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THE ANDROID-BASED COMIC OF GAJAH MUNGKUR DAM: IMPROVING MATHEMATICAL REPRESENTATION AND CRITICAL THINKING ABILITIES

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Abstract

This research aims to: (1) develop a feasible Android-based comic media of Gajah Mungkur Dam, and (2) reveal the effectiveness of the developed comic media in improving mathematical representation and critical thinking abilities on the materials of work and energy. The research subjects are senior high school students, consisting of 262 students for the empirical testing, 36 students for the limited trial, and 72 students for the field trial. This research is research and development applying the 4D model, consisting the stages of definition, design, development, and dissemination. The research instrument includes a validation sheet, evaluation sheet, questionnaire, lesson plans, comic media, and mathematical representation and critical thinking ability tests. The developed comic media contains an introduction, comic's work and energy materials, users' manual, instructional video, and discussion column. The data analysis used the MANOVA test. The finding shows that the developed Android-based comic media of Gajah Mungkur Dam is feasible to use with the assessment score of 3.70 or in a very good category from the validator, and score of 3.10 or in a good category from students in the limited trial. The MANOVA test result shows that there is a significant difference between the control class and experimental class. The developed comic is effective in improving mathematical representation ability in the small effect category and in improving critical thinking skill in the medium effect category.

Keywords – Android, Comic, Critical thinking, Gajah Mungkur Dam, Mathematical representation.

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1. Introduction

Nowadays, there is a need for technology-assisted learning, with the hope that students are accustomed to dealing with technology in learning. In the TPACK study, the technology domain score obtained a low score, this is due to the lack of experts in linking learning with technology. Based on this, it is necessary to improve teacher skills in using technology in learning. The form of technology that is commonly found today is smartphone technology based on android.

Media are used as an instrument to facilitate teachers to convey information to students. There are varieties of media teachers can use, so that teachers have to be selective in choosing suitable media. Teachers tend to use conventional media, such as the blackboard, or instant media in the form of a photographs, posters and maps (Rina, Suminar, Damayani & Hafiar, 2020). Therefore, there needs to be an appropriate medium in accordance with the students' needs. One of the appropriate media to show representation in words, diagrams, pictures, graphs visually and interestingly and related to local wisdom so as to be easily understood by students is comic (Husna & Kuswanto, 2018). Colloquial language in comics can change rigid language of science into a simple language so that it is easy to understand by students (Lin, Lin, Lee & Yore, 2015).

Comics are not only functioned as entertainment facilities but also able to be used in teaching (Widyastuti, Mardiyana & Saputro, 2017). They are issued not only on paper but also through the internet, and they can even be integrated to digital technology (Putra & Iqbal, 2014). Android smartphone is the digital technology and the software mostly used by high school students in school (Herwinarso, Untung, Wirjawan & Prathidina, 2020). It is a part of teaching processes in this modern era now (Sukariasih, Erniwati, Sahara, Hariroh & Fayanto, 2019).

Critical thinking skill is one of the skills that have to be mastered by the students in the era of Industrial Revolution 4.0. It needs to be developed in the students, and one of the ways is by applying a student-active instruction and by facilitating students to discover the solution to the problems surrounding them (Yuliati, Yuliyanti & Khanifayah, 2011) and global problems (Puspita, Kaniawati & Suwarma, 2017). In physics instruction, critical thinking skill is very important to master by students in order to solve problems.

The result of the National Examination (NE) analysis conducted by the Indonesian government shows that one of the physics materials whose percentage in the students' correct answers is decreasing is the work and energy materials. From 2015 to 2019, the percentages of the students' correct answers were 52.17 %, 47.35 %, 40.91 %, and 38.79% respectively. This shows a tendency of the decrease in the students' ability to answer the questions related to the work and energy materials.

One of the ways of problem solving exercises is through representation ability (Docktor & Mestre, 2014). The students' representation performance shows their ability to interpret physics phenomena, both verbally and mathematically using symbols and pictures (Fatmayanti, Suparmi, Sarwanto & Ashandi, 2017; Bego, Chastain, Pyles & DeCaro, 2018). Mathematical representation is the most commonly used way in solving problems found in learning physics (Kusumawati, Marwoto & Linuwih, 2015; Fatmayanti et al., 2017). The aim of choosing suitable representation is to minimize students' difficulties in learning physics (Widianingtiyas, Siswayo & Bakri, 2017). Based on all of those above, there is a need to improve students' mathematical representation and critical thinking abilities using comic media.

