and data-driven learning experiences through online platforms, classroom management applications, and automated evaluation tools. In this digital era, the use of technology also prepares students to face future

challenges by equipping them with essential digital skills (Purwoko et al., 2020). Therefore, the integration of technology in education is not merely a complement but a necessity to create inclusive and sustainable learning environments. Technology is particularly essential in online learning. One effective learning medium for online education is the e-comic. Based on experience, students often prefer illustrated, colored, and visually engaging materials over text-only books. E-comics, which offer more engaging content through illustrations and animations, are considered more appealing than traditional textbooks (Daryanto, 2013). E-comics are regarded as important pedagogical resources in education (Santana et al., 2012). With their unique features, e-comics can stimulate active and creative student participation in learning (Gafoor & Shilna, 2013).

E-comics are media that present a series of educational story images and function as learning tools in electronic format (Budi, 2016). Comics are found to be very effective as learning media in mathematics lessons (Restian, 2017). This is relevant with existing literature, which indicates that the average results of classes using math comics are better compared to conventional class results (Nida et al., 2017). E-comics can also develop students' creativity in learning by presenting problems contextually within the dialogue (Lestari et al., 2021). According to a study by Dwi Husnul Khotimah and Purwandari (Khotimah & Purwandari, 2018) students' creativity is enhanced with the use of comic learning media in the classroom, making comics a worthy learning medium as they can increase students' creative abilities. Therefore, e-comics can become a supportive learning medium that fosters students' creativity, particularly in learning mathematics.

Mathematics is a subject that requires high creativity, contextualized as students' numeracy skills. However, in reality, students' numeracy abilities in solving mathematical problems are still categorized as low. Existing literature reveals that in one intermediate school, the average percentage of students' numeracy abilities was 12.88%, indicating that students' numeracy skills are still classified as low (Putra et al., 2018). The role of teachers is crucial in enhancing students' numeracy abilities in learning mathematics. This can be achieved by relating mathematical material to everyday life aspects, including culture. However, the public often does not realize that mathematics is embedded in their culture. One approach that can bridge culture and mathematics is ethnomathematics.

Ethnomathematics was introduced by D'Ambrosio, a Brazilian mathematician, in 1977. *The tem 'ethnomathematics' has been used by D' Ambrosio (1985) to mean "The mathematical practices of identifiabel cultural groups and may be regarded as the study of mathematical ideas found in any culture".* D'Ambrosio's opinion can be interpreted as the use of mathematics from an identifiable cultural group, which can be considered as the study of mathematical ideas discovered in various cultures (Rosa & Orey, 2011). According to (François, 2012) the expansion of the use of ethnomathematics synchronizes with the cultural diversity of students and uses mathematical practices that are closely related to the students' environment. Ethnomathematics implicitly involves activities that convey mathematical values as well as mathematics education (Rosa et al., 2016). Ethnomathematics is understood as a lens to see and comprehend mathematics as a cultural product (Rosa et al., 2017).

Cultural products within society exhibit considerable variety, including artifacts, activities, values, and other elements. Cultural assessment should begin with the local environment (Astuti et al., 2019). An appropriate and relevant cultural form to explore as a

learning medium is the Lawet Dance from Kebumen. The Lawet Dance, an emblematic dance of Kebumen Regency, features distinct aesthetic characteristics such as shapes, lines, and appearances (Nurshanti & Iryanti, 2019). The cultural elements studied in the Lawet Dance encompass 16 types of movements that mimic the bird lawet, including ngulet, singgetan, angklingan, kirig, aburan, didis, jump egotistical, arrogant, arrogant proceed oblique, agile to bite, nyucuk, kepetan, trajalan, ngasah pukuk, erek/dribble, and nest making.

