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The Influence of Flipbook-Based Comics on Conceptual Understanding and Critical Thinking in Physics Education

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Abstract

Background/purpose. The urgency of this research stems from students' limited conceptual understanding of momentum material following low reading interest. In this context, students have difficulty solving problems that arise during learning activities. Therefore, this research aimed to develop a flipbook-based physics learning comic using the Pixton application as a learning medium to improve conceptual understanding and Critical Thinking Skills (CTS).

Materials/methods. The development method was adopted using the ADDIE model at four schools: SMAN 2 Peusangan as a small-scale test location and SMAN 1, 2, and 3 Bireuen as large-scale test locations. The population consisted of students in class XI at SMAN 3 Bireuen, totaling five classes. The sample consisted of 30 students from classes XI A and XI B, selected using a cluster random samplingmethod. The instruments used were a feasibility validation questionnaire given to 3 validators, tests, and response questionnaires.

Results. The results showed that the development of a flipbook-based learning comic on momentum material using the Pixton application improved students' conceptual understanding and CTS. Furthermore, CTS was influenced by conceptual understanding.

Conclusion. In conclusion, the development of comic media using momentum materials with the Pixton application and flipbooks can improve conceptual understanding and CTS. This is because approximately 50% of students' CTS are influenced by conceptual understanding. There was an increase in the N-Gain CTS value in the experimental and control classes of 0.50 and 0.25, respectively, at medium and low criteria. The increase in conceptual understanding occurred after the application of flipbook-based physics comic media for momentum materials. This can be seen from the high average final exam scores in the experimental and control classes with N-gains of 0.55 and 0.34, respectively, in the control and experimental classes, which are at medium criteria. Thus, it can be ascertained that students are at a critical point of good conceptual understanding.

1. Introduction

The field of education is entering the era of Society 5.0, which is a strategic response to the challenges posed by Industrial Revolution 4.0. In the era of Society 5.0, the demand for collaboration with technology is increasing. However, the presence of this new technology influences and changes human mindsets and behavior. In this context, students' reading activities are lower when using the Internet (Handayani et al., 2023), and educational materials used in schools include textbooks. Wahyuningsih (Agustin et al., 2018) stated that most textbooks are primarily instructional books. Illustrations are included to varying degrees, but are still insufficient to increase students' interest in reading. According to Chodijah et al. (Safarati & Zuhra, 2023b), physics is a discipline related to national intelligence and plays a major role in advancing science and technology. Therefore, teachers mustplan and implement training focused on mastering physics concepts. Conceptual understanding can vary even when the same material is studied. Students who incorrectly apply concepts are often considered to have poor cognitive skills (Analita et al., 2023). Physics learning requires students to master not only the basic concepts of physics but also the integrated mathematical concepts applied to these physical concepts (Astuti et al., 2025).

Based on the description above, physics has concepts that are widely used in life. Therefore, learning materials are needed that allow students to analyze the concept as a whole rather than focusing on deriving the formulas. Momentum is a physics subject whose applications are closely related to students' daily lives (Febrianti et al., 2022). Students struggle to understand the lesson when the focus of learning is on the teacher, the blackboard, and the textbook. The support of learning media allows teachers to convey messages more easily (Jhoni et al., 2023). Media have been instructional books, which are less interesting for students. In physics, a material cannot be easily understood when it is unreadable. An important obstacle to increasing reading interest is understanding students' interests (Safarati & Marlina, 2023). Understanding of physics concepts is better when students read and understand the material properly. In addition, the ability to understand physics concepts correctly can help develop critical thinking skills (CTS) (Mirnawati et al., 2021). According to Doughty (Akihary et al., 2024), critical thinking is an open-minded method of thinking that considers various alternatives and leads to problem-solving. An individual can use reasonable and reflective thinking to decide the steps required to investigate a problem with CTS (Kawuryan et al., 2022).

Based on observations, students consider physics to be a lesson full of formulas and abstract concepts. Therefore, interest in reading physics books is relatively low, and students do not understand the concept of momentum in their daily practice. There is also difficulty in correctly understanding the concept because textbooks are only read during class hours. Dominant learning is centered only on materials, such as instructional books and student worksheets, and focuses on explaining mathematical formulas and practicing problems. The concept of materials has not been connected to students' daily lives. In this context, the concept of momentum becomes increasingly more abstract. The textbooks used are also limited, and students are more interested in reading books with pictures or characters than texts and formulas.

Some of the problems were also conveyed by Amiruddin et al. (2025) based on several opinions of the respondents. Physics is often a frightening subject because of the complexity of the concepts, which can be difficult to understand. Based on the existing problems, an appropriate problem-solving method is needed to create engaging learning media and help students develop an interest in studying and reading the textbooks. Students can understand the concept of the material and also generate CTS to solve problems encountered in learning. Computer-based interactive media have more value than ordinary printed material. Interactive media increases interest in multimedia systems and motivates students to learn (Amanullah, 2019). The innovation of this study is the development of flipbook-based learning comic media designed using the Pixton application to create

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digital learning books in the form of a comic. Angresia et al. (2022) reported that comics are widely loved and can solve the problem of reading interest. This is because comics can vary with different written texts, presenting attractive, colored images to trigger interest in learning and understanding the material. Additionally, Firlan and Utami (2023) stated that media in the form of comics conveyed content briefly, clearly, and interestingly, and were flexible in nature. Digital comic media allows readers to access the concepts flexibly through smartphones without being tied to time and place (Santoso & Syafrida, 2023; Ghofur, 2022; Fitri et al., 2022).