The research by (Ridho, Wardani & Saptono 2020) reported indigenous knowledge-based media can improve students' critical thinking skill to a high category. Teachers could relate physics instruction to indigenous phenomena surrounding the students (Yuenyong & Yuenyong, 2012). Therefore, indigenous knowledge-based media have potentials to be developed and they can improve critical thinking skill. The indigenous knowledge in Wonogiri not much studied as physics learning materials is the Gajah Mungkur Dam. This dam is one of very famous tourist attractions in Wonogiri, Indonesia. One of the interesting media which can be related to indigenous knowledge so as to make it easy to understand by students is comic (Husna & Kuswanto, 2018). Therefore, Android-based comics integrated to indigenous knowledge have potentials to improve students' mathematical representation and critical thinking abilities on the materials of work and energy. That is why the researchers are interested in doing this research.

2. Literature Review

2.1. Android-Based Instructional Media Comics

Comics are one of vision-based media of pictures containing the information in accordance with needs. They can also be used as instructional media which make convenient situation, so that students find it easy

to understand and memorize the materials. (Rina et al., 2020). Comic media facilitate teaching especially in realizing abstract concepts to be more concrete in everyday lives (Jamal, Ibrahim & Surif, 2019). Therefore, comic media are suitable to be used to describe abstract physics problems to be concrete so that they are easy to be understood by students. This is in line with the finding of the research by (Atasoy, Taksoy & Calik, 2020) which states that further research can be done on difficult materials by using the concept of cartoon. Based on this, the work and energy materials can be presented well through comic media. Comics are a cartoon-style image involving a visual representation of scientific ideas involved in a particular subject (Cil, 2014). There were some aspects in comics, including structure, content, organization, presentation, spelling, language, and readability (Pardimin & Widodo, 2017). According to Wurwiarwin, Wahyono and Werdina (2018) the aspects to be paid attention to are the materials, language, display, and effect of presentation on teaching strategies. Pocket-book comic media which are valid and able to improve students' concept understanding consist of three parts: a user's manual, learning materials, and smart information (Winarto, Khiyarusoleh, Ardiyansyah, Wilujeng & Sukardiyono, 2018).

In the era of Industrial Revolution 4.0, the use of technology is very important, including in education. One of the uses of technology can be found in the use of instructional media in classroom teaching. One of the forms of technology very much used by students in school is Android-based smartphones. Android is an open-source cellular platform which is popular, free, and shocking the world (Annuzzi, Darcey & Conder 2016). Many students have smartphones because they are flexible to carry anywhere (Herwinarso et al., 2020). The teaching by using Android can improve teaching efficiency between teachers and students (Sukariasih et al., 2019). Android-based media and the created web can facilitate interaction between students and teachers whenever and wherever there is Internet connection (Sunarto, Hariadi, Sagirani, Amelia & Lemantara, 2020). However, there are constraints for the students since the Internet signal is not always guaranteed, and thus the researchers made media which are accessible offline, so that they can be used more flexibly in learning. One of the Android application development provider websites is www.kodular.io. This is very helpful for beginner developers (teachers) who are going to use Android as instructional media. There are five important advantages of using Android instructional media, including second voice choice system, data collecting instrument, teaching video, outdoor teaching, and learning physics simulation (Pokonwong & Wattanakasiwich, 2014). Mobile learning instruction will help students access new learning resources to get knowledge and improve learning flexibility (Marzouki, Idrissi & Bennani, 2017). Based on this, Android-based media as an instrument to read physics comics have a potential to be used in teaching, so that this research uses Android-based comics as instructional media.

2.2. Indigenous Knowledge of Gajah Mungkur Dam

When comics are used in teaching, the science content to be conveyed has to reach the readers, who are students in this case (Putra & Iqbal, 2014). The use of the everyday life information which is local and relevant can improve students' contextual understanding because they can relate theoretical knowledge in books to the surrounding reality in life (Husna & Kuswanto, 2018). The use of indigenous knowledge as the basis for learning media will make teaching contextual.

