

The Development of Physics Digital Comics on Temperature and Heat Material to Improve The Critical Thinking Ability

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Abstract

This study was conducted to develop temperature and heat learning media for high school students to improve their critical thinking skills regarding the phenomena related to temperature and heat material. This study uses the DDDE (Decide, Design, Development, Evaluation) method. This research begins with the stages of determining digital comics as learning media, compiling storylines and sketching comic images, compiling complete comics along with character dialogues, and evaluating the final results of digital comics. Three validators carried out validation test. The results of the validation test showed that digital comics were significantly suitable to be used as supporting media for temperature and heat learning based on several criteria, including learning aspects of 89.78%, material aspects of 93%, and media aspects 93.17%. These digital comics were consequently suitable to be used as a medium for supporting online learning and had time efficiency in delivering material. The implication of this study will facilitate the teaching and learning process from home or School from Home (SFH) during the pandemic period and is expected to be developed in further studies.

Keywords: Comics; Critical Thinking; Digital; Media

Received : 13 February 2021

Accepted : 16 May 2021

Published : 18 June 2021

DOI : <https://doi.org/10.20527/jipf.v5i2.2959>

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How to cite: Rosdiana, D. R. & Kholiq, A. (2021). The development of physics digital comics on temperature and heat material to improve the critical thinking ability. *Jurnal Ilmiah Pendidikan Fisika*, 5(2), 83-93.

INTRODUCTION

High school students' understanding of temperature and heat material needs to be significantly improved to avoid misconceptions (Wahidah, Kusairi, & Zulaikah, 2017). In this study, temperature and heat material were chosen as the topic to be discussed, because according to Sumardiana, Hidayat, & Parno (2019), the level of understanding of the concept of temperature and heat in high school students is still relatively low. Regarding this matter, learning media is considered necessary in assisting students to be

more focused and less likely to feel bored (Kanti, Suyadi, & Hartanto, 2018). Learning media is a means to convey learning information by teachers to stimulate students to be more interested and provide significant learning motivation (Irfana, 2017). Through appropriate learning media, students will efficiently learn to use their critical thinking skills when discussing and analyzing evidence, evaluating ideas and propositions, reflecting on data validity, processing, and concluding (Latifah, Setiawati, & Basith, 2016).

The learning media chosen in this study were digital comics. Digital comics are reading material in the form of a series of exciting pictures to convey the story's contents (Irfana, 2017) and are displayed digitally by using a smartphone (Haka & Suhandi, 2018). Through the release of this digital comic, students are expected to understand the concepts of temperature and heat more efficiently. Moreover, online teaching and learning activities will be appropriately facilitated.

A study conducted by Siswoyo, Mustokoweni, & Mulyati (2020) indicated the feasibility of the comic "Tempera-Tour" to be used as a learning media through four expert validators accompanied by excellent results. Furthermore, a study conducted by Sanyoto, Setyarsih, & Kholiq (2016) entitled "The Implementation of Interactive Demonstration Learning Model Assisted by Virtual Simulation Media to Reduce Students' Misconceptions on Temperature, Heat, and Heat Transfer Materials" utilized virtual simulation media to analyze the decrease in students' misconceptions. The results of this study indicated that students' understanding of temperature and heat tends to increase significantly.

The development of learning media has been conducted considerably. However, it is not the same as digital comic media. This media is specifically made to support high school students' learning activities to think critically about any temperature and heat material problems. Meanwhile, in previous studies, the development of learning media was more focused on students' interest in learning temperature and heat material. Besides, the application of learning media needs to be carried out in person. In digital comic media, students are not required to practice questions to make their learning time more efficient. Because, through examples of various problems, students will increasingly

understand the concept of temperature and heat and how to solve the problem. Compared to previous studies, the novelty of this digital comic media can be found in the learning process that can be carried out online due to pandemic conditions that require School from Home (SFH) procedures. The digital media appearance also facilitates the teacher to send media to students without physically printing comics. The digital comic using theme folklore. Four teens play the role of adventure on the Mount of Temperature and Heat. They were asked to take gold plants from the Mount of Temperature and Heat so that the giant would not disturb their village. During the trip to Mount of Temperature and Heat, they encountered several obstacles until they could take away gold plants. This theme will be easy for students to understand because they have known about folklores since childhood.

