Development of KoMaCu Learning Media for Probability: An Innovative Digital Comic to Enhance Learning Effectiveness

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Abstrak

Penelitian ini bertujuan untuk mengembangkan dan mengevaluasi validitas, kepraktisan, serta efektivitas KoMaCu (Funny Mathematics Comics) sebagai media pembelajaran berbasis komik digital pada materi peluang bagi siswa kelas IX di SMP Swasta Imelda Medan. Penelitian ini dilatarbelakangi oleh rendahnya motivasi dan hasil belajar matematika siswa yang disebabkan oleh dominannya praktik pembelajaran konvensional dan monoton. KoMaCu dirancang dengan mengintegrasikan narasi visual dan pendekatan Realistic Mathematics Education (RME) guna mendorong pembelajaran yang kontekstual dan bermakna. Penelitian ini menggunakan metode Research and Development (R&D) dengan model ADDIE yang meliputi tahap analisis, perancangan, pengembangan, implementasi, dan evaluasi. Data dikumpulkan melalui lembar validasi ahli, angket respons siswa, serta tes pre-test dan post-test. Subjek penelitian terdiri atas 18 siswa kelas IX. Hasil validasi menunjukkan bahwa KoMaCu berada pada kategori sangat valid ditinjau dari aspek materi, kebahasaan, dan desain media. Uji kepraktisan memperoleh skor kelayakan sebesar 66% yang menunjukkan respons positif dari siswa. Selain itu, hasil belajar siswa mengalami peningkatan yang signifikan, dengan nilai rata-rata meningkat dari 13,3 pada pre-test menjadi 40,5 pada post-test. Temuan ini menunjukkan bahwa KoMaCu valid, praktis, dan efektif dalam meningkatkan pemahaman serta motivasi siswa dalam pembelajaran peluang, sehingga berkontribusi pada pengembangan media pembelajaran digital inovatif dalam pendidikan matematika.

Abstract

This study aimed to develop and evaluate the validity, practicality, and effectiveness of KoMaCu (Funny Mathematics Comics) as a digital comic-based learning medium for probability topics among ninth-grade students at Imelda Private Junior High School, Medan. The study was motivated by students' low motivation and achievement in mathematics due to predominantly conventional and monotonous instructional practices. KoMaCu was designed by integrating visual narratives with the Realistic Mathematics Education (RME) approach to promote contextual and meaningful learning. The study employed a Research and Development (R&D) methodology using the ADDIE model, encompassing analysis, design, development, implementation, and evaluation stages. Data were collected through expert validation sheets, student response questionnaires, and pre-test and post-test assessments. The participants consisted of 18 ninth-grade students. The validation results indicated that KoMaCu achieved a highly valid category in terms of content, language, and media design. Practicality testing yielded a feasibility score of 66%, indicating positive student responses. Furthermore, students' learning outcomes improved substantially, with the mean score increasing from 13.3 in the pre-test to 40.5 in the post-test. These findings demonstrate that KoMaCu is valid, practical, and effective in enhancing students' understanding and motivation in learning probability, thereby contributing to the development of innovative digital learning media in mathematics education.

INTRODUCTION

Education plays a fundamental role in developing high-quality human resources by fostering not only knowledge acquisition but also character formation, values internalization, and

essential skills for social life. In the context of mathematics education, instructional quality is a critical determinant of students' cognitive development, particularly in cultivating logical reasoning, critical thinking, and problem-solving abilities. Numerous studies have emphasized that effective mathematics instruction significantly influences students' higher-order thinking skills and long-term academic achievement, especially when learning environments are designed to be meaningful and student-centered (OECD, 2019; English & Kirshner, 2016). Recent international research further highlights that coherent curriculum design, pedagogical alignment, and the integration of appropriate learning resources play a decisive role in improving students' mathematical proficiency and equity in learning outcomes (Hattie, 2015; Schleicher, 2018; NCTM, 2020; Kilpatrick et al., 2016; Darling-Hammond et al., 2020).

