

Interactive Digital Comic Based on Karo Culture: An Innovation to Improve Students' Numeracy Skills

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Abstract:

Introduction: Numeracy is a key competency for the 21st century, yet global and national trends show that many students still fall below adequate levels of competence. On the other hand, local culture faces the threat of extinction due to the lack of integration in the lives of the younger generation.

Objectives: This research offers an innovative new approach by developing an interactive digital comic based on Karo Culture as a learning medium to improve students' numeracy skills. The novelty of this research lies in combining authentic local cultural elements with interactive digital technology, creating a learning medium that is not only educative but also culturally relevant.

Methods: The method used is research and development with the five stages of the Plomp model.

Results: The results showed that the interactive digital comic based on Karo culture has a high level of validity, practical to use, and effective in improving students' numeracy skills. Analysis using e-Views software shows a significant increase in students' numeracy skills, which is 89%. In addition, this approach successfully integrates Karo cultural values into the modern learning process, making it not only an educational tool but also a strategic effort in cultural preservation.

Conclusions: The conclusion of this study is that interactive digital comic media based on Karo Culture is an effective and relevant innovation in answering today's educational challenges, as well as contributing to the preservation of local culture in the midst of globalization. The findings provide a strong basis for the development of other culture-based learning media in the future.

Keywords: Digital Comic, Interactive Comic, Karo Culture, Numeracy Skills.

1. Introduction

Numeracy skills are one of the key competencies of the 21st century, serving as a foundation for literacy and critical thinking. According to Herman [1], mathematical literacy and

mathematical thinking are essential skills demanded in the 21st century, which must be facilitated in learning to develop higher-order thinking skills. Additionally, numeracy literacy refers to the ability to use various numbers and symbols related to basic mathematics to solve practical problems in everyday life [2]. For example, a researcher named Genie [3] found that numeracy skills, particularly calculation abilities, significantly influence decision-making in the health sector. Individuals with higher calculation skills exhibit greater consistency in their choices and are more likely to weigh the positives and negatives of an option before making a decision. Hal ini ditegaskan juga oleh peneliti asal Brasil yang melakukan penelitian terhadap mahasiswa yaitu Campara [4] bahwa tingkat keterampilan berhitung yang lebih tinggi tidak sejalan dengan toleransi risiko yang lebih besar. Memiliki keterampilan berhitung yang lebih tinggi membuat orang lebih berhati-hati terhadap resiko yang akan mereka hadapi. Dengan demikian, penguasaan literasi numerasi menjadi esensial dalam membekali individu untuk berpikir kritis dan memecahkan masalah dalam berbagai konteks kehidupan. Namun, tren global dan nasional menunjukkan bahwa kemampuan numerasi siswa masih tergolong rendah. Di Afrika Barat dan Tengah hanya 45% siswa yang cukup kompeten dalam numerasi, di Nigeria hanya 19% siswa yang memiliki ketrampilan membaca dan berhitung tergolong baik [5].

A researcher named Ford [6] found that undergraduate college graduates in the United States lag behind in numeracy skills. In Indonesia, Khoirunnisa [7] discovered that the numeracy literacy level of junior high school students in the era of 'Merdeka Belajar' remains low, at only 37%. Similarly, Soesanto and Dirgantoro [8] highlighted in their research that the development of students' numeracy skills poses a significant challenge and problem. These findings underscore the low level of students' numeracy skills and the pressing need to address this issue. The latest PISA (Programme for International Student Assessment) report indicates that most Indonesian students have yet to achieve an adequate level of numeracy competence [9]. This has become a serious concern in education, as numeracy is crucial not only for everyday life but also for success in various professional fields.

On the other hand, the preservation of local culture faces significant challenges due to the strong currents of globalization and modernization. Karo culture, as one of Indonesia's local cultural heritages, is increasingly losing its appeal among the younger generation. The lack of integration of local culture into the learning process further accelerates the potential extinction of this cultural heritage. This concern is supported by Simbolon [10], who found that teachers often lack the knowledge and resources needed to incorporate culture into the learning process effectively. Existing culturally integrated learning media have yet to provide optimal solutions to this issue. Most learning media focus solely on academic aspects without considering the integration of local culture. Moreover, interactive digital learning media often lack cultural relevance for students from specific cultural backgrounds.