Through the development of digital comic media, students will be trained to think critically about temperature and heat material delivered by physics teachers. The digital comic media used are arranged in a short and straightforward story with a coherent storyline to understand it easily. Temperature and heat problems are incorporated in each obstacle course in the story. Then, the clue answers to these problems are briefly explained of the temperature and heat formulas. This is related to the 2013 curriculum standard, which requires students to learn independently. Through appropriate learning support media, students can connect their knowledge with their critical thinking skills to be able to solve problems critically (Septarini & Kholiq, 2021) through the material presented by the teacher in an attractive, simple, and straightforward manner.

Therefore, this media is specifically made to convey the concepts of temperature and heat in a simple way but

with varied examples of problems. Although the school applies the SFH procedure, students will more easily understand the concepts of temperature and heat and think critically about changes in temperature and heat that occur in various other problems. Regarding the previous description, the media would be developed to determining the validity of physics digital comic media to improve high school students' critical thinking skills so that it is suitable to be used as a medium in learning.

METHOD

This study was conducted to developed and validate educational products. The media developed in this study was learning media in the form of digital comics with the title "Adventure on the Mount of Temperature and Heat" for high school students. The development model used was the DDDE model (Figure 1), which consists of four stages, specifically Decide, Design, Development, and Evaluation (Ivers & Barron, 2002). The stages of the DDDE Model are shown in Figure 1.

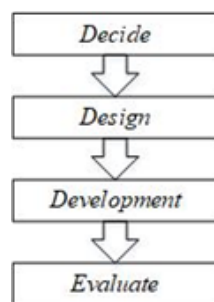


Figure 1 DDDE Model Research Stages (Ivers & Barron, 2002)

At the decision stage, the comics developed would be determined in advance, which was digital comics. At this stage, a literature study was carried out to discover some of the problems that occur in education and determine the objectives of digital comic learning

media as supporting material for physics lessons.

At the design stage, storylines and comic sketches were developed according to the temperature and heat of the material. The material was differentiated based on storytelling, the delivery of the material, and the suitability of the dialogue with the material presented so that the concepts of temperature and heat can be understood properly by the students.

The development stage was carried out to produce digital comic products designed according to the prepared material. At this stage, the comics began to be coloured, arranged according to the order of the story, and conversational texts were provided. All of the steps to create the digital comic is using Corel Draw. It helps make any design colourful and interactive, so the students won't be bored while reading this digital comic.

Finally, the evaluation stage provided the final result of learning through learning media made previously to determine the validity level of teaching media. This stage was carried out by evaluating the final results of digital comics to the selected validators.

To find out the feasibility of this digital comic media, the Likert validity criteria in Table 1 was used as a reference to determine the percentage of whether digital comic was feasible or not as a learning medium. Regarding the Likert criteria table, the digital comic media developed need to reach a minimum score of 60.01% to be suitable for learning support media.

Table 1 Likert Feasibility Scale

Feasibility Score	Validity Criteria
0 – 20 %	Not Feasible
20.01 – 40 %	Less Feasible
40.01 – 60 %	Enough Feasible
60.01 – 80 %	Feasible
80.01 – 100%	Very Feasible

(Maharani, 2018)

RESULTS AND DISCUSSION

This study produced a digital comic that will be used to stimulate high school students' critical thinking skills. The results of drawing comics that are interesting and easy to understand will facilitate students to understand the concepts of temperature and heat properly.

The appearance of this digital comic consists of the front cover, author's photo, character introduction, extras, story content, author's biography, and back cover with a very short storyline with a total of 39 pages. The parts of this digital comic can be seen in Figures 2a, 2b, 2c, and 2d.



Figure 2a Front and Back Covers



Figure 2b Digital Comic Author and Author's Biography



Figure 2c Character Introduction

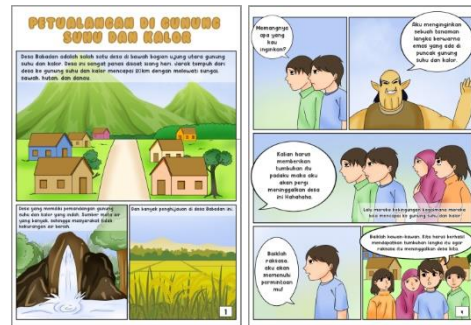


Figure 2d Comic Contents and Dialogue

In this digital comic, four characters go on an adventure on Mount of Temperature and Heat, namely Bima Biru, Yudha Hijau, Sri Pink, and Ira Orange. They were asked to take gold plants from the Mount of Temperature and Heat so that the giants would not disturb Babadan Village. During the Temperature and Heat Mountain trip, they encountered several obstacles ranging from crocodiles in the Thermometer River, lions in the Hot Forest, snakes in the Expansion Field, and crows on the Mount of Temperature and Heat. Each obstacle is given a challenge in the form of a question and an explanation so that the material about temperature, heat, expansion, and the Black Principle is easily understood by students. This digital comic is very different from the others because it makes it easier for students to study at home during a pandemic. For this reason, digital comics do not need to be printed but can be read via smartphones, laptops, notebooks, etc.