The Gajah Mungkur Dam is situated in Wonogiri, Central Java, Indonesia. The operation of this dam is the storage of river water into a reservoir and the release of the stored water for various specific purposes. This dam is a multi-purpose dam extending to more than 8,800 hectares (Santoso, Sudarsono & Sukmono, 2017). In the tourism sector, this dam can be visited by tourists at its operational time. There are many rides and natural scenery that can be visited by tourists. One of the natural attractions is boat joy-travelling to the dam pond under the writing of "Bendungan Serbaguna Wonogiri" (Multi-purpose Dam of Wonogiri) and to the fish cage in the middle of the dam. In the cultivation zone, the dam is used as a place to cultivate majority of tilapia fish, gold fish, and catfish. There is also a zoo which can be accessed from the east entrance gate.

There are other facilities which can be accessed by visitors, including the rabbit train, flower garden, photo spot, and souvenir zone which provides a lot of merchandise typical of Gajah Mungkur Dam, and the

food which is the product of the dam itself. In addition to being used directly by the people living around the dam, the local wisdom of Gajah Mungkur Dam can be used as study materials of physics concepts in high school teaching. One of the physics learning materials which can be learned through the phenomena and events in Gajah Mungkur Dam is the materials on Work and Energy for grade X students of senior high school in their second semester.

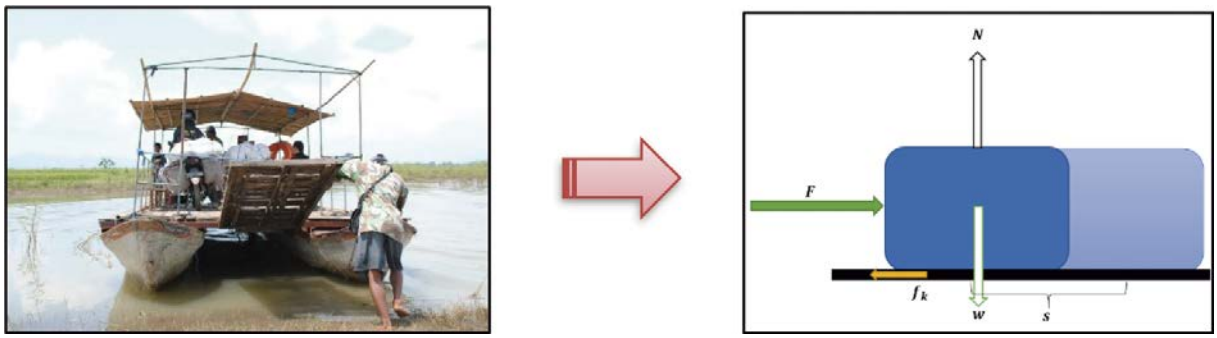

Figure 1. The concept of work in the phenomenon of a fisherman pushing a boat

3. Research Question

The aim of developing instructional media is to produce an Android-based physics comic of Gajah Mungkur Dam (GMD) which is feasible to use to improve mathematical representation and critical thinking abilities. Therefore, the research questions are as follows.

1. Is the developed Android-based comic of GMD feasible to use to improve mathematical representation and critical thinking abilities?
2. What does the effectiveness of the use of the developed Android-based comic of GMD in improving mathematical representation and critical thinking abilities look like?

4. Research Method

4.1. Research Design

This research is research and development applying the 4D model (define, design, develop, and disseminate).