Flipbooks are an electronic medium in the form of a digital book used to present images, videos, audio, quizzes, and texts (Prasasti & Anas, 2023). According to Fatmawati et al. (Putri et al., 2022), flipbooks are digital books that can be turned from page to page. The interactive characteristics and the skills to integrate various forms of content can be developed into learning media to create effective learning (Nurdin et al., 2023). Flipbook-based learning comics media can be produced using the Pixton application. Pixton is an online comic creation platform used directly on the web without downloading applications (Firliani & Utami, 2023). The platform can be accessed and used directly from the official website (www.pixton.com). There are many platforms for creating comics, but the use of Pixton is very rare (Putri & Ahmad, 2023). Through the Pixton application, we can create learning media in the form of comics combined with flipbooks as a container so that they can be used as digital books. Thus, the state of the art was based on previous research by Amanullah (2019), which presented new situations and atmospheres in learning activities for students. The results showed that flipbook-based media was the right solution for creating a more enjoyable learning atmosphere. This research only reviews literature using library data collection methods, reading, recording, and processing research materials, so it has not yet developed media. Furthermore, research conducted by Tsuroyya et al. (2022) developed cartoon-based digital media accessed online through flipbooks on chemical bonding materials. The purpose of this study was to develop digital comic-based learning media that are accessed online through flipbooks on chemical bonding materials and to determine students' responses regarding the digital comic-based learning media that were developed. In this study, comics were created using the Ibis Paint application with a pen tablet and required drawing skills because they were created manually. The results of the study in the form of student responses were obtained 85% for content suitability with very good criteria, 86% for presentation with very good criteria, 85% for language with very good criteria, and 84% for graphics with very good criteria. (2023) developed Pythagorean theorem learning media that support the learning process realistically and effectively by using e-comics. This study used the ADDIE development method; however, during the implementation phase, only media feasibility was assessed based on student responses through small-group trials. The results of this study indicate that the feasibility of media experts, the feasibility of material experts, and student responses to the learning process are categorized as very feasible. Based on these three measures, it is concluded that this learning medium is very feasible for use in learning.

Based on this description, this study was innovative by developing flipbook-based physics learning comic media using the Pixton application. Regarding the novelty, a flipbook-based physics learning comic using the Pixton application has never been developed. Therefore, flipbook-based physics learning comics were designed to be accessed digitally through the Pixton application. These comics focus on the momentum materials. Flipbook-based physics learning comic media on momentum materials improve conceptual understanding and CTS. In addition, this study aimed to develop a flipbook-based physics learning comic using the Pixton application to improve conceptual understanding and CTS.

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2. Literature Review

2.1. Comic as a Learning Medium

Comics combine comic strip elements (e.g., sequence of panels) with data visualization techniques to tell a story and convey information in data (Fogwill & Manataki, 2024). According to (2022), comics are still popular with students and can solve the problem of reading interest. This is because comics can be varied in various written text formats, present interesting images, and have various colors, so that they can trigger students' interest in learning and understanding the material. Comic is perceived to be more engaging, and participants have greater recall and understanding of the data within the story, compared with the text medium (Fogwill & Manataki, 2024). Furthermore, according to Firlan and Utami (2023), comics can convey material concisely, clearly, and engagingly, making them easy to remember and understand. Digital comics allow readers to access them from anywhere and at any time via smartphones (Santoso & Syafrida, 2023).

A flipbook is an electronic medium in the form of a digital book that can present images, videos, audio, quizzes, and text (Prasasti & Anas, 2023). A flipbook is a digital book that can be moved to the next page by turning the pages (Putri et al., 2022). The interactive characteristics of flipbooks and the ability to integrate various forms of content can be developed into learning media to create effective learning experiences (Nurdin et al., 2023). Flipbook-based comic media can be developed using the Pixton app. Pixton is an online comic creation platform that can be used without downloading the application on a computer or Android (Firliani & Utami, 2023). Pixton can be accessed and applied directly through its official website (www.pixton.com). Platforms for creating comics are actually very numerous; however, creating comics using the Pixton platform is still very rarely used (Putri & Ahmad, 2023).

The Pixton application is the first container for creating comics. After the creation process is complete, the comic enters the second container in the form of a flipbook, which is a digital book that can be accessed as a learning medium that can be used by students. Through digital comics as a physics learning medium, it is hoped that it can motivate students to learn physics, which was previously unpleasant to become liked and enjoyable, so that the concept of the material is easier to understand, and will also stimulate students' critical thinking skills towards the material. The impact of comics can strengthen conceptual understanding because step-by-step visualizations and representations of real situations help students build clearer knowledge structures, connect concepts with contexts, and reduce misconceptions.

2.2. Conceptual Understanding

Conceptual understanding is not just knowing information, but more than that, students can interpret the information into other forms that are more meaningful (Nahdi & Jatisunda, 2019). Understanding of concepts is the way students understand material or physics concepts, so as to enable them to explain again, group objects based on certain characteristics, convey physics concepts in various forms, provide different examples of concepts that have been learned, and solve daily problems in physics learning (Bahrudin & Yogihati, 2022). Understanding is the second level of the cognitive domain (Anderson et al., 2001). Students understand when they can build the meaning of learning that has been learned, both verbally and in writing (Manurung & Mihardi, 2016). Students' conceptual understanding is a determinant of the success of physics learning (Pamangin, 2025). Conceptual understanding is students' effort to become proficient and skilled in solving problems, both in academic and non-academic fields (Ningrum et al., 2022).