Despite its importance, mathematics is frequently perceived by students as abstract, difficult, and intimidating, which often leads to low motivation and poor learning outcomes. This perception is commonly associated with conventional instructional practices that emphasize procedural teaching, teacher-centered explanations, and limited use of learning media (Zakaria & Syamaun, 2017; Zhang et al., 2020). Contemporary studies indicate that prolonged exposure to such instructional approaches contributes to mathematics anxiety, low self-efficacy, and surface-level learning, particularly among secondary school students (Ashcraft & Moore, 2017; Mutlu & Söylemez, 2018; Supekar et al., 2015; Dowker et al., 2016; Carey et al., 2019).

The rapid advancement of digital technology has profoundly reshaped educational practices, especially within the framework of 21st-century learning. Teachers are increasingly expected to integrate digital tools and innovative learning media that promote interactivity, flexibility, and learner autonomy (Redecker, 2017; Tondeur et al., 2018). Large-scale reviews and meta-analyses suggest that technology-enhanced learning environments, when aligned with sound pedagogical principles, can significantly improve students' engagement, motivation, and conceptual understanding (Schindler et al., 2017; Bond et al., 2020; Puentedura, 2019; Voogt et al., 2018; Mishra & Koehler, 2016).

Learning media function as a critical bridge between teachers and students in facilitating effective knowledge transfer. Well-designed instructional media can reduce the abstractness of mathematical concepts and support students in constructing meaning through multiple representations (Ainsworth, 2014; Sung et al., 2016). Research grounded in cognitive theory of multimedia learning demonstrates that the integration of visual, verbal, and interactive elements enhances learners' processing capacity and conceptual understanding, particularly in mathematics learning contexts (Mayer, 2020; Moreno & Mayer, 2018; Clark & Mayer, 2016; Sweller et al., 2019; Fiorella & Mayer, 2016).

One form of digital learning media that has gained increasing attention is the use of comics, particularly digital comics or e-comics. Comics integrate visual elements, narratives, and dialogue to present information in an engaging and accessible format (Farinella, 2018; Özdemir, 2017). Empirical evidence over the last decade indicates that comic-based learning media can effectively enhance students' motivation, reading interest, and comprehension by reducing cognitive load and increasing emotional engagement, especially in subjects perceived as complex such as mathematics (Hosler & Boomer, 2017; Lin et al., 2019; Yang, 2020; Tatalovic, 2019; Jee & Anggoro, 2019).

In mathematics education, digital comics are particularly effective when combined with pedagogical approaches that emphasize contextual and meaningful learning, such as Realistic Mathematics Education (RME). RME encourages students to construct mathematical understanding through real-life contexts that are familiar and relevant to their experiences (Gravemeijer et al., 2017; Prahmana & Kusumah, 2016). A growing body of research confirms that RME-based instruction supports deeper conceptual understanding, mathematical reasoning, and students' ability to connect mathematics with everyday situations across diverse educational settings (Laurens et al., 2018; Widjaja et al., 2019; van den Heuvel-Panhuizen, 2020; Bakker et al., 2018; de Lange, 2019).

Responding to these pedagogical challenges, this study developed KoMaCu (Komik Matematika Lucu/Funny Mathematics Comics), a digital comic-based learning medium designed to support probability learning for junior high school students. KoMaCu integrates humor,

culturally contextual narratives, and RME-based problem situations to promote meaningful and enjoyable learning experiences. By combining digital comics with contextual mathematics instruction, KoMaCu addresses both cognitive and affective dimensions of learning. Therefore, this study aimed to develop and examine the feasibility, practicality, and effectiveness of KoMaCu using the ADDIE development model, contributing to the growing body of research on innovative digital media in mathematics education (Voogt et al., 2018; Mishra & Koehler, 2016; Tatalovic, 2019; Sweller et al., 2019; de Lange, 2019).