Stage	Activities	Result
Define	Analyzing needs based on curriculum, assignment, students, school, and indigenousness of Gajah Mungkur Dam. This stage includes interviews and observation.	Specification of the Android-based comic media
Design	Making the media development flowchart Making the story plots Designing media and comic interface	Developed direction Application design Comic design Story plot
Development	Making media using the CorelDraw 8 application Making application Writing lesson plans, test items, questionnaire, validation sheet, and product evaluation sheet Conducting validation, empirical testing, limited trial, and expanded field trial	Lesson plans Valid Android-based comic media of Gajah Mungkur Dam Valid evaluation test items
Dissemination	Disseminating media in international seminars or reputable journals	Journal article

Table 1. Stages of Developmental Research

4.2. Research Subjects

The research subjects are senior high school students. The empirical testing was conducted to 262 grade XI students of State Senior High School (SSHS) 2 Wonogiri and SSHS 1 Baturetno. The limited trial was conducted involving 36 grade X science students of SSHS 2 Wonogiri. The research population is grade X students of SSHS 2 Wonogiri. The sample was established using the cluster random sampling technique, consisting of grade X science 1 students as the experimental class and grade X science 2 students as the control class.

4.3. Analysis Technique

At the development stage, the media validation was done by experts and practitioners. The product feasibility evaluation was done by converting scores to the criteria shown in Table 2.

Score range	Category
$\bar{X} \geq Xi + 1.8\ Sbi$	Very good
$Xi + 0.6\ Sbi < \bar{X} \leq Xi + 1.8\ Sbi$	Good
$Xi - 0.6\ Sbi < \bar{X} \leq Xi + 0.6\ Sbi$	Sufficient
$Xi - 1.8\ Sbi < \bar{X} \leq Xi + 0.6\ Sbi$	Poor
$\bar{X} \geq Xi - 1.8\ Sbi$	Very poor

Table 2. Criteria of Sbi

The analysis of the reliability and validity was done by applying the QUEST program. The test items were analyzed for their fitness to the value of infit mean square used for determining whether the items are fit or unfit, as shown in Table 3.

Value of infit mean square	Category
>1.33	Unfit
0.7 - 1.33	Fit
< 0.7	Unfit

Table 3. Criteria of Sbi

Improvement in critical thinking ability is known from the analysis using the gain score. The gain score equation is as follows (Meltzer, 2002: pp 1260)

$$g = \frac{posttest\ score - pretest\ score}{maximum\ possible\ score - pretes\ score} \quad (1)$$

Based on the gain score, the improvement in students' mathematical representation ability and critical thinking skill can be seen in the gain criteria in Table 4.

Gain Score	Category
$g \geq 0.7$	High
$0.3 \leq g < 0.7$	Medium
$g < 0.3$	Low

Table 4. Criteria of gain score

The statistical testing of the improvement in mathematical representation and critical thinking abilities used the Two Group Multivariate Analysis of Variant (MANOVA) test. This was done with the help of the SPSS application. The criteria of decision made is based on differences between two groups used the MANOVA test statistic, i.e. Hotteling's Trace at the significance level of 5%. The MANOVA test requirement is that the data were normally distributed, linear, and homogenous.

When the difference between the control class and experimental class was known, the effectiveness test was administered. The effectiveness testing was conducted to see the effect size of the application of Android-based comic media of Gajah Mungkur Dam on the improvement in mathematical representation and critical thinking abilities.

5. Findings and Discussion

5.1. Gajah Mungkur Dam Integrated Teaching Materials

The stage of definition was followed to define and determine the general requirements for physics comic development. Observation was conducted at SSHS 2 Wonogiri. The result of this stage showed that the school implemented Curriculum 2013 of the revised version. Each class consisted of 36 students. The main topic to teach in this research was the materials on work and energy. The result of the curriculum analysis based on the relevant phenomena of Gajah Mungkur Dam is presented in Table 5.

The next stage is the stage of design which resulted in development direction. It also resulted in the design of the comic and media based on the product specification and story plot. The development direction was used as the guide to making the storyboard of the comic story. The development direction is presented in Table 6.

Phenomena	Materials	Core Competency	Explanation
A fisherman pushing or pulling a boat	Work	3.9	Analyzing the concept of energy, work, work-energy change relationship, law of energy conservation, and application in everyday activities
A boat travelling in a high speed	Kinetic energy		
Playing slides with different height variations in a water boom	Potential energy		
The water flowing towards the generator wheel through a special channel so that the speed of the water will be large when it hits the wheel	The law of mechanical energy conservation		

