DEVELOPMENT OF A DIGITAL COMIC FOR FRACTION LEARNING IN JUNIOR HIGH SCHOOL STUDENTS

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Abstract
Understanding fractions remains challenging for many junior high school students, especially in distinguishing numerators and denominators, identifying equivalent fractions, and converting contextual problems into mathematical models. Conventional learning media often lack interactive and engaging features, causing students to struggle with conceptual understanding. This study introduces a digital comic as an innovative and interactive learning medium designed to make fraction learning more contextual and appealing. The research employed a Research and Development (R&D) approach using the 4D model (Define, Design, Develop, and Disseminate). The product, a digital comic in PDF format accessible online, was tested on seventh-grade students at SMP Negeri 9 Banda Aceh. Validation results showed high validity from media (85.90%), content (84.97%), and language experts (100%). Practicality assessments from teachers (93.75%) and students (93.43%) also indicated that the comic is highly practical. These findings highlight the novelty and effectiveness of integrating digital comics into mathematics learning, demonstrating that such media can enhance students' motivation and conceptual understanding of fractions.

Keywords*:* Development of Learning Media, 4D Model, Digital Comic, Fraction Material

INTRODUCTION

Mathematics is one of the disciplines that enhances critical thinking skills, helps solve daily and workplace problems, and contributes to advancements in science and technology.[1] Mathematics is used in many other fields of science, both as a supporting tool and as a foundation for development, making it the mother of all sciences.[2] Therefore, mastery of mathematics is a key factor in understanding and advancing various branches of science and technology.

[1] Dodik Eko Yulianto and Nur Lailatul Qomaria, "Penerapan Model Pembelajaran Talking Stick untuk Meningkatkan Hasil Belajar Siswa Pada Mata Pelajaran Matematika Materi Mengenal Sifat-Sifat Bangun Datar dan Bangun Ruang Pada Kelas V di SD ISLAM AL-ABROR.", *CONSILIUM Journal : Journal Education and Conseling*, 2022, p. 217–224.

[2] Aldio Rahmata et all., "Validitas E-Comic Matematika Berbasis Pemecahan Masalah Pada Materi Kesebangunan," *Jurnal Review Pembelajaran Matematika*, 5(1), 2020, p.53–65.

Mathematics material taught at the junior high school level covers various topics, including fractions. Fractions are one of the essential concepts in mathematics. This concept refers to a whole divided into several equal parts. The number being divided is called the numerator, and the number dividing it is called $\frac{a}{b}$ where $b \neq 0$.[3] Understanding this concept enables students to more easily apply it in various mathematical situations as well as in daily life.

However, understanding fractions often poses a challenge for students. From observations and interviews conducted by the researcher during the preliminary study on Thursday, August 10, 2023, with a seventh-grade mathematics teacher at SMP Negeri 9 Banda Aceh, it was found that students frequently experience difficulties in solving fraction problems. These difficulties include an inability to distinguish between numerators and denominators, challenges understanding how one object can be divided among several people, trouble expressing everyday situations in fractional form, difficulty grasping the concept of equivalent fractions, and an inability to connect the material in problems with previously learned concepts.

From the interview conducted by Fobia et al. with seventh-grade mathematics teachers, it was found that the majority of students have not yet understood the concept of fractions and experience difficulties in solving fraction-related problems properly, as well as a lack of understanding in interpreting the meaning of the questions.[4] Students' understanding of mathematical concepts is still based on rote memorization. They cannot express the meaning or significance of fraction symbols, for example, the symbols $\frac{1}{2}$ or $\frac{1}{4}$ in the problem.[5] This condition indicates the need for more effective and contextual learning to help students deeply understand the concept of fractions, so they can apply it in various situations rather than merely memorizing the symbols.

In the study conducted by Parwadi et al., 10 students, or 30.3%, made errors in determining equivalent fractions on question number 2, and one student did not answer the question. The type of error made by students on this question was failing to multiply both the numerator and denominator by the same number. For example, when multiplying by 2, students should multiply the numerator and denominator by 2, not just one.[6] This indicates that some students still have difficulty understanding the basic concept of determining equivalent fractions, an important skill in fraction manipulation and correctly solving math problems.

In conventional teaching, the methods commonly used are blackboards and textbooks. However, this conventional approach is often less effective in helping students deeply understand fraction concepts and maintain their interest in learning mathematics. Frequently, textbooks only contain theories and mathematical formulas that may be considered uninteresting by students. Books designed as both learning resources and engaging

[3] Parwadi, Agus Susanta, and Effie Efrida Muchlis, "Analisis Kesalahan Siswa Dalam Menyelesaikan Soal Matematika Materi Pecahan Kelas VII SMP Negeri 16 Kota Bengkulu," *Jurnal Penelitian Pembelajaran Matematika Sekolah (JP2MS)*, 4(3), 2020, p.442–454

[4] Alfrida Saronita Fobia, Juliana M. H. Nenohai, and Ofirenty E. Nubatonis, "Pengembangan Media Pembelajaran Matematika Berbasis Android Menggunakan Smart Apps Creator Pada Materi Pecahan Untuk Siswa Kelas VII SMP Negeri 1 Amanuban Barat," *Haumeni Journal of Education*, 3(1), 2023, p.63–76.