Conceptual understanding in physics learning is a student's ability to correctly interpret, explain, and apply physics principles to various situations, whether symbolic, mathematical, or real-world. This allows students to build a coherent knowledge structure, rather than simply memorizing

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formulas. In this context, conceptual understanding is crucial because physics contains many abstract concepts. The integration of digital media, such as comics, into physics learning can strengthen conceptual understanding by providing visual and narrative representations that make it easier for students to construct meanings from abstract concepts.

2.3. Critical Thinking Skills

Critical thinking involves several abilities, including the ability to analyze, evaluate, and interpret information obtained logically (Atmojo et al., 2025; Ennis, 1987; Savchuk & Yehorova, 2024). Critical thinking skills are important to teach to all students, starting from elementary school students, as part of the educational reform efforts (Kettler, 2014) because people of all ages can engage in critical thinking (Abrami et al., 2015; Kawuryan et al., 2022). Critical thinking has been widely recognized as a core competency in 21st-century education, particularly in the context of science learning. It enables students to interpret information, evaluate evidence, and construct logical arguments, all of which are crucial for developing scientific literacy (Makhrus et al., 2025). Critical thinking skills are important for individuals as a fundamental tool for personal development, affording individuals the ability to understand and analyze events and situations more deeply (Facione, 2011; Aslan & Aybek, 2024). All aspects of CT are skills needed in life because CT is a logical and reflective way of thinking that focuses on student decision-making. It deepens students' thinking skills when interpreting information, making the information they receive more meaningful (Safarati & Zuhra, 2023a).

Critical thinking skills in physics learning are students' abilities to analyze an event, evaluate information, and draw correct conclusions based on physics concepts. These skills are crucial because they help students understand concepts more deeply, rather than simply memorizing formulas. When students are able to think critically, they can more easily discover relationships between concepts, avoid misconceptions, and understand the reasons behind the phenomena.

3. Methodology

This research used a research and development methodology through the ADDIE model. Media design and development are more efficient, as well as effective and systematic. The ADDIE model uses a scheme designed by Branch (Hidayat & Nizar, 2021) consisting of the following stages: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation.

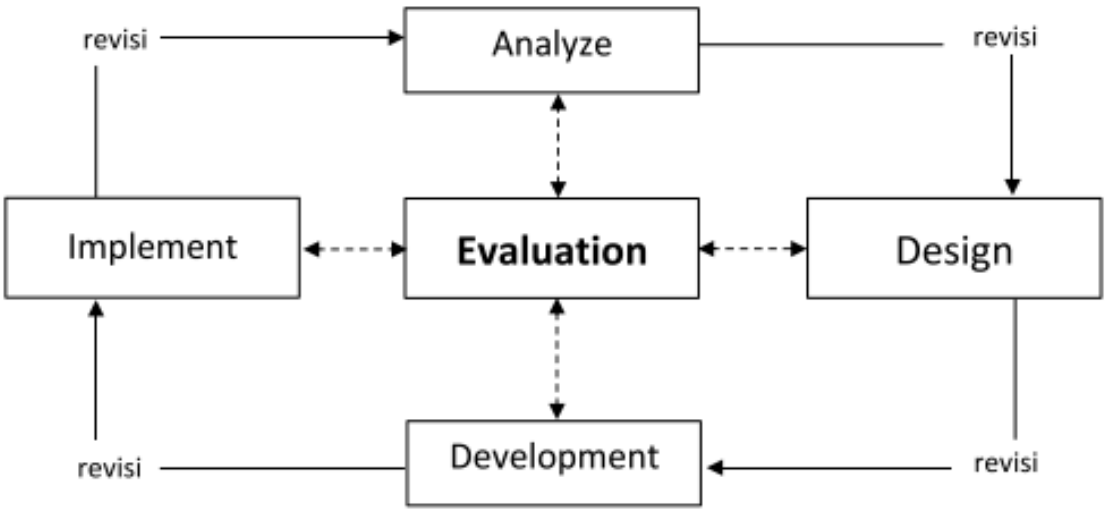

Figure 1. ADDIE Model Stages

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3.1. Location, Population, and Sample

This research comprised four schools, namely SMAN 2 Peusangan, the location of the small-scale trial, and SMAN 1, 2, and 3 Bireuen, the locations of the large-scale trial. The product of the development in the form of flipbook-based physics learning comic media was implemented at SMAN 3 Bireuen, Aceh, Indonesia. Furthermore, the location selection was based on observations and interviews, where students at SMAN 3 Bireuen faced obstacles in learning the physics material on momentum. The students of class XI at SMAN 3 Bireuen, with a total of five classes, formed the population. The sample comprised 30 students from classes XI A and XI B selected using the cluster random sampling method. The study was approved by the Human Research Ethics Committee of the Local University (approval number 230/LPPM-Umuslim/IX/2024). Ethical approval ensured that all research procedures complied with established ethical standards for studies involving human participants.

3.2. Research Instruments

The instrument used was the media suitability validation questionnaire given to three expert verifiers, namely media, material, and language. The validation results from several validators were averaged and analyzed using percentages to determine the feasibility of flipbook-based physics learning comic media. At the development stage for small- and large-group trials, the media feasibility trial questionnaire instrument was used. Based on the effectiveness and feasibility tests of the flipbook, a feasible product was implemented in physics learning to improve conceptual understanding and CTS.