Table 5. Core competencies in Gajah Mungkur Dam phenomena

	Indicator	Materials			
		Work	Potential Energy	Kinetic Energy	Law of Mechanical Energy Conservation
Mathematic representation	Analyzing facts based on problems	The phenomenon of a fisherman pushing a boat on the edge of the dam is presented	The phenomenon of children playing the slides of the dam waterboom is presented	The phenomenon of a boat changing its speed on the dam is presented	A picture of water discharging through the discharger to the hydropower is presented
	Formulating problems	Formulating the amount of work made by a fisherman on a boat	Formulating the amount of potential energy each child has	Formulating the amount of potential energy the boat has	Formulating the amount of energy affecting the speed of the water when it hits the generator wheel
	Expressing logical arguments	Expressing arguments about the amount of work made to push a boat	Expressing arguments about the amount of potential energy each child has	Expressing arguments about the amount affecting kinetic energy	Expressing arguments about the amount affecting mechanical energy conservation law
	Clarifying and drawing conclusions	Clarifying and drawing conclusions on the amount of work from the power for pushing and moving a boat	Clarifying and drawing conclusions on the amount of potential energy	Clarifying and drawing conclusions on the amount of kinetic energy	Clarifying and drawing conclusions related to the mechanical energy conservation law

	Indicator	Materials			
		Work	**Potential Energy**	**Kinetic Energy**	**Law of Mechanical Energy Conservation**
Critical thinking skill	Students translate problems into mathematical symbols	Writing the amount of force, movement into mathematical symbols	Writing the amount of known pieces into mathematical symbols	Writing the amount of pieces into mathematical symbols	Writing the amount of known pieces into mathematical symbols
	Students can determine equation	Determining mathematical equation to reveal the amount of work	Determining mathematical equation to discover potential energy	Determining kinetic energy equation in the event phenomenon of a ship about to stop	Writing a mechanical energy equation to determine the amount of water kinetic energy
	Students can apply mathematical equations in cases	Applying the work equation in cases correctly	Applying mathematical equations correctly	Applying mathematical equations of kinetic energy correctly	Applying the equation of mechanical energy conservation law to determine the amount of water kinetic energy

Table 6. Development Direction

The following stage was the stage of development. From the result of the previous stage were developed the comic media, Android application, lesson plans, validation sheet, questionnaire, and test items on mathematical representation and critical thinking. The writing of the comic began by drawing manually using pencils and drawing paper.

The figure above shows the process of initial drawing done manually using a pencil on drawing paper. The sketch was then bolded using a ballpoint pen so that the lines were clear. The next stage was doing the scanning and installing the Coreldraw 8 program for the process of editing, colouring, and dialogue writing of the comic.

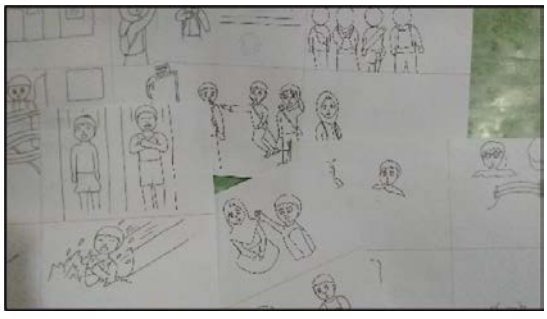

Figure 2. Manual drawing using pencil on drawing paper

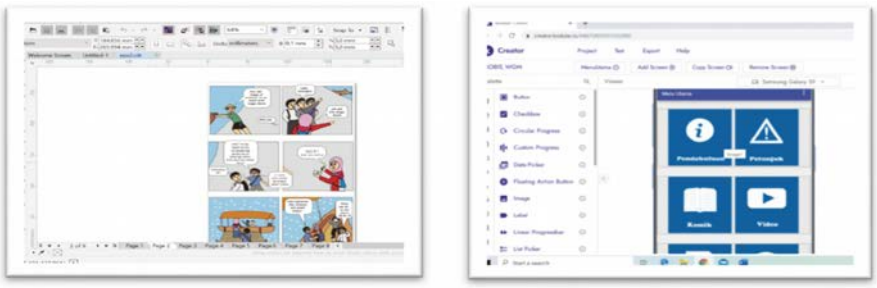

Figure 3. Making a comic using Coreldraw and application using *kodular.io*

The final stage of the media making was making the Android application using the website kodular.io. The product of this stage was validated by experts, practitioners, and peers.