[5] Sri Rahayuningsih and Tri Yanti Yuli Astuti, "Analisis Kesalahan Siswa SMP Dalam Menyelesaikan Soal Cerita Bilangan Bulat," *Jurnal Pendidikan dan Pembelajaran Matematika Indonesia*, 2022.

[6] Parwadi, Agus Susanta, and Effie Efrida Muchlis, "Analisis Kesalahan Siswa….", p.442–454.

entertainment are still scarce to find.[7] Therefore, a learning media is needed that supports how to solve problems related to fractions and helps students understand and master the concepts.

Learning media is an important component in the learning process. It serves as an effective learning resource to broaden students' understanding. Using learning media can stimulate students' interest in exploring the material delivered by the teacher, thereby facilitating their comprehension. Engaging learning media can function as a motivator for students to actively participate in the learning process.[8] One example of media that can be used in learning is comics.

Comics are a form of narrative presented in a series of entertaining images. Comic books offer simple and easy-to-understand stories, making them popular among various groups, from children to adults. The uniqueness of comics lies in their ability to convey messages across different fields of knowledge, often presented in a more engaging style than serious explanations. Over the past several years, comics have become a part of mainstream culture, increasingly visible and popular. Comics are now frequently reviewed in major newspapers and found on bookstore shelves. Major publishers have also started releasing works in comic formats, graphic novels, and the number of available comics continues to grow. School and public libraries have begun building graphic novel collections to attract students to visit. According to data from Tribunews in 2013, Indonesia ranks second in the world regarding the number of comic readers. On average, a person in Indonesia reads about 3.11 comic books, nearly three books per person. Indonesia is second only to Finland as the country with the most comic readers, with the average reader in Finland reading almost four comic books.

Comics can be presented through electronic media, thus called digital comics. In the early 2010s, comic fans began shifting to digital formats. This was marked by comic artists who utilized digital platforms, such as Si Juki and Haryadhi, publishing their works on blogs and various social media platforms. Subsequently, the development of digital comics accelerated, which was marked by the emergence of platforms like Webtoon and Clay Comics, and the presence of digital comics on social media such as Instagram and Facebook around 2014.[9] According to information provided by CNN Indonesia, the number of digital comic fans in Indonesia has increased over time. Based on statistics announced by Line Webtoon in April 2015, Indonesia led in the number of digital comic readers compared to other countries, reaching 6 million active users.

Along with information and communication technology development, digital comics have become an engaging and effective learning media. This is supported by research conducted by Rahmata et al., which concluded that the validity of problem-solving-based mathematics e-comics on similar material reached the very valid criteria with an average score of 4.48 on a scale of 1 to 5.[10] Furthermore, Witanta et al. in their research revealed that based on trials with seventh-grade students, digital comic media is practical (students' responses after using the comics were very positive) and effective (all subjects achieved scores above the minimum

[7] Tiadia Nendasariruna, Masjudin, and Zainal Abidin, "Pengembangan Komik Matematika Berbasis Kontekstual Pada Materi Persegi Panjang Bagi Siswa Kelas VII," *Jurnal Media Pendidikan Matematika*, 4(2), 2018, p.76–79.

[8] Teni Nurrita, "Pengembangan Media Pembelajaran untuk Meningkatkan Hasil Belajar Siswa," *Misykat*, 2018, p.171–187.

[9] Bobby Satya Ramadhan and Rasuardie, "Kajian Industri Komik Daring Indonesia: Studi Komik Tahilalats," JSRW (Jurnal Senirupa Warna), 8(1), 2020, p.2–18.

[10] Rahmata et all., "Validitas E-Comic Matematika …." p.53–65.

passing grade of 75).[11] In the context of education, digital comics can be used as innovative learning media to facilitate students' understanding of mathematical concepts.

Despite these developments, most existing studies and digital comic productions focus on entertainment purposes rather than mathematics education. Research on digital comics as instructional media for mathematical concepts, especially fractions, remains limited. Therefore, this study aims to develop and validate a digital comic designed specifically to help junior high school students understand fraction concepts.

Digital comics have many advantages compared to printed comics, including being cheaper, interactive, more dynamic, and easily accessible. Additionally, while printed comics have a limited lifespan due to paper durability, digital comics in electronic data form can be stored as digital files or bytes and transferred to various storage media and social networks.[12] For that, digital comics offer greater flexibility and ease of access, making them a more practical and adaptable choice compared to printed comics.

The advantages of using comics as learning media can capture students' attention due to curiosity and interest, as the material is packaged into illustrated storylines, allowing students to understand the material according to their abilities. Mathematics material presented in illustrated storylines can help students build imagination and ideas from abstract concepts. As a result, this media can enhance students' conceptual understanding of mathematics.