The feasibility of digital comic media is based on three aspects assessed by three validators referring to the Likert standard. The feasibility results processed based on Likert standards are shown in Tables 5, 6, and 7.

Learning Aspects

The learning aspects of digital comics include several criteria adjusted to the standards for preparing learning media to be applied to high school students. These aspects consist of criteria by Graduate

Competency Standard (GCS) content standards containing concepts, principles, and materials of temperature and heat and standards for presenting essential competencies covering all temperature and heat materials.

The results of the validation assessment regarding the learning aspects can be seen in Table 2. The table shows the results that the learning aspects obtained a very feasible category on the GCS criteria, which amounted to 86.67%. The suitability of content standards has amounted to 93.33%. The suitability of process standards amounted to 89.33%, with an average value of the learning aspects of 89.78%.

Table 2 Validation Results for Learning Aspects

Criteria	Percentage Criteria	Validation Criteria
GCS	86.67 %	Very Feasible
Content Standard	93.33 %	Very Feasible
Process Standard	89.33 %	Very Feasible
Average	89.78 %	Very Feasible

Based on the validation test, the digital comic learning media can provide the concepts of temperature and heat through natural contextual phenomena with dialogue and 2D image forms by the material. Besides, students' critical thinking skills will consequently increase with the explanation provided for each given problem. This digital comic can also be a solution as a medium for supporting physics learning during the pandemic so that time efficiency in teaching and learning activities can increase significantly.

Material Aspects

This digital comic's material aspects include several criteria adapted to physics lessons for high school students. These criteria consist of the relevance of the material by the needs and the truth of

the teaching material standards and the adequacy of the presentation of the material in the phenomena of everyday life and are interrelated with one another. Validation results for material aspects are listed in Table 3.

Table 3 Validation Results for Material Aspects

Criteria	Percentage Criteria	Validation Criteria
Relevance	89.33 %	Very Feasible
Adequacy	96.67 %	Very Feasible
Average	93 %	Very Feasible

The results of the validation assessment regarding the material aspects can be seen in Table 3. The table shows the results that the material aspects obtained a very feasible category on the criteria for the relevance of learning media with the material presented, which was amounted to 89.33%, the adequacy of the presentation of the material amounted to 96.67% so that the average value of validation on the material aspect has amounted to 93%.

Based on the validation test results, the material presented is by Core Competencies and Basic Competencies in the 2013 Curriculum. This digital comic consists of interests and benefits with a difficulty level of easily understood questions by students, which will consequently attract students' interest to read the comic. Presentation of material with the concept of folklore will further increase student interest in understanding temperature and heat material.

Media Aspect

The media aspect of digital comics consists of several criteria adjusted to the principles of preparing learning media to be applied to high school students. The results of the validation assessment regarding the media aspects can be seen in Table 4.

Table 4 Validation Results for Media Aspect

Criteria	Percentage Criteria	Validation Criteria
Principles of Media	89.52 %	Very Feasible
Principles of K13	96.67 %	Very Feasible
Design	93.33 %	Very Feasible
Average	93.17 %	Very Feasible

Table 4 shows the results that the media aspect obtained a very feasible category on the criteria for conformity to

the principles of learning media, which was amounted to 89.52%, the suitability of digital comics with the 2013 Curriculum principles has amounted to 96.67%. The systematic suitability of writing and media design has amounted to 93.33%, with an average value of validation on the media aspect of 93.17%.

The Average Percentage of Digital Comic Validation Test Results can be seen in Figure 3.

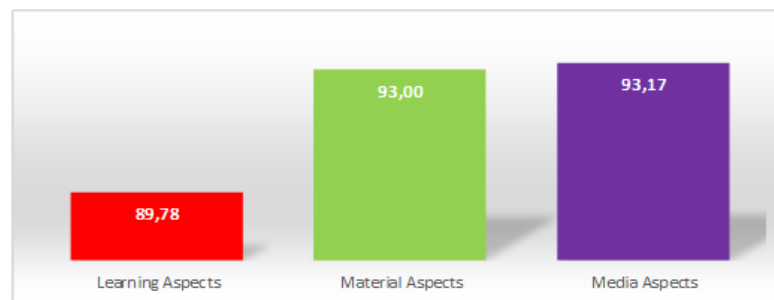


Figure 3 Average Percentage of Digital Comic Validation Test Results

Based on the validation test results, this digital comic learning media conforms to the principles of the preparation of learning media, including easy to see, attractive, simple, useful, right on target, sensible, and well structured. Designing images with complete information, suitable colour composition, illustrating images, and incorporated with learning motivation will allow students to learn appropriately.