3.3. Data Collection and Analysis Method

3.3.1. Conceptual Understanding and CTS Test

Data collection on conceptual understanding and CTS used a test instrument to obtain pretest, posttest, and N-Gain (g) scores. The pretest was administered before the learning process to assess initial conceptual understanding and CTS before receiving treatment. The posttest was provided after the learning process to evaluate conceptual understanding and CTS following treatment. The NGain Score was used to determine the increased scores using the following formula.

$$\text{N-gain} = \frac{\text{Posttest score} - \text{Pretest score}}{\text{Ideal Maximum Score} - \text{Pretest Scoret}}$$

The criteria are as follows:

Table 1. Criteria for the Eligibility of Learning Media

No	N-Gain Score	Classification
1	$0{,}70 < g \leq 1{,}00$	High
2	$0{,}30 < g \leq 0{,}70$	Medium
3	$g \leq 0{,}30$	Low

The hypothesis test was analyzed using the t-test at a significance level of 5% ($\alpha = 0.05$). The data to be tested were on conceptual understanding and CTS using the SPSS 23 application.

3.3.2. Student Response Questionnaire

To determine the responses to flipbook-based physics learning comic media, data were collected using a non-test instrument, a response questionnaire. The questionnaire was administered after

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students were given a flipbook-based physics comic as a learning medium. The student response questionnaire data is in the form of a checklist with a Likert scale, and the scoring system is as follows.

Table 2. Questionnaire Data Score

Types of Questions	Difficulty Level			
	Very Agree	Agree	Less Agree	Disagree
Negative Questions	1	2	3	4
Positive Questions	4	3	2	1

3.3.3. Research Procedure

1. Analysis: At this stage, an analysis of the learning materials and media was conducted. The availability of momentum material media was very low and did not changed. Various educational media provide opportunities for students to understand the concrete explanations of abstract content.

2. Design: At this stage, the following were carried out: a) designing flipbook-based physics comic learning media using the Pixton application, and b) designing expert validation sheets for media, materials, and language. A questionnaire was used as the validation instrument. Figure 2 shows the cover design of flipbook-based physics learning comic media.

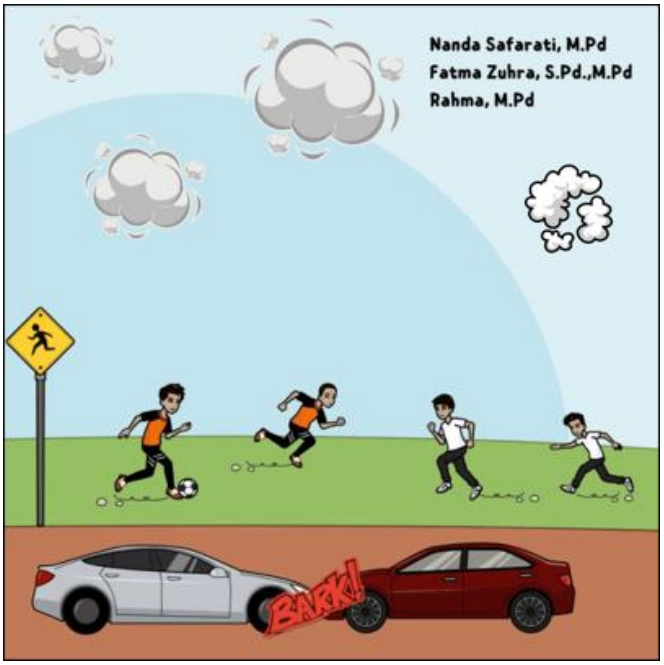

Figure 2. Draft Design of Comic Media Cover

3. Development: The results of this stage were a) a flipbook-based physics learning comic, b) validation scores of materials, media, and language, and c) small group tests and field tests.

4. Implementation: This stage was implemented at SMAN 3 Bireuen to determine its significant influence on conceptual understanding and CTS.

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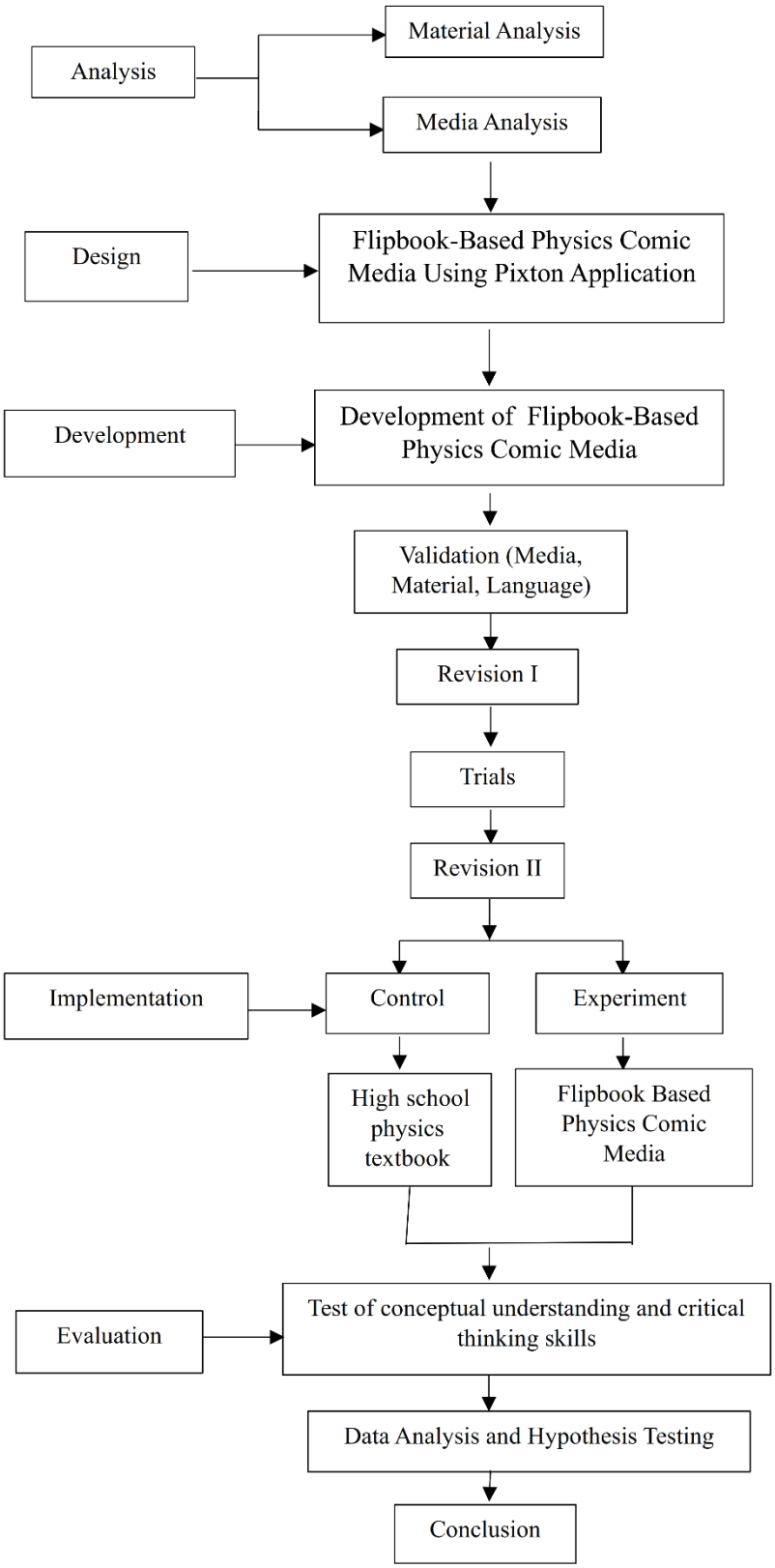