Through initial observation, the researcher also obtained information that students' learning at the school is already sensitive to digitalization. Besides Student Worksheets (LKPD), in mathematics learning, teachers have applied various learning media such as PowerPoint slide presentations and software. The material files compiled by teachers in PowerPoint are always sent via social media connected with students so they can review the material at home. Various teaching aids are also utilized by teachers during lessons to facilitate students' understanding of the material. However, the mathematics teacher at the school stated that digital comics have never been used as a learning medium in mathematics instruction. Specifically, for fraction material, the teacher tends to use teaching aids similar to puzzles and allows students to explore freely.

In this observation, the mathematics teacher added that SMP Negeri 9 Banda Aceh has implemented the School Literacy Movement (GLS), which involves a habit of reading non-academic books for fifteen minutes before lessons begin. GLS is a program launched by the Ministry of Education and Culture to foster a culture of reading and writing among students. Therefore, the SMP Negeri 9 Banda Aceh library deliberately includes non-fiction books such as novels, comics, motivational books, and others. From this observation, the researcher concludes that students at SMP Negeri 9 Banda Aceh are already familiar with comics.

The development of digital comics on fraction material for middle school students is an important step in improving the quality of mathematics learning. By combining abstract mathematical concepts with engaging and interactive media, this development is expected to provide an effective alternative learning tool that positively impacts students' mastery of fractions. This study aims to develop a digital comic for middle school fraction material,

[11] Vivian Alfinia Witanta, Baiduri, and Siti Inganah, "Pengembangan Komik Sebagai Media Pembelajaran Matematika Pada Materi Perbandingan Kelas VII SMP," *Lentera Sriwijaya: Jurnal Ilmiah Pendidikan Matematika*, 1(1), 2019, p.1–12.

[12] Untari, "Pengembangan Komik Digital Table Manner pada Jamuan Makan Formal untuk Pembelajaran Tata Hidang di SMK Negeri 4 Yogyakarta," *Jurnal Pendidikan Teknik Boga*, 2018, p.1–10.

focusing on the development process and evaluating the resulting comic based on validity and practicality criteria.

RESEARCH METHODS

This research is a development study aimed at producing a learning media product as a digital comic. The development procedure for the learning device based on the 4D model consists of four main stages: define, design, develop, and disseminate.[13] The define stage aims to identify and specify the required learning needs. The design stage is used to create a prototype of the learning media based on the previously determined requirements. The development stage focuses on producing the learning media according to the design plan. Finally, the disseminate stage is where the developed media is distributed and utilized.[14] However, in its implementation, this study was only carried out up to the develop stage due to time constraints. The main focus of this research is to develop digital comic learning media on the topic of fractions for seventh-grade students at SMP Negeri 9 Banda Aceh.

The research was conducted at SMP Negeri 9 Banda Aceh with research subjects consisting of seventh-grade students and validators, including content experts, media experts, and language experts. Students and teachers acted as media users who provided feedback on the practicality of the digital comic, while the validators were responsible for assessing the validity of the content, media appearance, and language used in the comic.

The research procedure began with the definition stage, which aimed to identify the needs for media development. At this stage, analyses were conducted on the curriculum and fraction material, the characteristics of the students, learning tasks, and key concepts related to the material. The results of these analyses served as the basis for formulating the learning objectives to be achieved through the digital comic media. To support data collection in this stage, instruments such as initial observation sheets and interview guidelines with the mathematics teacher at SMP Negeri 9 Banda Aceh were used.

The next stage is the design phase, where the researcher begins to create the content of the digital comic media. The material is prepared based on the results of the previous analysis, then developed into an engaging narrative story with illustrations that align with the learning objectives. The design process involves creating everything from the cover to the closing section, which includes a summary of the material and practice questions. After the design stage is completed, the research proceeds to the development stage. In this stage, the prepared digital comic is first validated by experts using validation sheets as instruments. Feedback from the validators is used to improve and refine the developed product. Subsequently, the revised media is trialed with students and teachers to assess the practicality of its use.

The research instruments used include interview guidelines sheets, validation sheets, and practicality questionnaires. Data collection was carried out through three techniques: observation, interviews, and questionnaire distribution. Observation was used to monitor the

[13] Fayrus Abadi Slamet. Metode Penelitian Pengembangan. Malang: Institut Agama Islam Sunan Kalijogo Malang, 2022, p. 19

[14] Dian Kurniawan and Sinta Verawati Dewi, "Pengembangan Perangkat Pembelajaran dengan Media Screencast-O-Matic Mata Kuliah Kalkulus 2 Menggunakan Model 4D Thiagarajan," *Jurnal Siliwangi*, 3(1), 2017, p.216–217.

needs and characteristics of students during the learning process; interviews were conducted to obtain in-depth information from teachers regarding the use of learning media; and questionnaires were used to gather data on the responses of students and teachers toward the developed digital comic media.

Data analysis techniques were conducted to evaluate the quality of the product from the aspects of validity and practicality. Validation data analysis aimed to determine the level of media validity based on the validation scores given by the experts, while practicality analysis was conducted to measure the level of practicality of the media based on the responses from students and teachers. The interpretation of the analysis results referred to the percentage criteria outlined in the Validation Criteria Table and Practicality Criteria Table.