In fact, culture-based education not only helps preserve cultural heritage but also strengthens students' character and identity. Local culture plays a vital role in shaping the identity of the younger generation, aligning with the goals of national education. This is supported by Hidayat [11], who states that incorporating culture into learning not only preserves the culture itself but

also addresses the issue of enhancing students' mathematical reasoning skills. Furthermore, he emphasizes that the process fosters ethics, mutual respect, and appreciation among students. Studies involving cultural elements also influence students' ability to reconstruct knowledge [12]. This positive impact of cultural integration is not limited to Indonesia but is also part of a global trend. For example, in China, Mao [13] found a strong correlation between cultural involvement and individual creativity levels.

To address these two challenges, innovation in learning media is needed to enhance students' numeracy skills while also supporting the preservation of local culture. Interactive digital comics based on Karo culture offer an innovative solution by combining modern digital technology with local cultural values. This medium is designed to be culturally relevant, engaging, and effective in increasing students' involvement in learning. Previous research supports this approach, showing that using comics as a medium can improve students' mathematical communication skills compared to learning that relies solely on textbooks or worksheets [14]. Other researchers have noted that humorous comics are effective communication tools for conveying messages [15]. Additionally, Fogwill and Manataki [16] found that comics can enhance literacy because they are more engaging, and participants demonstrate better recall and understanding of data presented within stories compared to text-based media. Comics can assist educators in teaching material in a way that is engaging, precise, and straightforward [17]. This educational tool also provides insights into various themes that can be addressed in classrooms through the use of comics.

Thus, this research is expected to make a tangible contribution to improving the quality of numeracy education in Indonesia and globally while promoting the preservation of local culture amid the currents of globalization. This approach is not only pedagogically relevant but also has the potential to make a significant impact in two key areas: first, by helping students develop numeracy skills through engaging and contextual media; and second, by contributing to the preservation of Karo culture through the integration of cultural elements into the learning process.

The contribution of this study is outlined through the following research questions:

1. How can Karo cultural values be integrated into digital learning media to enhance students' numeracy skills?
2. Are Karo culture-based digital comic media valid, practical, and effective for use in learning?

2. Objectives

In this study, the primary objective is to develop interactive digital comics based on local culture to enhance students' numeracy skills.

1. Design culturally integrated digital comics rooted in Karo culture to serve as an engaging and effective learning tool.
2. Create a valid, practical, and effective framework for incorporating Karo cultural values into digital comic development.

3. Evaluate the effectiveness of the proposed digital comic in improving numeracy skills compared to traditional learning media.
4. Compare the developed digital comic with standard educational tools to assess its relevance, usability, and impact.

3. Methods

This research was conducted at SMA Negeri 1 Brastagi by involving students as subjects for data collection. The research method for learning media in the form of culture-based interactive digital comics to improve numeracy skills uses the type of research and development by Plomp with the following steps: preliminary investigation, design, construction or realization, test, evaluation and revision, and implementation. Researchers use a mixed methods approach, which is a research method that integrates quantitative and qualitative approaches to gain a broader and deeper understanding of a phenomenon.

Preliminary Research

Preliminary research is an essential first step in the development of educational media. At this stage, a series of analyses are carried out to ensure the relevance and effectiveness of the developed media, namely analysis of problems, materials, students, teachers and culture. Based on observations and interviews, it was found that students often have difficulty understanding numeracy concepts due to monotonous and uninteresting learning methods. In addition, the lack of contextual and local culture-based learning media is a barrier to increasing student motivation and engagement. The concept of problem solving in numeracy is often considered difficult by students. Therefore, the numeracy material will be integrated into the story and visuals of digital comics to provide a more interactive and fun learning experience.

Student analysis is conducted to understand student characteristics, needs, and preferences in learning. Based on the survey results, students show high interest in digital-based learning media, especially those that use visual story formats such as comics. In addition, many students are interested in local culture, so incorporating elements of Karo culture into learning media can increase their engagement. The teacher analysis found that most teachers welcomed the use of interactive digital comics as an alternative to enhance student understanding. Finally, in the cultural analysis, Karo cultural elements became the main component in the development of this media. The cultural analysis was conducted to ensure that elements such as language, folklore, traditions, and symbols of Karo culture were appropriately integrated into the comic. This step aims not only to support numeracy learning, but also to preserve and introduce Karo culture to students. This preliminary research provides a solid foundation for the development of interactive digital comics based on Karo culture so that the resulting media will be relevant, interesting, and effective in improving students' numeracy skills.

