The Development of Science Technology, Engineering and Mathematics-Based Digital Comic of Number Patterns for Mathematics Learning

Pengembangan Komik Digital Pola Bilangan Berbasis *Science Technology Engineering and Mathematics* untuk Pembelajaran Matematika

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Abstract

Pengembangan media digital tidak hanya menunjang proses pembelajaran tetapi juga membuat pembelajaran mengikuti perkembangan teknologi terkini. Penelitian ini bertujuan untuk mengembangkan komik digital berbasis STEM. Penelitian ini merupakan jenis penelitian pengembangan. Model pengembangan yang digunakan adalah model ADDIE yang terdiri dari lima tahap yaitu analisis, desain, pengembangan, implementasi, evaluasi. Produk yang dikembangkan adalah komik digital berbasis STEM pada materi pola bilangan. Hasil validasi ahli media dan ahli materi menunjukkan bahwa produk komik digital berbasis STEM ini valid dan layak digunakan. Penggunaan komik digital berbasis STEM dalam kegiatan pembelajaran memperkenalkan cara baru dan inovatif untuk mempelajari pola bilangan dan dapat membantu siswa memahami konsep dengan lebih efektif. Komik digital berbasis STEM ini juga mendapat respon positif dari siswa dengan kriteria layak.

Keywords: *ADDIE; Komik Digital; Pola Bilangan; STEM.*

Abstrak

The development of digital media not only supports the learning process but also keeps up with the latest technological developments. This study aims to develop a STEM-based digital comic. This study is a type of development research. The development model used is the ADDIE model, which consists of five stages, namely, analysis, design, development, implementation, evaluation. The product developed are STEM-based digital comic focusing on number patterns. The results of the validation of media and material experts indicate that this STEM-based digital comic product is valid and feasible to use. The use of STEM-based digital comic in learning activities introduced a new and innovative way to learn number patterns and could help the students understand the concept more effectively. This STEM-based digital comic also gets positive responses from students with feasible criteria.

Kata Kunci: *ADDIE; Digital Comic; Number Pattern; STEM.*

Introduction

Mathematics learning is not limited to repetition and memorization of formulas but also increasingly emphasizes flexible and creative thinking. Students in the Internet of Things era should benefit from mathematics learning combined with technology. The problem of less than optimal utilization of technology, one of which is digital media, is one of the constant factors in mathematics learning. A mathematics teacher at an MTs in Tangerang Selatan stated that classroom learning media has used technology but is still limited to presentations using power points. In addition, they also use conventional media such as whiteboards and geometric frame props. Asadullah stated that students needed innovative learning media to help easily understand the material[1].

The development of digital media not only supports the learning process but also keeps up with the latest technological developments. Ming-Hung Lin et al.'s research results show that digital learning provides a better positive effect than conventional learning[2]. Using learning media for math allows students to turn natural objects into learning experiences. The results of the search on the importance of using meaningful learning devices and technology in mathematics learning did not meet expectations. The study by Atika et al. showed that, in addition to not using technology, mathematics teachers needed to develop their own learning devices in accordance with student characteristics and competencies that must be achieved[3].

The use of comic media in mathematics lessons has proven effective in increasing motivation and learning outcomes. Batubara et al.'s research results show that E-comic learning media is very effective as a mathematics learning medium to increase students' interest in mathematics during the COVID-19 pandemic[4]. Scott McCloud defines comics as a collection of images that convey information or produce an aesthetic response for those who view

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[1] Abdul Wahid Asadullah, Elly Anjarsari, and M. Ulul Albab, "Development of Learning Media with a Scratch-Based Ethnomathematical Approach on Reflection Material," *Proceedings of Annual International Conference On Religious Moderation* 1, no. 1 (March 21, 2024): 52–62, https://proceeding.unzah.ac.id/index.php/aicrom/article/view/119.