Table 1. Validation Criteria

Validity Score	Validity Level
80% < V ≤ 100%	Very valid, can be used without revision
60% < V ≤ 80%	Valid, can be used, but requires minor revisions
40% < V ≤ 60%	Quite valid, recommended not to be used because major revisions are needed
20% < V ≤ 40%	Less valid, should not be used
0% < V ≤ 20%	Not valid, should not be used

Source : Sa'dun Akbar, *Instrumen Perangkat Pembelajaran*[15]

Table 2. Kriteria Kepraktisan

Nilai Kepraktisan	Tingkat Kepraktisan
80% < V ≤ 100%	Very practical, can be used without revision
60% < V ≤ 80%	Practical, can be used, but requires minor revisions
40% < V ≤ 60%	Quite practical, recommended not to be used because major revisions are needed
20% < V ≤ 40%	Less practical, should not be used
0% < V ≤ 20%	Not practical, should not be used

Source: Sa'dun Akbar, *Instrumen Perangkat Pembelajaran* [16]

RESEARCH RESULTS AND DISCUSSION

The development used the 4D model consisting of four stages: define, design, develop, and disseminate. However, this study only reached the development stage due to time constraints and focus on product development.

At the define stage, the researcher gathered important information related to the product being developed. This information served as the basis for the design stage to create the digital

[15] Sa'dun Akbar**.** *Instrumen Perangkat Pembelajaran*. Bandung: PT Remaja Rosdakarya, 2013, p. 158.
[16] Sa'dun Akbar**,** *Instrumen Perangkat…*, p. 158.

comic as a learning media. Next, the media was developed in the develop stage through revisions based on expert feedback and field testing results. The following are the detailed outcomes of each research stage:

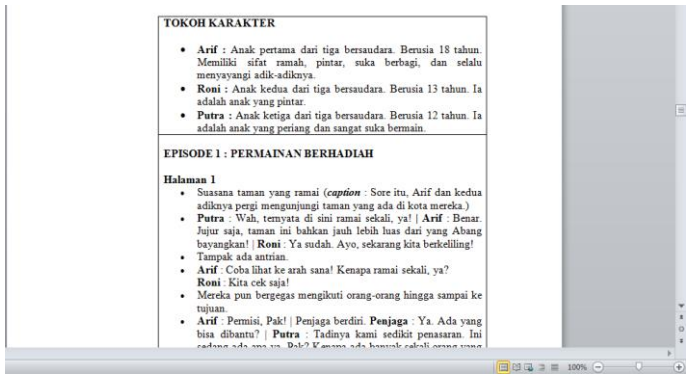
1. Define Stage

At this stage, several important analyses were conducted to develop a product suited to students' needs and characteristics. The initial analysis showed that students still faced difficulties in understanding the concept of fractions, such as distinguishing between the numerator and denominator and relating the material to real-life contexts. Based on observations and interviews at SMP Negeri 9 Banda Aceh, it was found that although digital learning media had been used, digital comics had not yet been utilized. However, since students were already familiar with comics through the School Literacy Movement (GLS), this medium was considered potentially effective in improving their understanding of fractions.

The student analysis also indicated that students' motivation to learn mathematics varied, suggesting that using interactive media could increase their interest and engagement. Furthermore, through task analysis and concept analysis, the researcher identified competencies based on the Merdeka Curriculum and organized the material systematically. The results of these analyses formed the foundation for formulating learning objectives and designing the content of the digital comic media to align with the contextual needs of fraction learning.

2. Design Stage

At the design stage, the researcher wrote the story script, designed characters and settings, and arranged the comic storyboard. The story was divided into several episodes. Each episode integrated mathematical concepts contextually and narratively, accompanied by a "Mathematics Plus" section to reinforce conceptual understanding. The story aimed to connect abstract material with the students' real-life experiences, enabling them to understand fraction concepts not only procedurally but also conceptually.


TOKOH KARAKTER

- **Arif** : Anak pertama dari tiga bersaudara. Berusia 18 tahun. Memiliki sifat ramah, pintar, suka berbagi, dan selalu menyayangi adik-adiknya.
- **Roni** : Anak kedua dari tiga bersaudara. Berusia 13 tahun. Ia adalah anak yang pintar.
- **Putra** : Anak ketiga dari tiga bersaudara. Berusia 12 tahun. Ia adalah anak yang periang dan sangat suka bermain.