From the validation test results for the three aspects above, it can be seen that this digital comic media is suitable to be used as learning support for high school students to think critically about temperature and heat phenomena. For the learning process to be more focused, students need to be motivated to learn by understanding the teacher's temperature and heat material. This learning motivation can be carried out by asking students to practice temperature and heat

events in digital comics. This implementation can stimulate students to find out the facts of the theory that exists in the material of temperature and heat. Students' critical thinking skills will be more trained through this method, and their curiosity will be even higher.

The objectives related to students' ability to think critically can be appropriately achieved. It is necessary to compare it with previous studies on temperature and heat material using learning support media. Regarding a study conducted by Siswoyo, Mustokoweni, & Mulyati (2020), the learning media used in this study have some similarities, specifically the utilization of comic media with adventure storylines. By the concept of writing story content that includes adventure accompanied by problems, *Tempera-Tour* comics have goals and theories that are in line with this digital comic media. However, the digital

comics in this study have different and more varied difficulty levels than the comics of Siswoyo, Mustokoweni, & Mulyati (2020).

Furthermore, a study conducted by Sanyoto, Setyarsih, & Kholiq (2016) applied digital simulation media to interactive demonstration learning aimed at reducing the level of the misconception of temperature and heat material in high school students by providing practice questions before and after the application of digital simulation media. The learning model provided is different from the purpose of preparing this digital comic. The provision of practice questions before and after applying learning media by Sanyoto, Setyarsih, & Kholiq (2016) will consume a lot of time and is less efficient in delivering material. This is different from digital comics, which immediately provide understanding to students without having to practice questions first and can be studied at school or home. Referring to these descriptions, this study intended to improve students' understanding of temperature and heat material.

Besides that, another study that discussed temperature and heat material is a study by Lailis, Arifuddin, & M. (2021) through a multimodel-based direct teaching model. The developed teaching materials included Lesson Plans, Student Worksheets, Learning Outcomes Test, and teaching materials categorized as very good with very high reliability. The temperature and heat materials taught in this study consisted of temperature and expansion, heat change in temperature and shape change, black principles, and heat transfer. This is by the material presented in digital comics, which includes these materials. The light delivery method with easy-to-understand explanations will make students better understand the concepts of temperature and heat.

Also, a study from Cahyani, Mayasari, & Sasono (2020) applied e-module project-based learning with STEM integration. The typical indicators of student creativity in this study were fluent thinking, flexible thinking, elaboration, and original thinking on temperature and heat material for vocational students. This study indicated the effectiveness of the e-module Project Based Learning with STEM integration in the medium category. The study objectives were in line with the development of this digital comic media, so this digital comic is considered to correct deficiencies in Cahyani, Mayasari, & Sasono (2020). Digital comic media take advantage of time efficiency in delivering learning materials so that students have plenty of time to study other materials.

Moreover, a study conducted by Dwiyantri & Rosana (2020) regarding temperature and heat learning through project-based learning media. The products developed in this study were high school learning tools including Lesson Plans, Student Worksheets, Peer Performance Appraisal Sheets, and authentic instruments in the form of questions on temperature and heat material. The validation results indicated their feasibility and effectiveness in the excellent category so that the goal of improving science process skills for students can be adequately achieved. The difference from this study is that digital comics are used as learning support materials so that giving practice questions to students was not necessary. This is in line to development digital comics to improve science process skills, especially critical thinking skills.

Furthermore, a study by Hidayat, Zainuddin, & Misbah (2021) on generative learning. The development plan was compiling Lesson Plans, Student Worksheets, Teaching Materials, and Learning Outcomes Test. In Student Worksheets, the phases of the generative

learning model were included, specifically application and conceptualization. Moreover, a challenge and confrontation phase was added to the teaching materials. The results showed that generative learning was suitable for use in the learning process. The test of teaching materials was declared valid, practical, and effective. In general, this study had the same material content as digital comics, but using this learning media is not effective if it is applied in School From Home (SFH) procedures. Because, in teaching materials on generative learning, many questions are used in several phases that require direct discussion between students and teachers.