[2] Ming-Hung Lin, Huang-Cheng Chen, and Kuang-Sheng Liu, "A Study of the Effects of Digital Learning on Learning Motivation and Learning Outcome," *Eurasia Journal of Mathematics, Science and Technology Education* 13, no. 7 (June 15, 2017): 3553–64, https://doi.org/10.12973/eurasia.2017.00744a.

[3] Nur Atika, Yenita Roza, and Atma Murni, "Development of Learning Tools by Application of Problem Based Learning Models to Improve Mathematical Communication Capabilities of Sequence and Series Materials," *Journal of Educational Sciences* 4, no. 1 (January 27, 2020): 62–72, https://doi.org/10.31258/jes.4.1.p.62-72.

[4] Yosse Andreas BatuBara et al., "Analisis Minat Belajar Siswa Menggunakan Media Pembelajaran E-Comic Aritmatika Sosial Masa Pandemi Covid-19," *Jurnal Derivat: Jurnal Matematika Dan Pendidikan Matematika* 8, no. 1 (July 19, 2021): 1–10, https://doi.org/10.31316/j.derivat.v8i1.1518.

them[5]. Comics present stories that are easy to understand and incorporate visuals that appeal to teenagers[6]. The language used in the media is simple, with a simple vocabulary that also follows the target comic users. Comics convey material with pictures and dialogues to attract students to learn. In general, digital comics are familiar to students. The advantages include more exciting learning and longer student memory because the story is translated into pictures[7]. In addition, digital comic media also helps students understand the concrete form of a mathematical context. However, there needs to be another approach that can strengthen the use of digital comics in mathematics learning. One alternative approach that can support mathematics learning is Science, Technology, Engineering, and Mathematics (STEM).

Science, Technology, Engineering, and Mathematics (STEM) is a growing trend in education. Integrating STEM into learning media can help students develop solutions in mathematics learning. Roehrig et al. stated that the STEM model has unique features that distinguish its four components[8]. The steps for learning using the STEM approach connect learning across each STEM element, making it more meaningful[9]. These different aspects collectively help students approach problem-solving more holistically. According to the research conducted by Yuanita and Feni Kurnia, it has been found that STEM education shows students the use of STEM concepts and principles in an integrated manner in developing products, processes, and systems that are beneficial to human life[10].

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[5] Scott McCloud, *Understanding Comics: The Invisible Art* (Harper Collins, 2010), https://openlibrary.telkomuniversity.ac.id/pustaka/9555/understanding-comics-the-invisible-art.html.

[6] Hanif Elmo Raharja, "The Effects of Digital Comic on Student's Reading Comprehension of Vocational School Students," *RETAIN: Journal of Research in English Language Teaching* 11, no. 02 (August 5, 2023): 73–77, https://ejournal.unesa.ac.id/index.php/retain/article/view/56595.

[7] Fitra Yurisma Kanti, Bambang Suyadi, and Wiwin Hartanto, "Pengembangan Media Pembelajaran Komik Digital Pada Kompetensi Dasar Sistem Pembayaran Dan Alat Pembayaran Untuk Siswa Kelas X IPS Di MAN 1 Jember," *JURNAL PENDIDIKAN EKONOMI: Jurnal Ilmiah Ilmu Pendidikan, Ilmu Ekonomi Dan Ilmu Sosial* 12, no. 1 (May 16, 2018): 135–41, https://doi.org/10.19184/jpe.v12i1.7642.

[8] Gillian H. Roehrig et al., "Beyond the Basics: A Detailed Conceptual Framework of Integrated Stem," *Disciplinary and Interdisciplinary Science Education Research* 3, no. 1 (December 13, 2021): 11, https://doi.org/10.1186/s43031-021-00041-y.

[9] Alif Maulana Arifin, Heni Pujiastuti, and Ria Sudiana, "Pengembangan Media Pembelajaran STEM Dengan Augmented Reality Untuk Meningkatkan Kemampuan Spasial Matematis Siswa," *Jurnal Riset Pendidikan Matematika* 7, no. 1 (September 13, 2020): 59–73, https://doi.org/10.21831/jrpm.v7i1.32135.