EPISODE 1 : PERMAINAN BERHADIAH

Halaman 1

- Suasana taman yang ramai (***caption*** : Sore itu, Arif dan kedua adiknya pergi mengunjungi taman yang ada di kota mereka.)
- **Putra** : Wah, ternyata di sini ramai sekali, ya! | **Arif** : Benar. Jujur saja, taman ini bahkan jauh lebih luas dari yang Abang bayangkan! | **Roni** : Ya sudah. Ayo, sekarang kita berkeliling!
- Tampak ada antrian.
- **Arif** : Coba lihat ke arah sana! Kenapa ramai sekali, ya?
  Roni : Kita cek saja!
- Mereka pun bergegas mengikuti orang-orang hingga sampai ke tujuan.
- **Arif** : Permisi, Pak! | Penjaga berdiri. **Penjaga** : Ya. Ada yang bisa dibantu? | **Putra** : Tadinya kami sedikit penasaran. Ini

Figure 1. Script Writing

The design process was carried out using Canva and Microsoft Word applications. This stage included creating the cover, foreword, learning outcomes and objectives pages, character designs, and story panels and speech bubbles. In each episode, the fraction material was packaged in real-life situations. The selection of characters and stories was tailored to the seventh-grade students' world so they would feel involved and motivated.

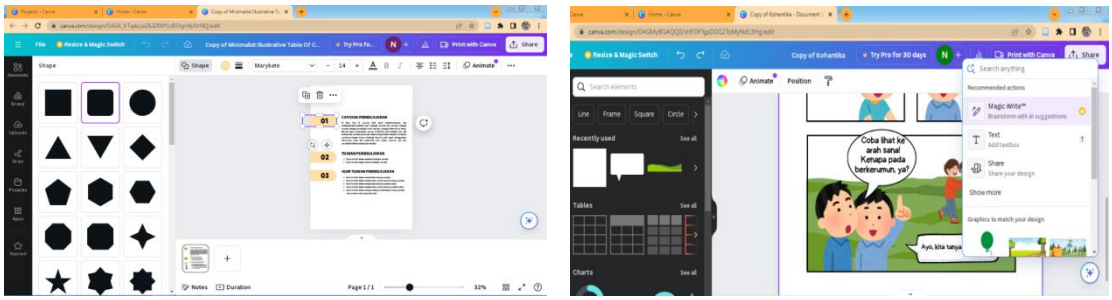


Figure 2. Comic Content Design

This media is also equipped with quizzes and interactive exercises created through the Wordwall platform, thereby strengthening understanding through repetition and direct application.

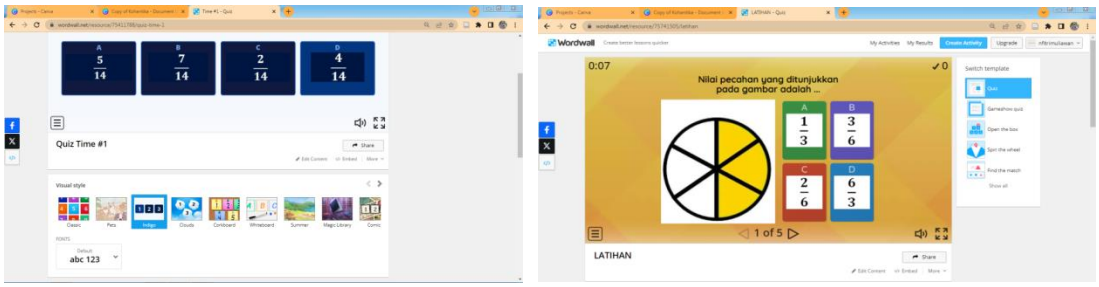
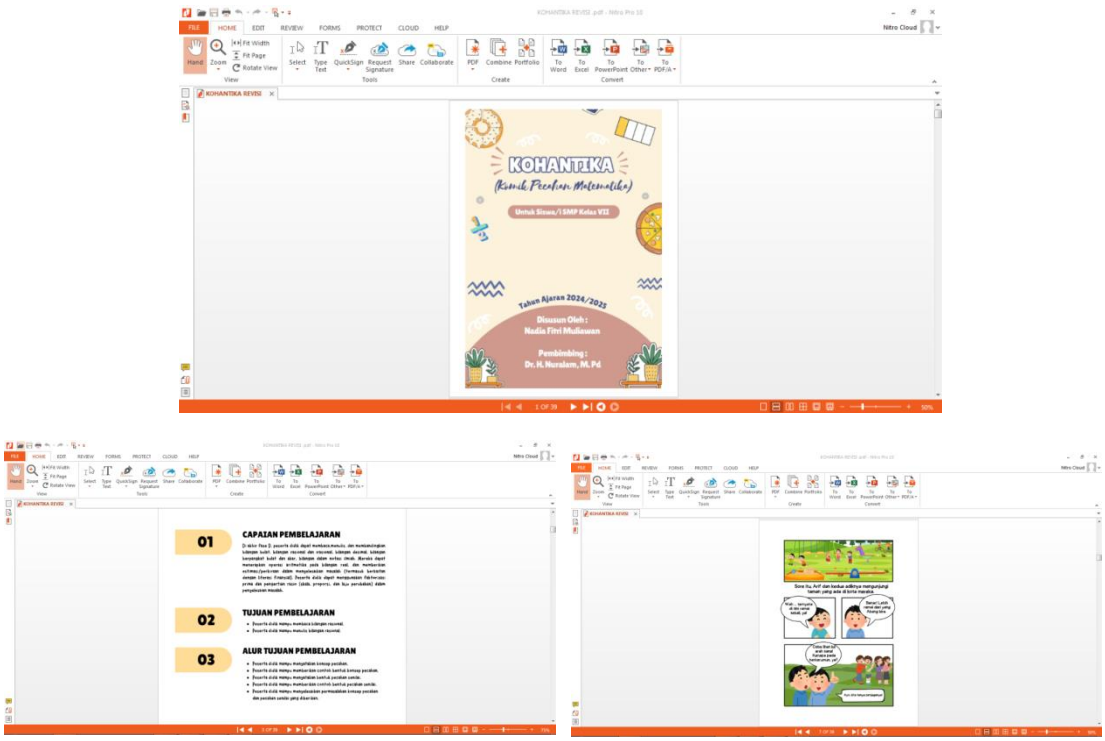