METHOD

This study employed a Research and Development (R&D) approach conducted during the odd semester of the 2024/2025 academic year at Imelda Private Junior High School, Medan. The participants were 18 ninth-grade students. The product developed was KoMaCu, a web-based digital comic designed to facilitate probability learning through visual narratives and contextual problems. The ADDIE development model was adopted, consisting of five stages: Analysis, Design, Development, Implementation, and Evaluation.
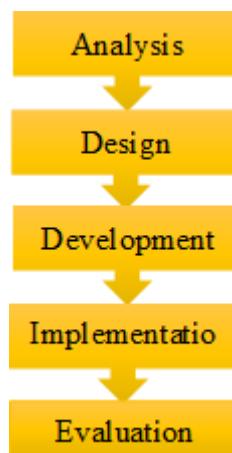
Figure 1.ADDIE Method of Research

During the analysis stage, needs analysis was conducted through interviews with mathematics teachers to identify students' learning difficulties, teaching methods, and existing learning media. The design stage involved determining the comic title, developing storylines and dialogues, designing characters and settings, and preparing the visual layout using Canva. The development stage focused on producing the digital comic and conducting expert validation involving two mathematics teachers. Validation instruments assessed content accuracy, language clarity, and media design using a Likert scale.

The implementation stage involved field testing with students, including the administration of pre-tests and post-tests to measure learning effectiveness, as well as student questionnaires to assess practicality. Learning effectiveness was analyzed using N-Gain scores. The evaluation stage examined validation results, student responses, and learning outcomes to determine the overall quality of the developed media.

The instruments used for data collection consisted of expert validation sheets and questionnaires. The expert validation questionnaire was administered to two mathematics teachers teaching at the junior high school level. The validator questionnaire items were adapted from a study conducted by Tri Handayani (2021) on the development of STEM-based digital comic learning media to enhance elementary students' scientific literacy.

In addition, a student response questionnaire was administered, which was adapted from a study by Rida Fironika Kusumadewi, Nuhyal Ulia, and Yunita Sari (2020) concerning the development of digital comic-based mathematics teaching materials to improve elementary students' reading interest. Furthermore, learning outcome data were collected through pre-test and post-test instruments adapted from an undergraduate thesis by Resy Karina Christine Bancin

(2025) entitled *The Effectiveness of Problem-Based Collaborative Learning Models in Overcoming Students' Difficulties in Solving Word Problems on Probability Material in Grade X of SMK Negeri 5 Medan, Academic Year 2024/2025*.

This study employed data collection and analysis techniques covering three main aspects: content, language, and media/design. Each aspect was intended to evaluate the feasibility of the developed learning media. Validation of these aspects was conducted using a Likert scale, and the validity score was calculated using the following formula:

$$V = \frac{\sum \text{scores given by validators}}{Maximum\ Possible\ Scores}\ x\ 100\%$$

Table 1. Validator Assessment Criteria

Interval (%)	Feasibility Criteria
80% – 100%	Very Feasible
60% – 80%	Feasible
40% – 60%	Moderately Feasible
20% – 40%	Less Feasible
0% – 20%	Not Feasible

The questionnaire administered to students also served as an indicator of whether the developed learning media were feasible. The questionnaire covered several aspects, namely preference (enjoyment of reading), enthusiasm, willingness (reading without being instructed), understanding (content comprehension), and motivation (learning encouragement). The purpose of administering the questionnaire based on these predetermined aspects was to evaluate the effectiveness of the developed learning media. The measurement was conducted using a Likert scale, calculated using the following formula:

$$Effectiveness = \frac{Actual\ Score}{Ideal\ Score}\ x\ 100\%$$

Table 2. Questionnaire Assessment Criteria

Interval (%)	Feasibility Criteria
80% – 100%	Very Feasible
60% – 80%	Feasible
40% – 60%	Moderately Feasible
20% – 40%	Less Feasible
0% – 20%	Not Feasible

The field trial involving pre-test and post-test assessments was conducted to evaluate the effectiveness of the developed learning media. To measure the effectiveness of the media, the N-Gain test was employed using the following formula:

$$N - Gain = \frac{posttest\ score - pretest\ score}{Maximum\ Score - pretest\ score}\ x100\%$$

Table 3. N-Gain Score Criteria

Score Range	Category
N-Gain ≥ 0.70	High
0.30 < N-Gain < 0.70	Medium
N-Gain ≤ 0.30	Low

RESULT AND DISCUSSION

Result

The results of this study are presented in accordance with the stages of the ADDIE development model, focusing on the validity, practicality, and effectiveness of the KoMaCu learning media.