Figure 3. Research Flow Design

4. Results

The research activity was conducted at SMAN 3 Bireuen on momentum material using physics learning comics and textbooks for the experimental and control classes, respectively. The stages of comic development were carried out based on the ADDIE method, namely (1) Analysis, (2) Design,

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(3) Development, (4) Implementation, and (5) Evaluation. At the analysis stage, the process of analyzing learning activities is carried out as described in the instructional design. During the learning process, needs were analyzed, including the determination of problems and solutions to achieve student competencies. Media and learning materials should also be examined in future studies. Based on the analysis, the existence of media for momentum materials was limited and did not vary. Therefore, teachers and students need varied media to understand and read textbooks with complete explanations of abstract material.

In the design stage, comic media were created using the Pixton application based on a flipbook, and an expert validation questionnaire was in the form of a survey to be given to the validator. Additionally, learning devices and materials were also designed, and the subsequent stage was to develop comic media. At the development stage, media or learning materials were used for the research. This stage should contain the analysis and design previously prepared to produce effective learning and achieve objectives. The creation of comic media was conducted using the Pixton application, starting with creating characters and entering materials according to the flow designed in the design stage. The trial was validated by media, material, and language experts. Table 3 shows some input from the validator on the flipbook-based physics learning comic.

Table 3. Validator's Suggestions/Input on Flipbook-Based Physics Learning Comic

No.	Validator	Suggestions/Input
1.	Media Expert	- The media color should not be extremely contrasting but varied to become more interesting, and use bright colors to increase enthusiasm. - The cover is not attractive enough and must be given a physical nuance. - A picture of the character should be provided before starting the comic.
2.	Language Expert	- Use standard words in line with the Grammar. - A glossary should be created for language rarely heard by students. - Correct typing errors.
3.	Materials Expert	- Evaluation and practice questions should be added. - Undelivered materials should be completed. - A simulation of the momentum used in everyday life must be provided. - An explanation should be provided when using a formula to be understood by students.

The flipbook-based physics learning comic was revised based on input from the three validators. Improvements to the flipbook-based physics learning comic were made comprehensively in terms of the background and color on each page. Revisions were made based on suggestions and input provided by the validator until the media was suitable for use without revision.

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The expert's validation showed that media was valid to proceed to the small group test stage conducted at SMAN 2 Peusangan. Furthermore, a large group test was conducted at three schools in Bireuen Regency, namely SMAN 1, 2, and 3 Bireuen. A second revision was made based on the two trials conducted. Subsequently, the stage was implemented at SMAN 3 Bireuen to have a significant influence on conceptual understanding and the CTS.

4.1. Conceptual Understanding of Students

Conceptual understanding was assessed using eight test questions arranged based on conceptual understanding indicators, totaling 8 questions. The validation level was 0.667, which fell the very valid category, with a reliability of 0.648. The questions given to the control and experimental classes were similar in nature. Table 4 shows the details of the questions for conceptual understanding indicators.

Table 4. Details of Questions Based on Conceptual Understanding Indicators

No	Conceptual Understanding Indicators	No. Question Item	
		Pretest	Posttest
1	Exampling	1,2	3,5
2	Interpreting	3,4	7,8
3	Explaining	5,6	4,6
4	Predicting	7,8	1,2

An increase in conceptual understanding was observed in the pretest and posttest. Figure 4 shows a recap of the conceptual understanding of the results.