[10] Yuanita Yuanita and Feni Kurnia, "Analisis STEM (Science, Technology, Engenering, and Mathematicss) Materi Kelistrikan Pada Buku Tematik Tema 3 Kelas 6 Sekolah Dasar," *Prosiding Simposium Nasional Multidisiplin (SinaMu)* 1, no. 0 (August 5, 2019), https://doi.org/10.31000/sinamu.v1i0.2174.

Although research on learning media in the form of digital comics already exists, the number still needs to grow. In addition, digital comics whose storylines follow learning materials in schools are not widely available. Some STEM-based comics that are available are translations of foreign comics. Although the material in the story has been adjusted to the level of students, the plot and situation in the comics sometimes need to follow conditions in Indonesia. Therefore, this study aims to develop learning media of STEM-based digital comics on number patterns material.

Methods

The study refers to Research and Development (R&D), which involves a systematic approach to creating a new product or improving an existing one[11]. This process can be documented and quantified[12]. The research adopts the ADDIE model (analysis, design, development, implementation, evaluation), with its stages tailored to fit the research needs as described by Martatiyana et al[13]. The process is depicted in Figure 1.

Figure 1. ADDIE model stages

This study was conducted during the second semester of the 2022/2023 academic year. It involved a group of nine individuals with expertise in the areas of content, learning design, and learning media. The final phase of the study included 30 eighth-grade students from MTsN in Jakarta. The methodology employed in this research consisted of observations and questionnaires for data collection. The questionnaire gathered feedback from a variety of participants, including experts, teachers, and students, to obtain valuable insights. The data collected was analyzed using both qualitative and quantitative descriptive methods.

The analysis phase involves literature and field analysis. In the design phase, the researcher determines the material, makes media flowcharts, determines the context of the story, characterizations and characters, STEM

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[11] Romi Mesra, *Research & Development Dalam Pendidikan* (OSF), accessed October 29, 2024, https://osf.io/preprints/osf/d6wck.

[12] Sutama, *Metode Penelitian Pendidikan Kuantitatif, Kualitatif, PTK, Mix Method, R & D* (Sukoharjo: CV Jasmine, 2019).

[13] Diana Rossa Martatiyana, Herlina Usman, and Hasanah Dewi Lestari, "Application of the Addie Model in Designing Digital Teaching Materials," *Jurnal Pendidikan Dan Pengajaran Guru Sekolah Dasar (JPPGuseda)* 6, no. 1 (March 31, 2023): 105–9, https://doi.org/10.55215/jppguseda.v6i1.7525.

integration, script making, lineart drawings, sketches, coloring, and detailing objects that need to be adjusted to the curriculum and the level of student age development. The third stage is the development of the media. The produced products are developed into interactive digital comics using a subscription platform. Subsequently, product validation is carried out by experts, specifically lecturers and teachers, who use assessment instruments.

During the implementation stage, which is the fourth phase of the process, product utilization trials are conducted after implementing modifications suggested by experts. Experiments are carried out with groups of students to evaluate their responses to the product under development and to gather feedback for the next revision phase. The fifth stage is evaluation, which assesses the feasibility of the learning media using both numerical data and textual analysis.

The Aiken V analysis of media validity was used to prove the validity of the media. Aiken's validity coefficient is calculated using raw scores from n experts. The formula obtains the content validity using the V Aiken coefficient[14].

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

Information:
r: number given by rater
l_o: lowest validity rating score
c: the highest number of validity assessments
n: the number of experts and practitioners who assess
i: i^{th} expert or practitioner

The criteria used to state that an item is valid according to Aiken is that the Aiken index must have a V value ranging from 0-1. The classification of the Aiken validity coefficient is shown in Table 1.