Figure 3. Design of Quizzes and Exercises

After that, the comic was prepared for publication by converting the file to PDF format and ensuring that the visual quality and content met the desired standards.



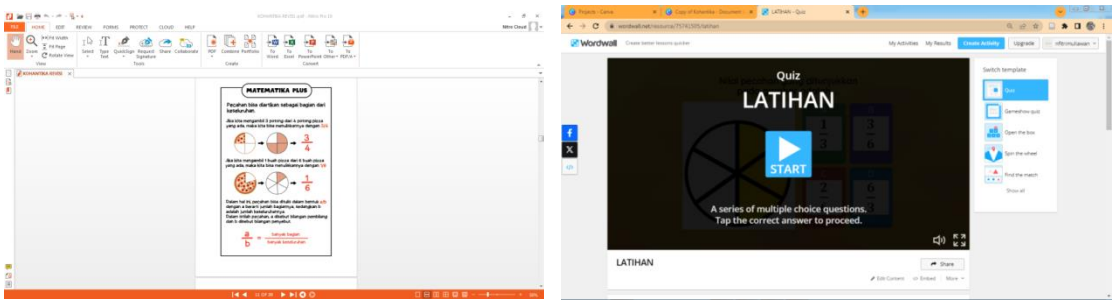


Figure 4. Digital Comic Appearance

3. Develop Stage

At this stage, the developed digital comic on fractions underwent expert validation and field testing to ensure its feasibility and practicality in learning. The validation process involved six experts: two media experts, two content experts, and two language experts. Each assessed the comic based on their area of expertise, covering aspects such as visual and technical quality, content accuracy, and language clarity.

The media validation obtained an average score of 85.90%, categorized as *very valid*. The content validation resulted in an average score of 84.97%, which is also *very valid*. Meanwhile, the language validation achieved a perfect score of 100%, indicating *very valid* and appropriate language use. These results confirm that the developed comic met the standards of quality and feasibility as a learning medium.

After expert validation and necessary revisions, field testing was conducted at SMP Negeri 9 Banda Aceh to assess the comic's practicality. One mathematics teacher and 31 eighth-grade students participated in the test. The teacher's assessment produced a practicality score of 93.75%, while the students' responses yielded 93.43%, both categorized as *very practical*.

Overall, both teachers and students responded positively, indicating that the digital comic was easy to use, visually engaging, and helpful in improving students' understanding and motivation in learning fractions. Therefore, the developed digital comic can be considered valid, practical, and feasible for use in mathematics learning.

DISCUSSION

Based on the results described earlier, it can be concluded that the developed product is a digital comic specifically designed to teach fractions to junior high school students. The product development follows the 4D model, which consists of four main stages: define, design, develop, and disseminate.[17]

The define stage aims to identify problems faced in mathematics learning[18], especially in the topic of fractions. From interviews with mathematics teachers at SMP Negeri 9 Banda Aceh, it was revealed that (1) there is no digital comic used as a learning media for teaching fractions to seventh-grade students. Students often use textbooks or PowerPoint presentations as learning media. (2) There is a lack of understanding of fraction concepts. These difficulties include the inability to distinguish between numerator and denominator, trouble understanding

[17] Fayrus Abadi Slamet. Metode Penelitian …, p. 19

[19] Puspita Ayu Damayanti dan Abd. Qohar, "Pengembangan Media Pembelajaran Matematika Interaktif Berbasis Powerpoint pada Materi Kerucut," *Kreano : Jurnal Matematika Kreati dan Inovatif*, 10(2), 2019, p.119-124.

how one object can be divided among several people, challenges in expressing daily situations in fractional form, and difficulties understanding equivalent fractions. The main reason behind these difficulties is the lack of contextual and engaging media to help students grasp abstract concepts such as fractions. (3) Students are already familiar with comics. The school has implemented a School Literacy Movement (GLS) requiring students to read any book before lessons begin. The school library is also equipped with various non-academic books, including comics, showing that students are accustomed to comics as reading material, and (4) students are also familiar with digital media. Based on these factors, the researcher is motivated to develop a digital comic as a learning media, hoping that this media can help students understand fraction concepts in a more engaging and easily understandable way.