Figure 4. Display of Android-based comic media of Gajah Mungkur Dam

5.2. Product Validation

Before the product feasibility evaluation sheet was used, it was validated by an instrument validator. Table 7 below presents the result of the validation.

Based on the result of the analysis, the feasibility evaluation sheet is in a valid category and ready for use to evaluate the developed comic. The next stage was product evaluation by media and materials experts, and peers. The result of the analysis of the product feasibility is presented in Table 8.

Based on the result of the evaluation of the developed Android-based comic media by seven validators, it was in a very good category. Therefore, it was feasible to use in the readability testing in the limited trial.

No	Instrument	Score	Category
1	Lesson plans	0.95	Valid
2	Test item evaluation	1	Valid
3	Media evaluation by experts	1	Valid
4	Students' Responses	0.98	Valid

Table 7. Result of Instrument Validation

No	Instrument	Score	Category
1	Suitability of content with materials, model, and variable of the ability to be developed	3.6	Very good
2	The language used	3.7	Very good
3	Display of media interface, pictures, and menu feature	3.5	Very good
4	Display of picture quality, writing, and video	3.7	Very good
5	Effectiveness of the use of Android-based comic media	3.9	Very good
Average		3.7	Very good

Table 8. Result of feasibility evaluation of android-based comic media

5.3. Limited Trial

The developed comic was tried out to 36 grade X students. The following is the result of the limited try out for its readability using a questionnaire.

No	Aspect	Evaluation result	Category
1	Perception of use facility	3.19	Good
2	Perceived utility	3.09	Good
3	The real use of the product	3.05	Good
4	The use of the media in teaching	3.10	Good
Average		3.10	Good

Table 9. Students's responses in the limited trial

No Item	Delta score	Infit Meansquare	Category
Item 1	0.6	1.07	Valid
Item 2	-0.37	1.17	Valid
Item 3	0.05	1.03	Valid
Item 4	0.22	1.26	Valid
Item 5	-0.03	0.77	Valid
Item 6	-0.14	0.85	Valid
Item 7	-0.41	0.94	Valid
Item 8	-0.30	1.07	Valid
Item 9	-0.38	1.09	Valid
Item 10	1.30	0.81	Valid

Table 10. Result of item empirical test

The result of the limited try out showed that the Android-based comic media of Gajah Mungkur Dam was in a good category, so that it was feasible to use in the extended field trial. The test items to be used in the trial were empirically tested prior to the trial. The empirical testing involved 262 grade XI students who had undertaken the learning materials on work and energy. The result of the empirical testing was analyzed using the QUEST program, which is presented in Table 10.

Items 1-5 are the items to measure mathematical representation ability, and Items 6-10 are the items to measure critical thinking ability. Based on the result of the empirical testing, it could be concluded that all of the test items on mathematical representation and critical thinking abilities were valid and could be used in the extended field trial.

5.4. Field Trial

The field trial was conducted using the quasi-experimental model, consisting of two classes: the experimental and control classes. The experimental class used the developed media and lesson plans, while the control class used the power point media and the lesson plans made by the physics teacher. The teaching was done three times, beginning with a pretest and ended with a posttest. The following is the result of the assessment of students' mathematical representation and critical thinking abilities.

Class	Average mathematical representation ability		Gain score	Category
	Pretest	Posttest		
Experimental	35.83	86.94	0.79	High
Control	41.25	82.92	0.69	Medium

Table 11. Result of mathematical representation ability test

Class	Average score of critical thinking ability		Gain score	Category
	Pretest	Posttest		
Experimental	12.08	85.14	0.83	High
Control	24.58	78.89	0.71	High