Hartini, Zainuddin conducted another study on temperature and heat learning regarding temperature and heat learning means oriented to science process skills using a guided discovery learning model based on validity, practicality, effectiveness, and achievement of science process skills. This study used Lesson Plans, Student Worksheets, Learning Outcomes Tests, and teaching materials. The results showed that the means was categorized as an effective, very practical, and skilled learning tool for students. However, if it is viewed from the efficiency of time, this means was still not able to fulfil this significantly compared to digital comics. This was regarded because of the many means that had to be tested on students so that the learning time needed would be even longer.

Moreover, a study conducted by Ariendhany, Wati, & M. (2016) on the development of teaching materials with the Community Technology Science Model (CTS) which aimed to study temperature and heat to find and apply the concept in everyday life, as well as train students to actively think and physically active. The teaching materials developed Lesson Plans, Student Worksheets, Learning Outcomes Test,

and teaching materials with very good validity results, very practical, and very effective. The CTS model was very suitable for students, but pandemic conditions will not allow students to experiment and work on questions about temperature and heat in schools. Therefore, digital comics are made as an alternative to student learning to learn and try to experiment individually and independently at home.

Furthermore, the results of a study by Sari et al. (2019) with her team, Riswanto and Partono through an Android-based Mobile Pocket Book by utilizing Adobe Flash to be used online and offline. The material contained concepts, the law of equations, example questions, questions, and supporting animation so that the display is easy to understand and attracts students' interest in learning. Regarding the validity results, this learning media was very suitable for learning material on temperature and heat. The difference between this learning media and digital comics is in its visual appearance. Suppose a mobile pocketbook is a teaching material in the form of a book that is displayed on a smartphone. In that case, digital comics are supporting teaching materials that can be displayed on smartphones or laptops/computers. Because, digital comics are made to facilitate students in understanding the concepts of temperature and heat simply with a pleasant appearance, while the mobile pocketbook is to improve practicality in reading material so that manual/physical books are no longer needed.

Another comparison of studies based on the use of digital media is found in a study conducted by Kholiq (2020), which used a digital book based on Augmented Reality (BDF-AR2) to train students' literacy skills, including the Augmented Reality (AR) feature to realize more significant and real learning. The results of the BDF-AR2

validity showed the feasible category to be developed in physics learning to support student learning in the 21st century. Although digital comics have not been made at the AR level, they have practical value that is not much different from BDF-AR. The real appearance of the book provides an attractive visual effect for the readers so that students can imagine any material presented to them. The concise content of the material will certainly help students understand each material presented in the digital comic.

Furthermore, a study by Kusumawati, Wasis, Sanjaya, & Kholiq., (2020) compiled an e-book called e-book literacy (ELITE). ELITE was created to train students' scientific literacy, integration as a source of student learning, and teacher teaching materials in learning. The results showed that scientific literacy competence to explain this phenomenon increased by 52%, and scientific literacy competence to interpret scientific data and evidence increased by 59%. The ELITE presentation was made more interactive with attractive illustrated images and colors like BDF-AR2. This is different from digital comics used as learning support media so that the preparation of materials, pictures, and questions is not as much as ELITE. This will be a unique attraction for digital comic readers because of its simplicity in its delivery to make students more critical of every phenomenon of temperature and heat.

Finally, a study by Adam, Suprpto, Kholiq, & Mubarak., (2019) regarding a bilingual (English-Indonesian) e-book with a virtual laboratory feature called Beboo. Beboo is specifically designed to succeed in international high school level programs in Indonesia as a learning resource. Through Beboo, students learn in a virtual laboratory and practice their skills, particularly in speaking English. The strengths in Beboo serve as inspiration for digital comic media so that it can be further developed to be

more interesting. However, folklore and the Indonesian language used in everyday life will make digital comics more comfortable for students. This is due to preparing a script that is familiar with the stories they hear in childhood so that it can be an option for students to understand the concepts of temperature and heat without the need to observe other language delivery.

CONCLUSION

The conclusion of this scientific article based on the study conducted is that the validation test results of digital comic learning media from 3 validators obtained an average result on the learning aspect, which amounted to 89.78%, the material aspect has amounted to 93%. The media aspect has amounted to 93.17%. The validation test results indicated that this digital comic is significantly feasible for use as a learning support medium and helps students think critically about temperature and heat material.

The results of this study can be used as recommendations for teachers to further choose digital comics as learning support media with temperature and heat material. In a subsequent study, the development of other media is highly required, such as audio and 3D animation, to show a more attractive appearance.

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