Table 1. Aiken Validity Coefficient Classification (V)

Aiken validity coefficient value (V)	Criteria
$0 < V \leq 0,4$	low
$0,4 < V \leq 0,8$	moderate
$0,8 < V \leq 1$	high

Source: Retnawati[15]

[14] Lewis R. Aiken, "Three Coefficients for Analyzing the Reliability and Validity of Ratings," *Educational and Psychological Measurement* 45, no. 1 (March 1, 1985): 131–42, https://doi.org/10.1177/0013164485451012.

[15] Heri Retnawati, "Proving Content Validity of Self-Regulated Learning Scale (the Comparison of Aiken Index and Expanded Gregory Index)," *REID (Research and Evaluation in Education)* 2, no. 2 (December 28, 2016): 155–64, https://doi.org/10.21831/reid.v2i2.11029.

Result and Discussion

1. Analysis Phase

During the analysis phase, important things were found in making digital comics as learning media. The results of the literature analysis showed that students were interested in comics, and learning outcomes increased with the help of comics. In addition, the STEM approach that is integrated with learning can also improve students' learning outcomes, mathematical behavior, and creativity in learning to solve a problem. Study results conducted by Suciana et al. revealed that the PBL integrated with STEM has an effect on improving student learning outcomes at various levels of education and various subjects[16].

Based on the curriculum analysis, the learning indicators used in this media are identifying types of number patterns, determining the nth term of a number sequence, determining the n value of a number sequence, and generalizing a number pattern. The field analysis at 3 MTs in Tangerang Selatan showed that they never used digital comics in learning at school. However, the technology was already available in schools; even every student had it. The Media often used in learning include projectors, power points, whiteboards, teaching aids, and learning platforms such as Quizizz, Kahoot, and Google Classroom. In addition, the available computer lab has never been used in mathematics learning at school. In line with study conducted by Permana et al., while recognizing the positive potential of technology-based learning media, it is important to design and implement effective strategies to ensure that technology is used optimally in educational contexts[17].

2. Design Phase

The design phase activities involved the preparation and conceptualization of the product. This phase involved the development of digital teaching materials tailored to the results of the previous needs analysis, curriculum analysis, and student analysis. Additionally, the materials required for the digital teaching resources will be determined based on the specific needs within the field[18]. Before starting the production process, researchers extensively reviewed relevant literature from various sources to obtain

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[16] Dola Suciana et al., "A Meta-Analysis Study: The Effect of Problem Based Learning Integrated with STEM on Learning Outcomes," *European Journal of Education and Pedagogy* 4, no. 2 (March 29, 2023): 133–38, https://doi.org/10.24018/ejedu.2023.4.2.619.

[17] Belva Saskia Permana, Lutvia Ainun Hazizah, and Yusuf Tri Herlambang, "Teknologi Pendidikan: Efektivitas Penggunaan Media Pembelajaran Berbasis Teknologi Di Era Digitalisasi," *Khatulistiwa: Jurnal Pendidikan Dan Sosial Humaniora* 4, no. 1 (January 5, 2024): 19–28, https://doi.org/10.55606/khatulistiwa.v4i1.2702.

[18] Martatiyana, Usman, and Lestari, "Application of the Addie Model in Designing Digital Teaching Materials."

pertinent information for reference purposes and as a source of direction. Creating digital comic learning media requires a systematic method and preparation of tools and materials. The necessary equipment includes a laptop and a pen tablet. The author begins by writing the script in Microsoft Word (.doc) and then transferring it to a Storyboard. The next stage involves the designer reading and analyzing various collections of illustrations, studying their structure, and then sketching them out. Once the sketch is completed, basic coloring is applied, followed by detailing the main object and enhancing the background color. The storyboard is then drawn and the background color strengthened using Medibang Paint software. After completing the comic, each page is converted into an image (.png format). The final step is developing the comic into an interactive learning media with EPUB format to incorporate interactive features. The final design of the STEM-based comic is shown in Figure 2.