Design Phase

The design stage is a strategic step in designing interactive digital comic learning media based on Karo culture that can improve students' numeracy skills. At this stage, the main focus is to

determine the concept, structure, and visual and interactive elements that will be used. This phase includes the following steps:

1. Design the media concept: Formulating specific learning objectives, namely to improve students' understanding of numeracy concepts such as number operations and problem solving. Elements of Karo culture were incorporated, such as daily folk life, traditional symbols, and the use of local language in character dialogues. This is done to create an emotional connection between the students and the learning media. The interactive digital comic can be accessed through the web platform.
2. Content and Story Design: Develop a narrative that combines elements of Karo culture with the concept of numeracy. The comic tells the story of a young Karo character who uses numeracy skills to solve problems in everyday life. Weave numeracy problems and concepts into the story in a contextual way so that students can learn while enjoying the story. Design a main character that represents the Karo culture, with a setting that reflects the daily life of the Karo people.
3. Design interactive elements: Include interactive features such as practice problems or quizzes that engage students in the story process. Students must complete the.
4. Visual and Aesthetic Design: Develop character designs that reflect the characteristics of the Karo people, including traditional clothing, accessories, and cultural expressions. Use attractive illustrations with a color palette that reflects the atmosphere of Karo culture, such as the colors often used in Ulo fabrics. Choose fonts that are easy to read and appropriate to the cultural theme.
5. Designing the technical structure: Adding sound elements, such as Karo narration or traditional music, to enhance the learning experience.
6. Storyboard and prototype development: Create rough sketches of each comic panel, including dialogue, illustrations, and math problems. Develop an initial version of the interactive digital comic that includes the storyline, interactive elements, and visual design to test with a small group of students and teachers.

This design phase will serve as a basic framework to ensure that the interactive digital comics are appropriate for students' numeracy learning needs, relevant to Karo culture, and visually appealing and interactive. The results of this phase will move into the realization phase for full media development.

Realization/Construction

Development of interactive digital comic learning media based on Karo culture into a real product ready for testing. At this stage, the previously formulated design is realized through the creation of visual content, narrative and interactive features using design software and digital platforms. Character and setting illustrations were developed in accordance with Karo cultural elements, while the storyline was integrated with relevant numeracy materials. In addition, interactive features such as practice questions, quizzes, and multimedia elements such as traditional music or sound effects were added to enrich the students' learning experience. The first prototype of the comic was then designed to be tested on small groups of students and

teachers to identify any shortcomings that needed to be addressed before proceeding to further testing.

Testing, Evaluation and Revision

Ensure that the developed interactive digital comic based on Karo culture is effective and in line with the numeracy learning objectives. At this stage, the media prototype is tested with students and teachers to measure their response, engagement, and impact on students' numeracy skills. Data was collected through observation, questionnaires, interviews and numeracy tests to evaluate aspects such as visual design, storyline, level of interactivity and understanding of numeracy concepts. Based on the evaluation results, revisions were made to correct deficiencies. This process is repeated until the media are considered optimal, relevant, and effective before being used in the implementation phase.

Implementation

This stage is the final step in the development of interactive digital comics based on Karo culture to improve students' numeracy skills. At this stage, the revised learning media will be widely used in the classroom learning process. Teachers are given guidance and training on how to integrate these digital comics into the learning process to ensure that the media is used to its full potential. Students then use these digital comics as part of their learning activities, either independently or with teacher guidance. During implementation, monitoring is conducted to see how the media is used in real situations, including student response to learning, level of engagement, and improvement in numeracy skills. The results of this implementation stage provide a final picture of the effectiveness of the media and a basis for further development if needed. The full series of Plomp stages in this study are summarized in Figure 1 below:

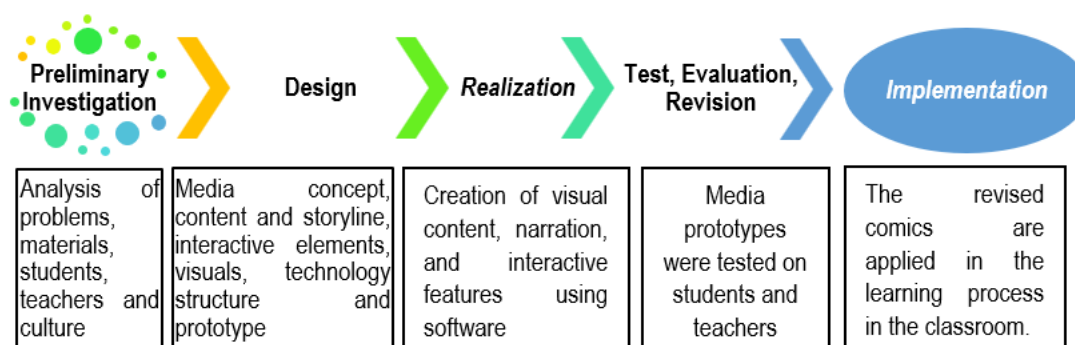


Figure 1. Research Stage

4. Results

The preliminary research phase led to the results of an overall analysis involving teachers and students in a school where Karo culture is part of the community. Based on interviews and questionnaires:

1. Most students find it difficult to understand numeracy concepts due to the lack of contextualized learning media based on interactive digital and local culture.
2. Teachers expressed the need for learning media that is relevant to the local culture to engage students.

The design phase resulted in the design of an interactive digital comic that tells the story of the success of 4 young people Karo achieved his goals. In the process of achieving success, the story tells the daily life of the youth in their home region, Karo. The comic is designed to be relevant to the topic of numeracy. There are interactive features on the comic platform, such as quizzes, simulations, and tasks that can be completed directly on the digital platform. The comics have colorful illustrations and audio in Karo and Indonesian in some scenes. The realization stage produces comics according to the previous design, as shown in Figure 2 below:



Figure 2. Comic Realized

The fourth stage, namely testing, evaluation and revision, produces an analysis table of validity, practicality and effectiveness tests of culture-based interactive digital comics. The product was tested for validity by material experts, media experts and educational practitioners. The validation results show:

Table 1. Validity of karo culture-based interactive digital comics

Assessed Aspect	Validator 1	Validator 2	Validator 3	Average
Visual Design	4.3	5	4.7	4.7
Material	4.7	4.3	4	4.3
Content				
Interactivity	4.5	4.5	4.5	4.5
Student	4.5	5	5	4.9
Engagement				
Use of Technology	4	3.5	4.5	4

Learning Effectiveness	4.5	4.5	4.5	4.5
User Feedback (Students and Teachers)	4.5	4.5	4.5	4.5
Average Value	4.4	4.5	4.5	4.5

Table 1 shows the scores of 3 validators averaged on the basis of the evaluation indicators. The visual design evaluation indicators are the appropriateness of the images to the cultural context of Karo, the quality of the illustrations and attractive colors, and the clarity and readability of the text. These three indicators for each validator have an average of 4.3, 5, and 4.7. The material content indicator consists of the alignment of numeracy materials with the curriculum, the variety and depth of numeracy materials presented, and the relevance of Karo cultural elements in the learning materials, with an average of 4.7, 4.3, and 4 for each validator. Indicators of interactivity are interactive features (quizzes, exercises, etc.) that are easy to use and response to student input (automatic feedback) with an average of 4.5 for each of the three validators. Indicators of student engagement are the ability of comics to hold students' attention and whether comics are interesting and fun to use, with an average of 4.5, 5, and 5, respectively. Indicators of technology use are compatibility with different devices (PC, tablet, smartphone) and ease of interface navigation with an average of 4, 3.5, and 4.5 for each validator. Indicators of learning effectiveness, namely increased student understanding of numeracy material and success in improving student numeracy skills with an average of 4.5 for each validator. Finally, the user-friendliness indicator.