Analysis Phase Result

During the analysis stage, interviews with mathematics teachers revealed that students experienced low motivation and difficulties in understanding probability concepts due to the dominance of conventional teaching methods and the limited use of engaging learning media. These findings justified the need for developing a digital comic-based learning medium tailored to students' characteristics.

Design Phase Result

This stage was carried out through four main steps. First, the title of the developed e-comic learning media was determined as "*Kasino Budaya: Learning Probability through Indonesian Cultural Traditions.*" Second, the storyline was developed by designing the plot and creating dialogue among the characters. At this stage, the visual design was also specified, including the use of a 22-point Papyrus font for titles and a 7–9 point Para font for the main text. The comic was designed in a card format (5 × 5 inches square) using the Canva application. The color scheme was intentionally diverse to reflect the cultural theme, combining dominant shades of brown, pink, blue, and gold.

Third, character and setting development was conducted. The characters featured in the learning media included Gomgom, Maria, Ampong, Komang, Adi, Rahayu, and a guide character. The settings used in the e-comic consisted of several culturally inspired locations, such as a house terrace, a glowing gate, and a cultural room. Fourth, the development of the learning media was completed by designing a web-based platform that presents the e-comic in a digital book format. This design allows students to access and read the e-comic easily without the need to download additional applications. The color usage was adjusted to match the background and character dialogues, while the cover page design incorporated the title, key character elements, and supporting visual components to enhance visual appeal and readability.
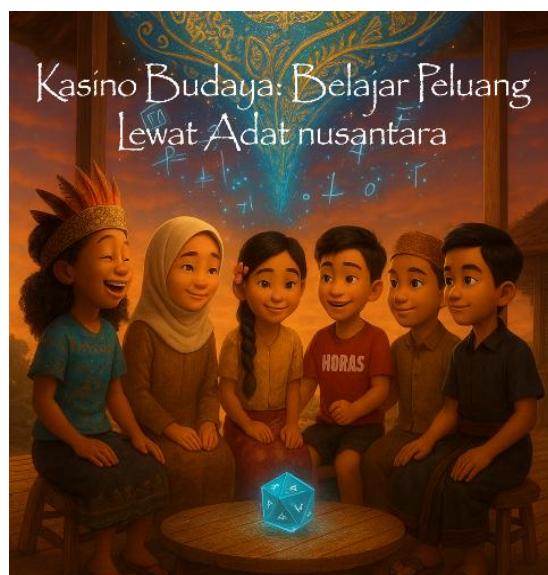

Figure 2. Cover E-Comic

The e-comic is entitled "*Kasino Budaya: Learning Probability through Indonesian Cultural Traditions*" and focuses on probability material. The main characters in the story include Gomgom, Maria, Ampong, Komang, Adi, and Rahayu.

Figure 3. Main Characters of the E-Comic

After determining the main characters or roles in the e-comic, the next step was designing the illustrations. In the image design process, several steps were carried out, including generating background descriptions using ChatGPT. The generated images were then downloaded and imported into Canva, after which narrative text and speech bubbles were added.
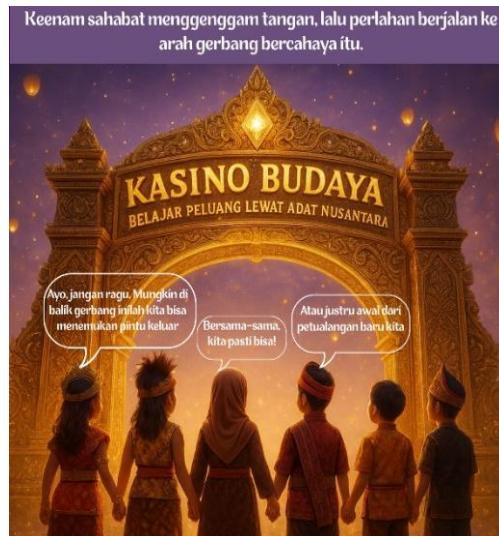
Figure 4. E-Comic Development Process