The relevant ethnomathematical activities in the Lawet Dance involve geometric designs, such as the construction of squares and triangles in floor patterns and dance movements. The following examples illustrate floor patterns and dance movements that correspond to and form geometric shapes.
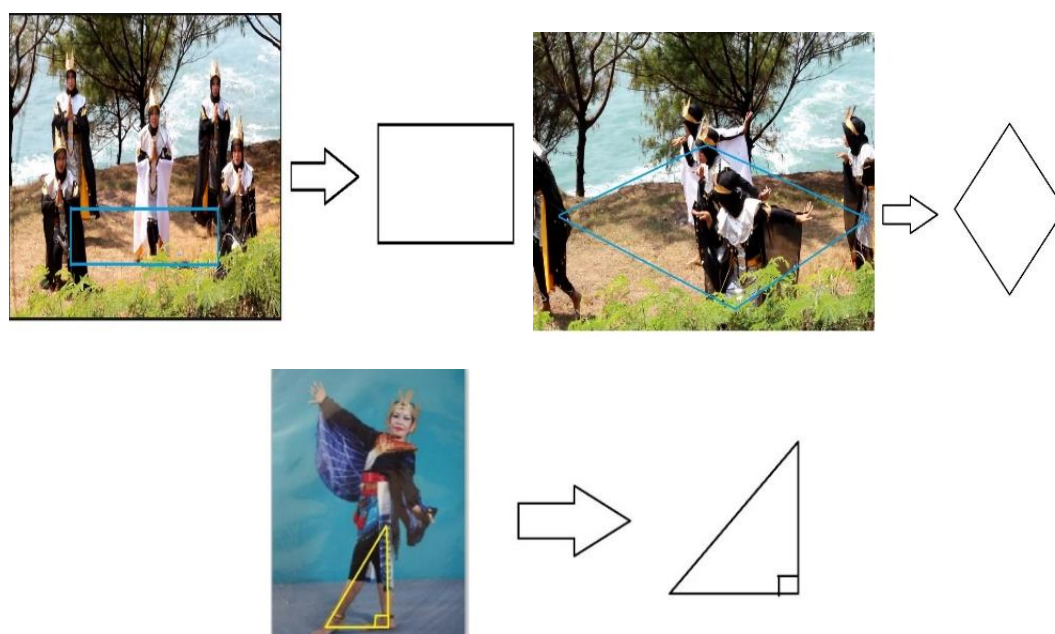

Figure 1. Activity Patterns in the Lawet Dance that are Appropriate with Two-Dimentional Figure

Figure 1 demonstrates that the floor patterns and movements in the Lawet Dance are relevant to mathematical concepts that can be incorporated as a learning resource, particularly in mathematics education. One of the learning media that can be used to assist students in learning in a contextual and enjoyable manner is comic learning.

Several researchers have conducted studies on the integration of ethnomathematics in the development of learning media. One such study developed Islamic Media Math Comics, which positively impacted students' understanding of mathematical concepts related to comparisons (Basir et al., 2020). This study focused more on counting activities, while the current research emphasizes pattern movements. Additionally, research by Desinta and D. Setiana found that teaching materials in the form of student worksheets, developed using the context of Yogyakarta Palace structures, had positive effects. Besides understanding the geometric concepts of flat shapes, students also gained knowledge about the history and values associated with the Yogyakarta Palace buildings (Ayuningtyas & Setiana, 2019).

In the context of education, numeracy skills form the foundation for learning other subjects, especially science, technology, engineering, and mathematics (STEM), which are key to innovation and global development. Strong numeracy skills help individuals think

logically, solve problems, and adapt to the increasingly complex challenges of the digital era (Purwaningrum et al., 2023). Numeracy can also be interpreted as the ability to recognize numerical patterns and use them to solve practical daily problems. Another opinion is that numeracy encompasses the ability to apply basic mathematical concepts to solve contextual problems (Han et al., 2017). This definition is highly relevant if mathematics learning always begins with a context that directs students to break down problems gradually, especially if the activities are designed to meet students' needs and make learning enjoyable. Consequently, numeracy is not only an academic skill but also a fundamental requirement for a productive and independent life. Therefore, the goal of mathematics education is to develop students' numeracy skills.

Based on the aforementioned explanation, this study aims to develop mathematics learning media in the form of e-comics, using the cultural product of the Lawet Dance Pattern from Kebumen as a contextual starting point for learning. This approach is intended to make students' learning of mathematics, specifically the concepts of squares and triangles, more contextual. The e-comics are designed to be simple, making them easy and enjoyable for students to use as a fun learning resource. These e-comics are developed through dialogue with lighter questions that focus on developing students' numeracy skills. Consequently, students will consistently become accustomed to the patterns presented in the developed products.

Method

This study uses the ADDIE method, which consists of five steps: Analyze, Design, Development, Implementation, and Evaluation (Tegeh & Kirna, 2013). This research method is used to produce a product and test its effectiveness (Wardani et al., 2019). The study was implemented in the seventh grade of State Middle Schools in Kebumen Regency. The total subjects involved in this study included 5 mathematics teachers and 57 students.