Using digital comics as a learning media in mathematics has been proven effective in improving students' understanding of mathematical concepts.[19] Digital comics also enhance students' learning motivation because the material is presented as engaging and interactive illustrated stories.[20] In addition, digital comics provide flexibility in learning and align with students' current digital literacy habits.[21] The use of digital comics in mathematics learning can significantly improve the understanding of mathematical concepts among middle school students.[22] Therefore, the development of digital comics as a mathematics learning media is supported by various studies showing their effectiveness in increasing students' understanding and motivation. This study differs from previous research as it develops digital comic media focused on fractions for middle school students, while earlier studies were conducted at the elementary school level. Furthermore, this study not only presents the comic in digital form but also integrates it with the Wordwall platform to reinforce fraction concepts interactively. This makes the study a new contribution to developing digital-based mathematics learning media.

After the first stage was completed, the design stage was carried out to develop learning tools in accordance with the results of the analysis obtained.[23] The researcher prepared the learning outcomes, objectives, and learning objectives flow. The main characters and storyline were also determined to connect the fraction material with relevant real-life situations for the students. Character designs and storyboards were created to ensure the developed comic was engaging and easy to understand. Then, the researcher began working on various comic elements using the Canva application. Additionally, quiz and exercise sessions were designed and linked to the Wordwall application, where students can test their understanding of fractions through interactive quizzes and exercises. All completed pages were combined into a single file, making the digital comic ready. The digital comic was then converted into a PDF format to make it easily accessible for the students.

The development stage consists of two activities: expert validation and field testing. Expert validation is a technique used to assess the feasibility of the product design. In this activity, evaluations are conducted by experts in their respective fields. The suggestions

[19] Rida Fironika Kusumadewi, Amos Neolaka, dan Mahmuddin Yasin. "Improving the Ability of Understanding Mathematical Concepts through Digital-based Comics for Elementary School Students." *Al Ibtida: Jurnal Pendidikan Guru MI,* 10(1), 2023, p. 85–101.

[20] M. A. Subroto, A. Qohar, dan H. Dwiyana, Efektivitas Pemanfaatan Komik sebagai Media Pembelajaran Matematika, *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, 5(2), 2020, p.135–141

[21] Tri Wahyunisari, dkk. " Media Komik Berbasis Digital dalam Pembelajaran Matematika di Sekolah Dasar." *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, 6(10), 2023, p.8135–8140.

[22] Nita Andriani, "Penerapan Media Komik Digital terhadap Pemahaman Pembelajaran Matematis Siswa SMP," *Diskusi Panel Nasional Pendidikan Matematika (DPNPM) UNINDRA*, 2023. P.31-37

[23] Fayrus Abadi Slamet. Metode Penelitian …, p. 19

provided will be used to improve the material and the media design that has been prepared.[24] Validation was carried out by media, content, and language experts, each group consisting of two lecturers. After the validation, the researcher conducted a practicality test on the actual users, namely a mathematics teacher and a group of students.

The experts involved in the validation process will be given the developed digital comic along with a validation form. This form contains statements designed to assess various aspects of the comic as a learning media. The results from this validation will be used to improve and ensure that the digital comic meets the expected quality standards before being used in learning.

Based on the assessment by media experts, the digital comic obtained an average score of 85.90%, which falls into the very valid category.[25] This means the comic meets the required quality standards and can be used as a learning aid. Based on the content experts' assessment, an average score of 84.97% was obtained, also categorized as very valid. This indicates that the material presented in the comic is highly suitable for use as a learning medium and aligns correctly with the fraction concepts. Furthermore, based on the language validators' assessment, the comic received a perfect average score of 100.00%, placing it in the very valid category. This means the language used in the comic is very effective in conveying mathematical concepts clearly and understandably for middle school students.

After the digital comic on fractions was validated by experts, the next stage was to test the practicality of this media in the field. The practicality test aimed to determine how well the comic could be used in classroom learning. The test was conducted with two groups: a teacher and students at SMP Negeri 9 Banda Aceh. The first practicality test was conducted with a mathematics teacher who teaches grade VII at SMP Negeri 9 Banda Aceh. The teacher was given the developed digital comic and asked to assess the media's practicality in the context of classroom teaching. Afterward, the teacher completed a prepared questionnaire. Based on the teacher's responses, the digital comic on fractions obtained a practicality score of 93.75%. This score indicates that the comic falls into the very practical category.[26] It means that the comic is considered very easy for the teacher to use during instruction, presents the material clearly, has an attractive appearance, and is beneficial in helping students understand fraction concepts. With this high score, the digital comic is deemed highly suitable for use in the classroom learning process.

The second practicality test was conducted with 31 seventh-grade students at SMP Negeri 9 Banda Aceh. Similar to the teacher's practicality test, the students were given the digital comic in PDF format and asked to study the material inside. They were also directed to try the quizzes and exercises available in the comic through links to the Wordwall application. After using the comic and completing the quizzes and exercises, the students were asked to fill out a practicality questionnaire. The results from the 31 students showed that the digital comic achieved an average practicality score of 93.43%. This score also falls into the very practical category, meaning the comic was highly accepted by the students as a learning media.