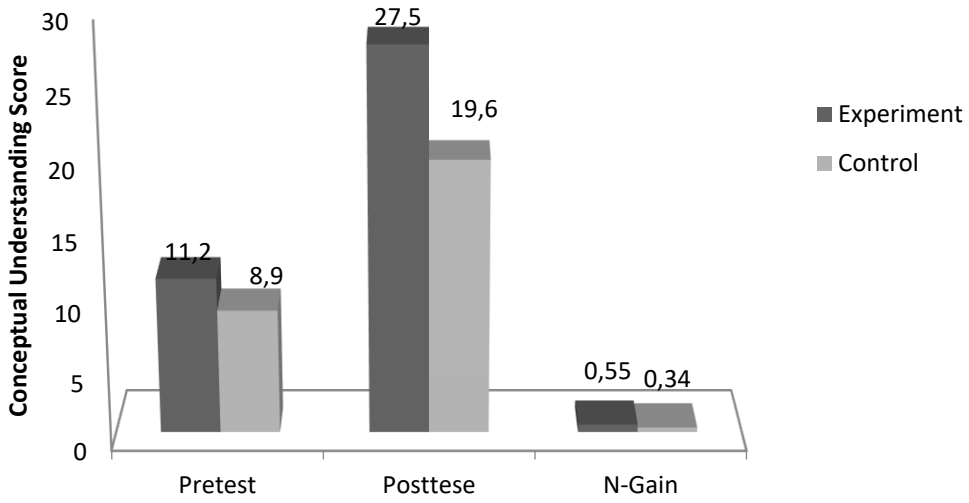

Figure 4. Improvement in Students' Conceptual Understanding of Score

Conceptual understanding has increased with the appliaction of flipbook-based physics learning comic media to momentum materials. This can be seen from the high average scores on the final test in the experimental and control classes. The N-gain was 0.55 and 0.34 in the control and experimental classes,respectively, within the moderate criteria. Table 5 shows the increase in conceptual understanding through the application of flipbook-based physicslearning comics.

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Table 5. Improvement in Students' Conceptual Understanding of Each Indicator

No	Conceptual Understanding Indicators	Experiment Class		Control Class	
		N-Gain	Criteria	N-Gain	Criteria
1	Exampling	0,36	Medium	0,42	Medium
2	Interpreting	0,51	Medium	0,16	Low
3	Explaining	0,62	Low	0,35	Medium
4	Predicting	0,58	Medium	0,17	Low
	Average	0,52	Medium	0,28	Low

Students in the experimental class understood the concept better than those in the control, specifically with the regard to explanation. Based on N-gain, the increase in conceptual understanding in the experimental and control classes was categorized as moderate and low, respectively. Flipbook-based physics learning comics can improve conceptual understanding using SPSS 23 at a significance level of 5%. Before the hypothesis test, a prerequisite test was performed with the following results.

Table 6. Normality Test Result

	Class	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
N_Gain_Conceptual	1.00	.107	28	.200*	.964	28	.439
	2.00	.242	29	.000	.806	29	.000

Based on the normality test, the data obtained were normally distributed with a Sig. Value of 0.44> 0.05. Table 7 presents the results of the data homogeneity test.

Table 7. Homogeneity Test Result

Levene Statistic	df1	df2	Sig.
.741	1	55	.393

The homogeneity test results showed Sig. The value of 0.39 > 0.05 because the datasets were homogeneous. T-test is used after ensuring that the data distribution was normal and homogeneous.

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Table 8. Hypothesis Test Results Using the Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
									Lower	Upper
N_ Gain_ Conceptual	Equal variances assumed	.741	.393	-3.929	55	.000	-.20897	.05318	-.31554	-.10239
	Equal variances are not assumed.			-3.948	52.101	.000	-.20897	.05292	-.31516	-.10277

Table 8 shows that α = 0.00 < Sig = 0.05 due to significant differences in conceptual understanding between the control and experimental classes. The use of flipbook-based physics learning comic media on momentum material improves conceptual understanding.

4.2. Students' Critical Thinking Skills

The assessment of CTS was conducted using six test questions arranged based on indicators, totaling 6 questions. The validation level was 0.688, falling in the very valid category, and the reliability was 0.662. The questions given to the control and experimental classes were identical.

Table 9. Question Details Based on CTS Indicators

No.	Critical Thinking Skills Indicators	No. Question Item	
		Pretest	Posttest
1	Interpretation	1, 2	3, 5
2	Analysis	3, 4	1, 2
3	Inference	5	6
4	Evaluation	6	4

The increase in CTS was observed from the pretest and posttest scores. The results of the CTS of tests recap are shown in Figure 5.

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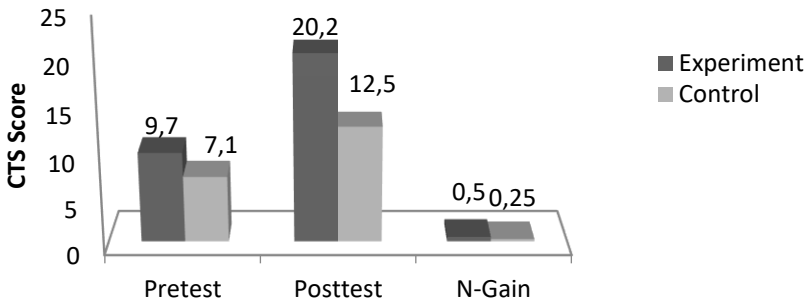

Figure 5. Increase in Students' CTS Scores

There is an increase in CTS, as reported from the high average value of the final test score in the experimental and control classes of 20.2 and 9.7 with an N-Gain of 0.50 and 0.25 in the medium and low criteria, respectively. Table 10 shows the increase in CTS through the application of the flipbook-based physics learning comic.

Table 10. Improvement of Student CTS for Each Indicator

No	CTS Indicator	Experiment Class		Control Class	
		N-Gain	Criteria	N-Gain	Criteria
1	Interpretation	0,53	Medium	0,33	Medium
2	Analysis	0,50	Medium	0,00	Low
3	Inference	0,28	Low	0,45	Medium
4	Evaluation	0,26	Medium	0,00	Low
Average		0,39	Medium	0,19	Low

On the interpretation indicator, students in the experimental class performed better than those in the control class. Students in the experimental and control classes had moderate and low CTS, respectively. A test was conducted using SPSS 23 to test the hypothesis that using flipbook-based physics learning comic media can improves CTS.