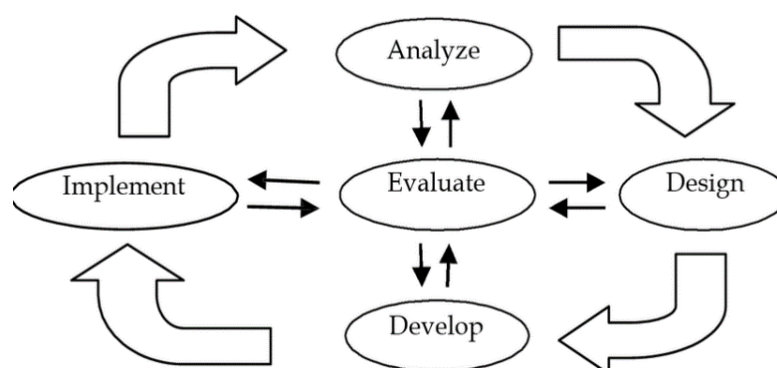The stages of product development are depicted as follows:

Figure 2. Stages Development with the ADDIE Method

From Figure 2, it can be explained that the analysis stage involves identifying existing problems. The design stage includes planning prototype-1, the development stage encompasses product validation and pre-test/post-test issues, the implementation stage

includes field trials, and the evaluation stage covers the analysis of each achieved ADDIE stage.

Data collection techniques in this study utilize both test and non-test methods. Non-test techniques involve instruments such as questionnaires, observations, and interviews, while test techniques involve pretests and posttests. At each development stage, the instruments used are analysis stage (observation questionnaires and interviews), planning stage (validation questionnaires), and implementation stage (evaluation questionnaires to assess the practicality and effectiveness of the developed products, using tests that measure students' numeracy abilities before and after the learning process is implemented).

Data analysis techniques consist of both qualitative and quantitative data analysis. The eligibility analysis includes the assessment of validity, practicality, and effectiveness (Nieveen & Folmer, 2013). Validity analysis is conducted by calculating the average validation score, followed by categorizing validity based on the average validation score. Practicality analysis involves calculating the average evaluation scores from students and teachers and categorizing practicality based on these average scores. The classification criteria for validity and practicality are determined on a five-point scale. Effectiveness analysis is carried out through quasi-experimental learning using the developed product. The experimental test design is presented in the following figure.
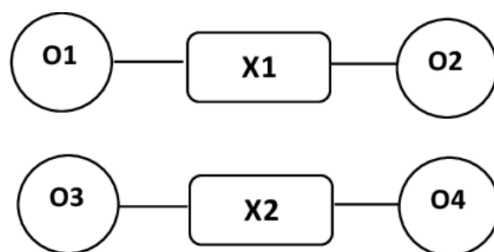

Figure 3. Experimental Test Design Study

Notes:
O1: Class experiment
X1: Treatment with e- comics
O2: Ability numeracy student post X1
O3: Class control
X2: Treatment without e- comic
O4: Ability numeracy student post X2

To evaluate the potential impact, an analysis of pretest and posttest scores was conducted to measure the significance of the improvement in numeracy skills. Statistical tests, specifically t-tests, were utilized for this purpose.

Results

This study produced an e-comic based on ethnomathematics, utilizing the cultural context of the Kebumen Lawet Dance Pattern. The study employed the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. The development stages are detailed as follows.

Analysis

The analysis stage consists of media needs analysis and material analysis. Based on an interview with a math teacher at a public junior high school in Kebumen district, the media analysis revealed the following: (1) students' motivation to participate in online learning activities has decreased; (2) there is a lack of learning media to support online learning; (3) there are no learning media that utilize cultural contexts. Additionally, a questionnaire distributed to students indicated that the average student prefers e-comics and is unfamiliar with the Lawet Dance, which is an icon of Kebumen Regency. Moreover, the material analysis, based on discussions with the math teacher, revealed that some students still find the concepts of squares and triangles challenging.

Design

The design stage aims to produce prototype-1 in the form of e-comics for use (see Figure 4 and Figure 5). This stage includes: (1) media selection; (2) compilation of the storyline and creation of character figures; (3) comic creation using applications such as Canva and Manga Maker Comipo; (4) digitalization using Kodular.