Development Phase Result

The development stage involved expert validation conducted by two mathematics educators. The validation results indicated that KoMaCu achieved a highly valid category across all assessed aspects. The first validator reported an overall validity score of 93%, while the second validator reported a score of 96%. These scores demonstrate that the content accuracy, language clarity, and media design of KoMaCu met the required pedagogical and technical standards.

Table 4. Expert Validation Results of the KoMaCu Learning Media

Validator	Content Aspect	Language Aspect	Media Design Aspect	Total Score	Average (%)	Category
V1	46	48	45	139	93%	Very Valid
V2	48	47	49	144	96%	Very Valid

Implementation Phase Result

During the implementation stage, KoMaCu was tested on 18 ninth-grade students. The effectiveness of the media was evaluated through pre-test and post-test assessments. The total pre-test score was 240, with a mean score of 13.3, while the total post-test score increased to 730, with a mean score of 40.5. Although the calculated N-Gain value was categorized as low, the descriptive results indicate a substantial improvement in students' learning outcomes after using the KoMaCu media. In addition to learning outcomes, the practicality of KoMaCu was assessed using student response questionnaires. The results showed a practicality score of 66%, which falls into the feasible category. Students expressed positive perceptions regarding enjoyment, motivation, comprehension, and willingness to engage independently with the learning material, indicating that KoMaCu was generally well received by learners.

Table 5. Descriptive Statistics of Students' Pre-Test and Post-Test Scores

Statistic	Pre-Test	Post-Test
N (Students)	18	18
Minimum Score	0	20
Maximum Score	30	90
Total Score	240	730
Mean Score	13.3	40.5

Evaluation Phase Result

At the evaluation stage, students' learning outcomes were examined through pre-test and post-test assessments as well as questionnaire results obtained from expert validators in their respective fields. The students' learning outcomes showed an N-Gain value of 15%, which falls within the range of N-Gain ≤ 0.30 and is therefore categorized as "Low." The results of the validator questionnaires were classified as "Very Valid," indicating that the media can be used as an effective learning medium. However, limitations were observed in students' learning outcomes during the implementation of the media. Despite this, an improvement was evident when comparing the pre-test and post-test results. The total pre-test score was 240, and after the trial implementation, the total post-test score increased to 730. This indicates that the students' mean score improved from 13.3 to 40.5.

In addition to the pre-test and post-test results, the practicality test conducted with students yielded a score of 66%, which falls within the "Feasible" category. These results indicate that students had positive perceptions of the KoMaCu (Funny Mathematics Comics) learning media. Overall, this evaluation suggests that the media provides learning encouragement and supports students' engagement in learning probability concepts.

Table 6. Descriptive Statistics of Students' Practicality Questionnaire Results

Statistic	Preference (Reading Interest)	Enthusiasm	Willingness (Self-Initiated Reading)	Understanding (Content Comprehension)	Motivation	Total Score
N (Students)	18	18	18	18	18	18
Minimum Score	6	5	5	5	5	27
Maximum Score	15	15	14	14	15	72
Total Score	201	185	163	188	186	923
Mean Score	11.17	10.28	9.06	10.44	10.33	51.28

Discussion

The findings of this study indicate that KoMaCu has strong potential as an innovative digital learning medium for probability instruction at the junior high school level. The high validity scores obtained from expert evaluations suggest that the integration of visual narratives, contextual problems, and Realistic Mathematics Education (RME) principles was pedagogically sound. Previous studies have emphasized that digital learning media grounded in clear instructional design and contextual pedagogy are more likely to support students' conceptual understanding and engagement in mathematics learning (Mayer, 2020; Fiorella & Mayer, 2016; Tondeur et al., 2018). Furthermore, the use of comics as a narrative-based medium has been shown to enhance meaning-making processes by combining visual and verbal representations, which is particularly beneficial for abstract mathematical concepts (Farinella, 2018; Lin et al., 2019).