Table 11. Normality Test Results

	Group	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Ngain_CTS	Control	.117	28	.200*	.963	28	.405
	Experiment	.145	29	.123	.934	29	.070

Based on the normality test, a value of 0.41 was obtained greater than the Sig. value. The data distribution was normal and a homogeneity test was carried out, as reported in Table 12.

Table 12. Homogeneity Test

Levene Statistic	df1	df2	Sig.
.180	1	55	.673

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Based on the homogeneity test, the value obtained is 0.67 > Sig. (0.05) since datasets are considered homogeneous. Furthermore, the hypothesis test is continued since the data is normal and homogeneous, as shown in Table 13.

Table 13. Results of Hypothesis Test Using the Independent Samples Test

Independent Samples Test									
		Levene's Test for Equality of Variances		t-test for Equality of Means					
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference
									Lower / Upper
N-gain _ CTS	Equal variances assumed	.180	.673	-5.749	55	.000	-.25873	.04500	-.34892 / -.16854
	Equal variances not assumed.			-5.751	54.992	.000	-.25873	.04499	-.34888 / -.16858

The value of 0.00 < Sig. (0.05), Ha is accepted, and Ho is rejected. Therefore, there was a significant difference in the CTS scores between the control and experimental classes. The use of flipbook-based learning comic media on momentum material can improve CTS.

4.3. Relationship between Conceptual Understanding and CTS

The correlation between the CTS and conceptual understanding was analyzed using SPSS 23 to determine the relationship and the influence, using correlation coefficients, significance tests, and regression equations.

Table 14. Relationship between Conceptual Understanding and CTS

				KB_ Critical	P_ Conceptual
KB_Critical	Pearson Correlation			1	.629**
	Sig. (2-tailed)				.000
	N			29	29
	Bootstrap[c]	Bias		0	-.009
		Std. Error		0	.110
		95% Confidence Interval	Lower	1	.397
			Upper	1	.814

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				KB_ Critical	P_ Conceptual
P_Conceptual	Pearson Correlation			.629**	1
	Sig. (2-tailed)			.000	
	N			29	29
	Bootstrap[c]	Bias		-.009	0
		Std. Error		.110	0
		95% Confidence Interval	Lower	.397	1
			Upper	.814	1

Based on the data analysis, α = 0.00 (p < 0.05), indicating a relationship between conceptual understanding and the CTS. This test was conducted to determine the extent to which conceptual understanding influences CTS. The test was performed using regression tests in SPSS, and the results are presented in Table 12.

Table 15. Influence of Conceptual Understanding on CTS

Model	R	R Square	Adjusted R-Square	Std. Error of the Estimate
1	.629[a]	.396	.374	.13597

The results showed a determination coefficient of 0.396, ≈ 0.40, indicating that CTS is influenced by conceptual understanding to the extent of 40%. Therefore, 50% of the CTS is influenced by conceptual understanding. This shows that students will be critical when they understand the concept.

4.4. Student Responses to the Use of Flipbook-Based Physics Learning Comic Media

Responses were collected by distributing questionnaires to students for use with flipbook-based physics learning comic media. The questionnaire was administered after the participants received treatment using a flipbook-based physics comic as a learning medium. The data from the students' responses are presented in Figure 9.

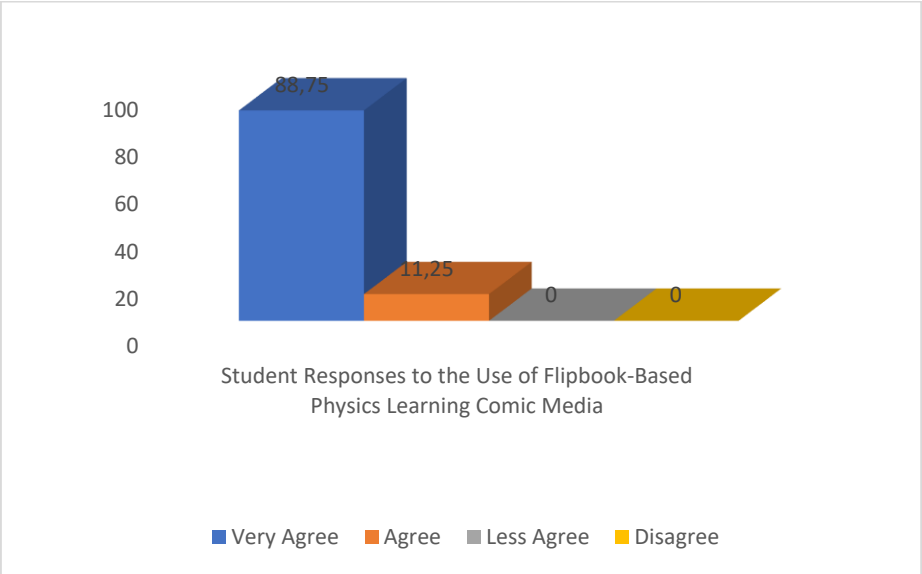

Figure 9. Student Responses to the Use of Flipbook-Based Physics Learning Comic Media

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Based on Figure 3, 88.75% of students strongly agreed that using flipbook-based physics learning comics is more enjoyable than using regular textbooks. Students prefer reading comics that contain learning materials. Physics comic media can improve memory of the material because the concept is presented in an interesting form. Evaluation is conducted to determine the effectiveness of comics in improving conceptual understanding and CTS by administering a test to assess effectiveness. The process is carried out from the beginning, during, and at the end of the learning process to ensure the sustainability of learning products.