Figure 4. E-comic Cover

Figure 5. Activities on E-comic

Development

The development stage aims to produce an ethnomathematics-based e-comic media that is validated by experts and ready for testing with students. This development process involves three validators who are expert product evaluators, comprising two mathematics education lecturers and three junior high school mathematics teachers. The validation results from the validators are presented in Tables 1 and Table 2.

Table 1. Assessment Results by Product Expert I

No	Aspect	Score	Criteria
1	Presentation	3.33	Valid
2	Picture	3.6	Valid
3	Linguistics	3.4	Valid
4	Implementation	3.5	Valid
Mean		**3.45**	**Valid**

Based on the evaluation by expert product I, it is concluded that the ethnomathematics-based e-comic received an average score of 3.45, indicating valid criteria.

Table 2. Assessment Results by Product Expert II

No	Aspect	Score	Criteria
1	Ethnomathematics	3.5	Valid
2	Ability Numeracy	3.5	Valid
3	Linguistics	3.3	Valid
Mean		**3.43**	**Valid**

Based on the evaluation by expert product II, it is concluded that the ethnomathematics-based e-comic received an average score of 3.43, indicating valid criteria.

Implementation

The revised e-comics were implemented in learning. The implementation stage aims to demonstrate that the ethnomathematics-based e-comic is both practical and effective in teaching mathematics, specifically the material on quadrilaterals and triangles, to seventh-grade students in State Middle Schools in Kebumen Regency. This stage consists of: Validation of pre-test and post-test questions, Limited trial, Broader trial. Data regarding this stage can be seen in Tables 3, 4, 5, and 6.

Table 3. Expert Validation Results for *Pre-Test* and *Post-Test Questions*

No	Aspect	Criteria
1	Competence	Valid
2	Numeracy Aspect	
	a. Fluency	Valid
	b. Flexibility	Valid
	c. Oryginality	Valid
	d. Elaboration	Valid
3	Validity	Valid
4	Junior High School Context	Valid
5	Convenience	Valid
6	Consistency	Valid
7	Accuracy	Valid
Total Average		**Valid**

Based on the evaluation by experts of the pre-test and post-test questions in Table 3, it is concluded that the ethnomathematics-based e-comic, incorporating the cultural product of the Lawet Dance Pattern of Kebumen, meets valid criteria. During the limited trial phase, a practicality test and an effectiveness test were conducted using practicality evaluation instruments and pre-test/post-test questions. The limited trial was conducted with 32 students, and the obtained results are as Table 4.

Table 4. Assessment Results of Practicality

No	Aspect	Average	Criteria
1	Ease of Use of e-comics	3.2	Pretty Practical
2	Ease of Understanding Teaching Materials	3.3	Practical
3	Benefits	3.3	Practical
	Mean	**3.27**	**Practical**

Based on Table 4, the average respondent rating value is 3.27, indicating that the ethnomathematics-based e-comic is practical for use in the mathematics learning process. In the product effectiveness test, there is an improvement in scores between before and after using the e-comic, with the average numeracy ability score of students increasing from 72 to 83. Given this improvement, the ethnomathematics-based e-comic, incorporating the cultural product of the Lawet Dance Pattern of Kebumen, is effective for use in seventh-grade mathematics learning and can proceed to the wide-scale trial phase.

The wide-scale trial phase is conducted after the e-comic is deemed practical and effective in limited trials. Wide-scale trials involve practicality and effectiveness tests using practicality evaluation sheets and pre-test/post-test questions. The wide-scale trial was conducted with two classes, involving 57 students, and the results are as Table 5.

Table 5. Assessment Results of Practicality

No	Aspect	Average value	Criteria
1	Convenience Use	3.28	Enough Practical
2	Convenience Understanding the Material	3.37	Practical
3	Benefit	3.35	Practical
	Mean	**3.34**	**Practical**

Based on Table 5, the respondents' evaluation results yielded an average score of 3.34. This indicates that the ethnomathematics-based e-comic is practical and can be used in the mathematics learning process. In the effectiveness test, a comparative analysis was conducted to examine the average differences between the control and experimental classes. Prior to conducting the t-test, a prerequisite test was performed, confirming that the data is normal and homogeneous, allowing for further testing.

The results indicated a significant difference between the experimental and control classes, with the t-test showing that the class using the e-comic performed better than the control class. The final stage of data analysis involved measuring the improvement in numeracy skills using the t-test to determine the significance of the enhancement in students' numeracy abilities after using the e-comic. The calculation results based on pre-test and post-test data are presented as Table 6.