The improvement in students' post-test scores compared to their pre-test performance demonstrates that KoMaCu contributed positively to students' understanding of probability concepts. Although the N-Gain value was categorized as low, the observed increase in mean scores indicates that students experienced meaningful initial learning gains. Similar findings have been reported in prior studies, where digital comic-based or multimedia learning interventions led to gradual improvements in mathematical achievement, especially during early stages of implementation (Hosler & Boomer, 2017; Yang, 2020; Bond et al., 2020). From a cognitive perspective, such improvements can be explained by the reduction of cognitive load and the provision of multiple representations that support schema construction in learners (Sweller et al., 2019; Clark & Mayer, 2016).

In addition to cognitive outcomes, student responses revealed positive affective impacts of using KoMaCu. The feasibility score of 66% indicates that students perceived the media as enjoyable, motivating, and accessible. Research in mathematics education consistently shows that affective factors such as motivation, interest, and enjoyment play a crucial role in sustaining students' engagement and persistence in learning mathematics (Schindler et al., 2017; Carey et al., 2019). Comic-based learning media, in particular, have been found to reduce mathematics anxiety and foster positive learning attitudes by presenting content in a less intimidating and more relatable format (Özdemir, 2017; Jee & Anggoro, 2019).

The integration of Realistic Mathematics Education within a digital comic format represents a key pedagogical strength of KoMaCu. By embedding probability concepts in culturally relevant and realistic contexts, the media enabled students to connect abstract mathematical ideas with everyday experiences. Previous research has demonstrated that RME-based instruction supports deeper conceptual understanding, mathematical reasoning, and transfer of knowledge by encouraging students to actively construct meaning from contextual problems (Gravemeijer et al., 2017; van den Heuvel-Panhuizen, 2020). When combined with digital media, RME has been shown to further enhance students' engagement and learning effectiveness, particularly in secondary mathematics classrooms (Widjaja et al., 2019; Bakker et al., 2018).

Overall, the discussion confirms that KoMaCu is not only valid and practical but also pedagogically effective in supporting probability learning. However, the relatively low N-Gain results suggest that the intervention may require longer implementation periods, repeated use, or integration with complementary instructional strategies to maximize learning gains. Similar recommendations have been highlighted in previous studies on digital learning media, which emphasize the importance of sustained exposure and instructional alignment for achieving higher learning outcomes (Voogt et al., 2018; Mishra & Koehler, 2016). Therefore, future research should involve larger sample sizes, extended intervention durations, and comparative experimental designs to strengthen the empirical evidence regarding the effectiveness of digital comic-based learning media in mathematics education (Bond et al., 2020; de Lange, 2019).

CONCLUSION

This study concludes that KoMaCu (Funny Mathematics Comics) is a valid, practical, and pedagogically effective digital learning medium for teaching probability at the junior high school level. Expert validation confirmed that the media meets high standards of content accuracy, linguistic clarity, and visual design, indicating its suitability for classroom implementation. In terms of effectiveness, the use of KoMaCu resulted in a meaningful improvement in students' learning outcomes, as reflected by higher post-test scores compared to pre-test scores. Although the N-Gain value was categorized as low, the observed increase demonstrates that KoMaCu supports students' initial conceptual understanding of probability, particularly in introducing abstract concepts through contextual and visual representations. Regarding practicality, students' responses indicated positive perceptions of enjoyment, motivation, and accessibility. The integration of humor, culturally relevant contexts, and Realistic Mathematics Education principles contributed to a more engaging and meaningful learning experience. Overall, KoMaCu represents a promising digital learning innovation for mathematics education in the context of 21st-century learning. Future studies are recommended to involve larger samples, longer intervention periods, and experimental designs to further strengthen empirical evidence and optimize learning gains.

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