Based on the results of the overall good average per validator for all indicators consisting of 16 indicators summarized in 7 aspects of evaluation, the results obtained are 4.5 for the validity criteria of the developed Karo culture-based interactive digital comic learning media. Then, for the practicality test of interactive digital comics in the test, evaluation and revision stages, the results are summarized in Table 2 as follows:

Table 2. Practicality of karo culture-based interactive digital comics

Assessed Aspect	Validator 1	Validator 2	Validator 3	Average
Ease of Use	4.3	4.7	4.7	4.7
Interactivity	4.5	4.5	4	4.4
Cultural Relevance	4	4.5	4.5	4.4
Time Effectiveness	4	5	5	4.7
Use of Technology	5	5	5	5
Visual Comfort	5	4.5	4.5	4.7

User Satisfaction	5	5	4.5	4.9
Average Value	4.4	4.5	4.5	4.7

Table 2 shows the results of the assessment of 3 practitioners, averaged on the basis of the assessment indicators. The assessment indicators for ease of use are comics that are easily accessible to students and teachers, clear usage guidelines, and do not require equipment that is too complex. These three indicators for each validator have an average of 4.3, 4.7, and 4.7. The interactivity indicator consists of interesting interactive features (quizzes, simulations, animations) and interactive features that run well without interruption, with an average of 4.5, 4.5, and 4 for each validator. Indicators of cultural relevance are comic book content in line with Karo culture, and illustrations and stories reflect local values with an average of 4, 4.5, and 4.5 for the three validators, respectively. Indicator of time effectiveness is that students understand the material in a relatively short time and teachers can make better use of learning time with this media with an average of 4, 5 and 5 from each validator. Indicator for use of technology is that it does not require a very high Internet connection to operate has an average of 5 for each validator. The visual comfort indicator is that the design is attractive and does not tire the eyes quickly and the layout of the elements is easy to understand and not confusing with an average of 5, 4.5 and 4.5 for each validator.

Finally, the indicators of user satisfaction, namely students feeling satisfied with the learning experience of using this media and teachers feeling helped in delivering material with this comic, have an average of 5, 4.5 and 4.5 also for each validator. Based on the results of all good averages per validator for all indicators consisting of 14 indicators summarized in 7 aspects of assessment, the results obtained are 4.7 for the practicality criteria of the Karo culture-based interactive digital comic learning media developed.

Still at the test, revision and evaluation stage, the results of the effectiveness test of Karo culture-based interactive digital comic learning media are seen from how many students get scores above the KKM (70) if it exceeds 80% then interactive digital comics are said to be effective [18]. Then based on the responses of students and teachers also obtained effective status if it exceeded 80% who stated that the response to the comic was positive. The results of the descriptive statistical test on e-view show that there are 9 (90%) people who have scores above the KKM out of 10 students who take part in small group tests at the test, evaluation and revision stages. Then 92.35% of students have a positive response to interactive digital comics. With indicators summarized in the response graph presented in Figure 3 below:



Figure 3. Student Response to Karo Culture-Based Digital Comic Media

After the four stages were completed, the answer to the problem formulation regarding the validity, practicality, and effectiveness of Karo culture-based interactive digital comics was obtained. The answer to the second problem formulation regarding the improvement of students' numeracy skills was obtained through the final stage of the Plomp method, namely the implementation of interactive digital comic media on a larger scale, namely in a class consisting of 36 students at SMA Negeri 1 Brastagi. The experimental results in this stage in one class obtained difference test data using e-views, which is shown in Figure 4 for the data normality test and Table 3 for the improvement results:

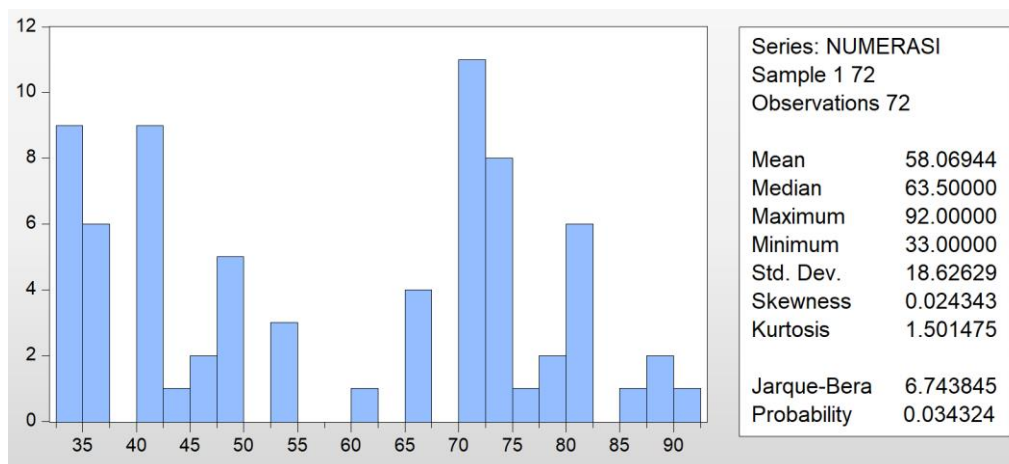


Figure 4. Normality test

Based on Figure 3 above, the probability result is 0.034324. This result is an interpretation that the experimental data of interactive digital comics on a broader subject is abnormal because the probability value is <0.05 . Therefore, in order to see the improvement of numeracy skills after receiving a learning treatment facilitated by interactive digital comics based on Karo culture, the Wilcoxon test was conducted. The results of the Wilcoxon signed rank test with e-views are shown in Table 3 below:

Table 3. Wilcoxon Test with E-views

Method	df	Value	Probability
Wilcoxon/Mann-Whitney		7.292333	0.0000
Wilcoxon/Mann-Whitney (tie-adj.)		7.329906	0.0000
Med. Chi-square	1	72.00000	0.0000
Adj. Med. Chi-square	1	68.05556	0.0000
Kruskal-Wallis	1	53.26027	0.0000
Kruskal-Wallis (tie-adj.)	1	53.81053	0.0000
van der Waerden	1	48.07090	0.0000

The conclusion of the Wilcoxon test is that there is a difference in numeracy skills between before and after being given a learning treatment using interactive digital comics based on Karo culture. because the results from table 3 obtained a probability value of $0.000 < 0.05$. After the treatment, numeracy skills increased significantly.

5. Discussion

Based on the results of the validity and practicality test evaluation, the Karo culture-based interactive digital comic is valid and practicable with average scores of 4.5 and 4.7. Small group trials conducted with 10 students resulted in an increase in the average numeracy score from 43 to 79. And there are 9 students (90%) above 70 (KKM) and 10 (100%) students who have a positive response to culture-based interactive digital comics. Thus, based on the percentage of numeracy scores above KKM and a positive response of more than 80% of students, culture-based interactive digital comics are said to be effective in improving students' numeracy skills. This is consistent with Putri's research [19] that comics are effective in increasing students' interest in reading. High reading interest often improves cognitive skills such as critical thinking, comprehension, and problem solving, which are the foundation for mastering numeracy. By reading different types of texts, such as stories, informational content, or interactive digital comics, readers can be exposed to mathematical concepts in a real-world context. This exposure helps deepen numeracy understanding by presenting it in a meaningful and relevant way. Other researchers have also stated that comics that are appropriate, interesting, and acceptable have the potential to improve behavior [20].

The extensive trial conducted with 36 students resulted in an increase in the average score of the numeracy test from 40 to 75. There were 4 students who scored below 70 (KKM) and 32 (89%) students who scored above 70 (KKM). The lowest score after treatment increased from 33 to 67 from before treatment while the highest score changed from 60 to 92. Then, there were $92.35\% > 80\%$ of students who had a positive response to this interactive digital comic based on Karo culture. These results are related to the analysis conducted by [21] that students are very interested in comic media and comic media is needed to improve students' numeracy skills. Increased comprehension skills of students can be achieved if facilitated with media that are interesting and familiar, and many students like comics [22].

Interactive digital comics based on Karo culture have been shown to be effective in improving students' numeracy skills [23][24]. This is consistent with the theory that learning media based on local culture can increase student engagement and understanding of the material. This effectiveness is supported by the presentation of comics based on interesting storylines and interactive everyday conversations to motivate students to learn more enthusiastically. In addition, math comics designed to incorporate local cultural elements add value by helping students feel more connected and understand the context of the stories presented. The questions in this comic book are also designed to promote numeracy by presenting information in the form of numbers, dates and mathematical symbols that are enriched with cultural context, making them more relevant and meaningful to readers. This interactivity and cultural relevance reinforces the role of math comics as a learning medium that is both fun and educational.

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