Table 6. Pre-Test and Post-Test Data

t count	t table	Information	Conclusion
5.29	1,645	t count > t table	There is improvement

From the data on Table 6, it was found that t count = 5.29 and t_{table} = 1.645, indicating that t_{count} > t_{table}, which means the null hypothesis (H_0) is rejected. This shows that there is a significant improvement in scores between before and after using the e-comics. Due to this improvement, the ethnomathematics-based e-comic, incorporating the cultural product of the Lawet Dance Pattern of Kebumen, is effective for seventh-grade mathematics learning activities. This finding is consistent with studies by (Nida et al., 2017), which stated that the results of classes using math comics are better compared to those using conventional methods. This reinforces the potential of developing ethnomathematics-based e-comics with the cultural product of the Lawet Dance Pattern of Kebumen as a support for mathematics learning in the classroom.

Based on all stages conducted and comprehensive measurements, the ethnomathematics-based e-comic learning media has consistently fulfilled the valid, practical, and effective criteria. This condition ensures that the produced product can be used by teachers and students to assist in learning mathematics with the aid of information technology, focusing on developing junior high school students' numeracy skills. Additionally, this product can also be used to introduce local culture as part of the history of a specific region, helping students to appreciate local wisdom.

Discussion

From the development stages carried out, it is evident that learning media in the form of interactive e-comics based on ethnomathematics, oriented towards enhancing students' numeracy skills, are necessary. This is because teachers and students have not previously utilized e-comics as a learning medium in mathematics education. Additionally, from a curriculum perspective, this media is appropriate as it can stimulate students to solve contextual problems, aligning with efforts to improve their numeracy skills. This aligns with research indicating that learning media are essential to support understanding and solving mathematical problems, providing students with more contextual learning activities (Purwoko et al., 2023; Purwoko et al., 2020).

In the subsequent stage, limited and large-scale tests were conducted. Generally, the interactive e-comics based on ethnomathematics, oriented towards enhancing students' numeracy skills, showed a potential effect by improving these skills. The activities developed were contextual and closely related to students' experiences. This is because the cultural products used as a starting point in learning were understood by students in tangible terms, providing a sense of enjoyment at the beginning of the learning process. This aligns with research showing that students can make discoveries from initial problems by presenting contextual problems based on culture (Khoirunisa et al., 2023; Nuryadi et al., 2023).

E-Comics can enhance students' numeracy skills, particularly through the selection of a contextual product culture, such as the Lawet Dance Pattern of Kebumen. This context provides a hands-on experience where students can practice dance movements while simultaneously observing mathematical forms, thereby gaining direct experience. This

approach increases students' enthusiasm and enjoyment in learning mathematics (Astuti et al., 2023). The storyline, set within the cultural context of the Kebumen Lawet Dance pattern in the developed comic, offers a unique perspective on learning mathematics. It allows students to engage in inventive activities in diverse ways. The product development employs context and open-ended problem-solving, making the comic an effective and valuable tool for mathematics learning.

Conclusion

The development of the e-comic based on mathematics, utilizing the cultural context of the Lawet Dance Pattern of Kebumen, is deemed suitable for use as a mathematics learning medium, especially for seventh-grade junior high school students, because it fulfills valid, practical, and effective criteria. The data obtained and analyzed indicate that the e-comics, developed based on expert evaluations, meet valid criteria. Practicality test data conducted by teachers and students indicate that the e-comic is easy to use, fulfilling the very practical criteria.

In the final test to assess the product's effectiveness in improving students' numeracy skills, an analysis of pretest and posttest results indicates that the e-comic has a positive effect on enhancing students' numeracy abilities. Therefore, it can be concluded that the ethnomathematics-based e-comic, oriented toward developing students' numeracy skills, is suitable for use as a mathematics learning medium for seventh-grade junior high school students. This e-comic is expected to be utilized as an alternative and valuable learning resource, particularly in mathematics education.

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Author Contribution	:	RYP: Resources, Writing - Original Draft, Data Curation, and Visualization
		WIP: Resources, and Project Administration
		N: Resources, and Funding Acquisition
Conflict of Interest	:	The authors declare no conflict of interest.
Additional Information	:	Additional information is available for this paper.

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