Figure 2. Design of STEM-based Digital Comic

The research conducted involved number patterns material and integrating them with STEM. During the design stage, the researcher created a storyline that was tailored to the material studied and reflected real-life situations. The storyline also included STEM elements relevant to the story's context. More details regarding the context and integration of STEM can be found in Table 2.

Table 2. STEM Context and Integration

No.	Contextual Situation	STEM
1	Even Number Pattern: There are two queues: Queue A has odd-numbered positions, while Queue B has even-numbered positions. The goal is to identify even-numbered positions and create a formula to predict the number of participants based on the queue number. This scenario takes place at a school where there is a free dental check-up.	Science: Caring for teeth Engineering: Ability to operate automatic queueing devices
2	The Exercise of Even Number Pattern: "Buy one, get one free" is a concept where the customer pays for one item and receives an additional item for free. This means that for every one item purchased, the customer receives two items. You can use the general formula for even number patterns to calculate the number of bonus items received based on the total items purchased.	Mathematics: Logic of "buy one, get one free" and "buy two, get one free" Technology: Use of queueing machines
3	Square Number Pattern: Using the Wolfram application to find the square number pattern formula, specific terms are determined using the square number pattern formula.	Mathematics: Formula for square area Technology: Utilizing Wolfram
4	The Exercise of Square Number Pattern: The context involves kindergarten students participating in performance activities that involve using square-shaped stickers on the stage. Users are asked to determine the number of stickers needed based on information about the stage size and the length of the sticker's side.	Mathematics: Formula for the area of a square. Science: Irregularly shaped stickers can damage the paper shredder. Engineering: The use of the internet as a source of information support.
5	Fibonacci Number Pattern: The activity is identifying tree branches. The character finds that tree branches create a pattern. Namely, the number of branches at a	Science: tree branches

No.	Contextual Situation	STEM
	certain stage is the sum of the two previous stages.	
6	The Exercise of Fibonacci Number Pattern: A comic strip story features a character who owns a rabbit farm where rabbit breeding follows the Fibonacci number pattern rules, resulting in the birth of pairs of baby rabbits. As a result, the character can predict the number of rabbits for the upcoming months based on this pattern.	Science: the time it takes for a rabbit to give birth

3. Development Phase

In the development phase, a validation process will be carried out to assess the practicality of the STEM-based comic. The average combined score from nine validators was calculated to be 0.805, which falls within the high validity category. The results for each aspect are presented in Table 3.

Table 3. Result of nine expert validation on the STEM-based comic

Rated Aspect	V Aiken's Average
Appearance Aspect	0.80
Content Aspects	0.82
Language Aspect	0.80
Graphic Aspect	0.80
Average	0.805

Description of aspects assessed:
1. Presentation Aspect: presentation techniques and completeness of the presentation
2. Content or Material Aspect: suitability with the knowledge and skills of the mathematics subjects, alignment with the development of science and technology, and suitability with STEM
3. Language Aspect: accuracy of sentences, communicative content, and suitability with student development
4. Graphic Aspect: readability of text or writing, clarity and attractiveness of images to readers, completeness of cover design and illustrations, and color integration

The results of the validation in Table 3 discovered that the STEM-based comic is valid because it can assist teachers in teaching number pattern material integrated with STEM and everyday life contexts. In addition, this comic makes it easier for students to understand number pattern material in accordance with the basic competencies of mathematics subjects with contextual problems. This aligns with the study conducted by Fakhriyah and

Merliza, which states that comic learning media can help students learn number pattern material better[19].

4. Implementation Phase

This STEM-based comic was distributed 30 to eighth-grade students of MTsN in Jakarta, both online and offline. For those who received the comic offline, the researcher directly observed their reactions, comments, and interest in learning mathematics.