5. Discussion

Based on the data, the transition from analysis to evaluation was carried out effectively and yielded satisfactory results. Table 16 shows the physics comic media development product using the flipbook-based Pixton application.

Table 16. Results of Comic Development

Section	Picture	Description
Cover		The comic cover section includes the title of the material and the setting, emphasizing the occurrence of momentum and application in everyday life.
Introduction		The introduction section introduces the characters who will appear in the comic, as well as their hobbies and interests that are connected to the comic's story.
Main Content		The main content section contains an explanation related to the momentum material in the story from the comic, as told by the character.
Closing		The closing section contains a conclusion, student worksheets in the form of simulations, evaluation questions, and acknowledgments.

The physics concept related to momentum is explained in comic form, including explanations of momentum in everyday life, equations, student worksheets, and evaluation questions. The comic media were developed using the Pixton application and processed into flipbooks. The characters were tailored to those of high school students to read and analyze the material. This is in line with Mustadi et al. (2022), who found that reading comprehension is directly proportional to understanding across all disciplines that require it. Nurjamal (Sunarti et al., 2023) reported that reading was important for gathering information. Comics can provide attractive visuals, helping readers learn and understand information (Willya et al., 2023). The assumptions about the scary formulas in physics lessons disappear when explaining the abstract series of events in the momentum material. Anjani et al. (2022) stated that interesting resources could promote student motivation and concentration, leading to effective learning. Furthermore, difficulties in understanding concepts can be minimized by engaging with physics comics. Pangriptaningrum et al. (2024) who found that digital comics in learning activities could increase reading interest. This statement was consistent with Sa'diyah et al. (2021), who found that a digital comic had a positive impact on reading interest.

Physics comic media can improve conceptual understanding and CTS, in line with Afifah & Arisca Dewi, 2022; Fikriyah et al., 2023; Ghifary et al., 2024; Khoiriyah & Suprapto, 2021; Maarti Hutami et al., 2021; Purwanto et al., 2022; D. A. Putri et al., 2023; N. R. Putri et al., 2023; Setyowati et al., 2023; Yulaichah et al., 2024. Students prefer to read physics through attractive displays and without the fear of existing equations. Conceptual understanding has a strong correlation with CTS, as shown by the data analysis results, yielding a coefficient of determination of 0.396 0.40. Therefore, the conceptual understanding of CTS is 40%. Nugraha et al. (2022) reported a strong correlation between conceptual understanding and CTS. In this context, there is a direct influence between conceptual understanding and students' CTS. This statement is confirmed by Irka et al., who reported a positive relationship between conceptual understanding and CTS. The development of digital materials can be adjusted to enable access to learning anywhere and at any time. According to Putri et al. (2023), the development of e-comic learning materials includes the types of e-comic characters and images that are interesting to students, stories that attract attention, and the flexibility and practicality of physics. Furthermore, Nurcholisah et al. (2022) reported that comics can be used as a digital medium to increase interest in learning.

Challenges in using the Pixton app primarily arise from technical and operational issues that affect the smoothness of the digital comic design process. First, Pixton requires a stable internet connection due to its cloud-based features and storage, so teachers in areas with inconsistent network connections often experience difficulties accessing, saving, or editing comics. Second, the app has a fairly complex interface for new users; teachers unfamiliar with digital platform design need more time to understand the navigation, character customization features, panel settings, and comic export mechanisms. Third, the device specifications can also be a constraint. Pixton works best on devices with powerful processors and sufficient memory; laptops or devices with lower specifications often experience lag, delayed rendering, or difficulty loading visual elements.

6. Conclusion

In conclusion, the development of comic media using momentum materials, such as the Pixton application and flipbooks, can improve conceptual understanding and CTS. This is because approximately 50% of students' CTS are influenced by conceptual understanding. There is an increase of 0.50 and 0.25 in the CTS N-Gain values for the medium and low criteria, respectively. The increase in conceptual understanding occurred after the application of flipbook-based physics comic media for momentum. This is evident from the high average final exam scores in the experimental and control classes, with N-gains of 0.55 and 0.34, respectively, which are in the medium criteria. Therefore, it can be ascertained that students are at a critical point when the concept is well -understood. Physics comic media can motivate students to read and improve their memory of the material when presented interestingly. Positive responses were also

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obtained, and most students found physics more interesting to learn through comics. Based on this description, this study only focused on comic development, conceptual understanding, and CTS. Further research is needed to analyze the student learning process using physical media in the Indonesian context.

7. Suggestion

The recommendations from this research are that the use of comics as a learning medium needs further development, as it has proven effective in enhancing conceptual understanding and fostering students' critical thinking skills. Teachers are advised to integrate comics with active learning methods to optimize learning outcomes, while further research should test the effectiveness of this medium in other subjects and educational levels. Furthermore, comic development should consider cultural and local contexts so that the resulting media is closer to students' real-life experiences and can have a more meaningful impact on learning.

Furthermore, comic development should consider cultural aspects and local contexts so that the resulting media are closer to students' real-life experiences and can provide a more meaningful learning impact. However, this study has several limitations, including a small sample size, a focus on a single topic (momentum), and an absence of analysis of the learning process when students interacted with the comic media. These limitations restrict the generalizability of the findings. Therefore, future studies should employ larger and more diverse samples, analyze classroom interactions in depth, and explore how physics comics function across various school contexts in Indonesia.

Declarations

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