This study also shows results consistent with previous research. The findings align with the study by Rahmata et al., which stated that problem-solving-based math e-comics were deemed very valid. The validation results in this study also fall into the very valid category.[27] The

[24] Fayrus Abadi Slamet. Metode Penelitian …, p. 19
[25] Sa'dun Akbar**,** *Instrumen Perangkat…*, p. 158
[26] Sa'dun Akbar**,** *Instrumen Perangkat…*, p. 158
[27] Aldio Rahmata et all., "Validitas E-Comic Matematika…", p.53–65.

research by Witanta et al. further supports that digital comics are practical and effective as learning media, as confirmed by the practicality results in this study.[28] Meanwhile, Kusumadewi et al.'s research also demonstrated that digital math comics are feasible and practical for teaching fraction material to fifth-grade elementary students.[29] Previous studies have also shown that using e-comics can enhance students' critical thinking skills and conceptual understanding of mathematics. Rahmasantika and Prahmana developed a Math e-comic with an ethnomathematics context entitled "Joko Kendil and Si Gundul" for deaf students, and the results showed a significant improvement in their critical thinking skills. Similarly, Hartati et al. found that e-comic media effectively improved reading and comprehension skills in mathematics among students with special needs. These findings reinforce the results of the present study, highlighting that digital comics have great potential to help students understand abstract concepts such as fractions in a contextual and engaging way.[30]

However, the novelty of this study lies in its integration of digital comics with the Wordwall platform. Unlike earlier research focusing solely on visual storytelling, this study introduces an interactive element through digital quizzes and exercises embedded within the comic. This integration not only enhances students' conceptual understanding but also provides immediate feedback, supporting independent learning and self-assessment, an aspect that aligns with the principles of formative assessment emphasized in current mathematics education frameworks (NCTM, 2020)[31]

Additionally, this research contributes to the growing emphasis on contextual and digital-based learning within the Merdeka Curriculum implemented in Indonesia. The use of real-life scenarios within the storyline helps bridge the gap between abstract fraction concepts and students' everyday experiences, consistent with constructivist learning theories that advocate for contextualized instruction.[32] The positive responses from both teachers and students indicate that digital comics can foster engagement and motivation, supporting mathematics learning in a more enjoyable and accessible way.

Despite these promising results, several challenges remain. The practicality test was conducted in only one school, with one teacher and a limited number of students. Therefore, broader testing in schools with varying characteristics is needed to generalize the findings. Moreover, integrating Wordwall requires technological facilities such as smartphones or computers and stable internet connectivity, which may pose limitations in schools with inadequate infrastructure. Future studies should consider offline accessibility and wider implementation to maximize the potential of digital comic media across diverse learning environments.

[28] Vivian Alfinia Witanta, Baiduri, and Siti Inganah, "Pengembangan Komik Sebagai ….", p.1–12

[29] Ni Luh Wahyu Kusumadewi, I Wayan Gunartha, and I Putu Wisna Ariawan Ariawan, "Pengembangan Media Komik …", p. 103–116.

[30] Hartati, A. D., Maryanti, R., Azizah, N. N., Al Husaeni, D. F., Wulandary, V., dan Irawan, A. R. "Webtoon Comic Media to Improve Reading Comprehension for Students with Hearing Impairment in Special Primary Schools." *ASEAN Journal of Community and Special Needs Education*, 2(1), 2023, p. 9–16.

[31] National Council of Teachers of Mathematics (NCTM), *Catalyzing change in high school mathematics: Initiating critical conversations*, 2020, Reston, VA: NCTM

32 Bruner, J. (1996). *The culture of education*. Cambridge, MA: Harvard University Press; Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

CONCLUSION

This study developed a digital comic on fraction material for junior high school students using the 4D model (Define, Design, Develop, and Disseminate). The product was validated by media, content, and language experts, and tested for practicality by teachers and students. The validation and practicality results indicated that the digital comic met the very valid and practical criteria, showing that it is feasible for classroom implementation.

Beyond these results, the study contributes to the field of mathematics education by introducing a novel integration of interactive Wordwall activities within a digital comic format, providing an engaging and contextual way for students to understand abstract mathematical concepts. This innovation bridges the gap between visual storytelling and digital interactivity, making mathematics learning more dynamic and aligned with students' digital habits.

From a practical perspective, this digital comic offers teachers an alternative instructional medium that simplifies the delivery of fraction concepts, promotes student engagement, and encourages self-directed learning. Its integration with Wordwall also allows teachers to assess student understanding easily through interactive exercises. Therefore, this study supports the adoption of digital comics as an effective supplementary tool in mathematics learning, particularly in topics requiring conceptual visualization.

For future development, it is recommended that the digital comic be tested on a broader scale across schools with varying characteristics to evaluate its effectiveness in different learning contexts. Additionally, future researchers could expand the content to other mathematical topics or develop an offline or mobile application version to increase accessibility in schools with limited internet access.

In conclusion, this study not only provides evidence of the validity and practicality of the developed digital comic but also highlights its potential as an innovative and interactive medium that supports contextual, engaging, and technology-based mathematics learning.

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