After reading the comic, users are asked to fill out a questionnaire to share their responses. Researchers then analyze the data obtained from the responses. The questionnaire includes three main areas for users to provide feedback: appearance aspect, access aspect, and STEM aspect. The analysis of user responses revealed the overall percentage obtained from the analysis was 75.2%, meeting feasible criteria. The results are shown in Table 4.

Table 4. User response results on the STEM-based comic

Rated Aspect	Percentage
Appearance Aspect	79.3
Access Aspects	73
STEM Aspect	80
Average	75.2

In qualitative interpretation, the average number of each aspect is based on the criteria shown in Table 5.

Table 5. Conversion of quantitative data to qualitative feasibility

Percentage	Decision
81-100	Very Feasible
61-80	Feasible
41-60	Enough Feasible
21-40	Less Feasible
<21	Very Less Feasible

Source: Pujiastuti[20]

Users initially felt comfortable reading the comic, but they encountered difficulties when they had to perform calculations. Many users expressed that

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[19] Fitri Nur Fakhriyah and Pika Merliza, "Development of Ethnomathematics-Based Comics on Number Pattern Material," *Unnes Journal of Mathematics Education* 13, no. 2 (August 10, 2024): 152–61, https://doi.org/10.15294/bwt9yv40.

[20] Heni Pujiastuti, Rudi Haryadi, and Alif Maulana Arifin, "The Development of Augmented Reality-Based Learning Media to Improve Students Ability to Understand Mathematics Concept," *Unnes Journal of Mathematics Education* 9, no. 2 (August 31, 2020): 92–101, https://doi.org/10.15294/ujme.v9i2.39340.

they struggled to understand the concepts conveyed in the dialogue and had to read the comic repeatedly to grasp the message.

Students commented that the comic introduced a new and innovative way to learn number patterns and could help them understand the concept more effectively. They also noted that using comics in learning could make the understanding of concepts more engaging and foster a positive outlook on this teaching method's potential. According to the findings of a study conducted by Topkaya et al, despite some minor flaws of the comic, it has been seen that it has positive effects on academic achievement, attitude, and cognitive and affective dimensions of students[21].

5. *Evaluation Phase*

As we move through the implementation stages of the STEM-based comic, it is important to conduct a thorough evaluation of various aspects. This evaluation phase involves making final adjustments to the product based on the feedback and suggestions received from experts and students during the development and implementation stage. While the generated comic have been well-received by students, there is still a need to address certain student responses through the implementation of additional educational interventions.

Conclusion

The study led to the development of a learning media that integrates STEM principles in the form of digital comics focused on number patterns, specifically designed for eighth-grade students. These STEM-based comics were developed using the ADDIE approach, which consists of five stages: analysis, design, development, implementation, and evaluation. Validation results from nine reviewers indicated that the STEM-based comics have a high level of validity. Experts, including lecturers and teachers, evaluated the comics and assigned an average score of 0.805, reflecting their high viability. Furthermore, user feedback showed an overall satisfaction rate of 75.2%, which meets the criteria for feasibility.

Further research is needed to develop digital comic media for mathematics learning to make students more comfortable using comics. This refers to the results and discussion, specifically the students' comments indicating that they are still struggling with the calculations in the comics. However, it's important to recognize that mathematics is inherently tied to calculations and logical thinking. Therefore, the use of digital comic media in

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[21] Yavuz Topkaya et al., "The Effectiveness of Using Comics in Education: A Meta-Analytic and Meta-Thematic Analysis Study," *Ahmet Keleşoğlu Eğitim Fakültesi Dergisi* 5, no. 3 (October 29, 2023): 922–40, https://doi.org/10.38151/akef.2023.92.

mathematics learning should be accompanied by teachers or other practitioners. Additionally, it is suggested that researchers further explore more diverse materials and broader subjects in their research. It is recommended that a greater variety of media be introduced for mathematical learning to enhance the quality of comic media produced and minimize errors.

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