Table 12. Result of critical thinking ability

Based on the result of the analysis of mathematical representation ability, the gain score of the experimental class is 0.79 or in the high category and that of the control class is 0.69 or in the medium category. In terms of the critical thinking ability, the gain score of the experimental class is 0.83 or in the high category, and that of the control class is 0.71 or in the high category. This result is in line with the research by (Atasoy et al., 2020) reporting that the cartoon concept in comics can improve students' argumentation ability, which is one of the indicators of critical thinking skill. Table 12 shows the improvement which is in a high category for both classes, but the gain score of the experimental class is higher than that of the control class. This result is in line with the research by (Adlina & Supahar, 2019) which shows that Android-based media can improve motivation, so that it can help students understand learning materials and is effective in improving students' mathematical representation ability. The research by Albe, Venturini and Lascours (2001) also explains that students can count and determine mathematical equations by using mathematical representation ability, although some students find difficulties in relating concepts to mathematical representation. The difficulty is due to the fact that students must be able to understand concepts and visualize problems before continuing to mathematical representation (Tms & Sirait, 2016). The next stage was the analysis of the prerequisite of the MANOVA statistic which is presented in Table 13 and Table 14.

Table 14 above shows that the data obtained meet the requirement for homogeneity and normality. The linearity test was conducted to see that the data obtained were linear.

Variable	sig.	Category
Pre_experimenal_mathematical	0.089	Normal
Pre_experimental_critical	0.051	Normal
Pre_control_mathematical	0.143	Normal
Pre_control_critical	0.74	Normal
Pos_ experimenal_mathematical	0.73	Normal
Pos_ experimental_critical	0.80	Normal
Pos_ control_mathematical	0.97	Normal
Pos_ control_critical	0.70	Normal

Table 13. Result of normality test

Variable	Box's M	F	Category
Mathematical representation and critical thinking abilities	14.687	1.378	Normal

Table 14. Result of homogeneity test

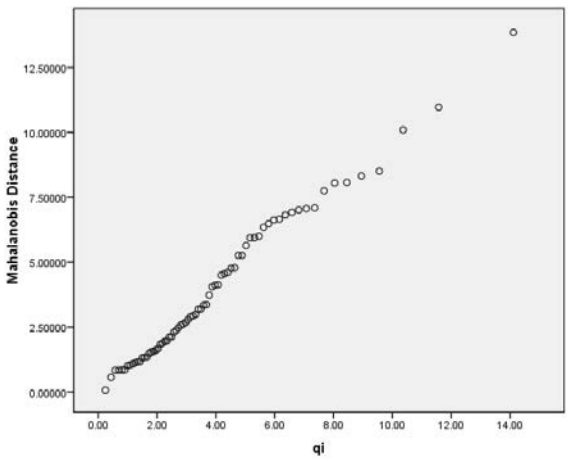

Figure 5. Graph of data linearity

Figure 5 shows that the data obtained are linear because they tend to follow the straight line. After the prerequisite tests of normality, homogeneity, and linearity, the statistic testing of the hypothesis was conducted using the MANOVA test. The result of the MANOVA test is presented in Table 15.

The result of Hotteling trace test shows the significance value lower than 0.05, and thus H0 is rejected. This means that there is a significant difference in the average score in the improvement of mathematical representation and critical thinking abilities between the experimental class which used the developed comic and the control class which used conventional media usually used by teachers. Based on this finding, further test of product effectiveness was conducted. The result of the effect size analysis is presented in Table 16.

Based on the result of the effect size analysis, the use of Android-based comic of Gajah Mungkur Dam has effects on mathematical representation ability in the small effect category, and it has effect on critical thinking ability in a medium effect category. This result is in line with the research by (Damayanti & Kuswanto, 2020) which states that comic media can improve critical thinking ability and (Priyadi, Kuswanto & Sumarna, 2020) mathematical representation ability.

The multivariate statistical testing was conducted to see the effective contribution of teaching through Partial Eta Squared. The effective contribution of the variable to teaching is presented in Table 17.

Effect	Sig.	Criteria of decision	Decision
Hotteling's Trace	0.005	Sig.<0.05	H_0 rejected

Table 15. Result of Hotteling's Trace MANOVA Test

Variable	Eta Square	Cohens' f	Interpretation
Mathematical representation	0.064	0.06	Small effect size
Critical thinking	0.102	0.11	Medium effect size

Table 16. Effect size

Variable	Class	Sig.	Partial Eta Squared
Mathematical representation ability	Experimental	0.000	0.871
	Control	0.000	0.818
Critical thinking ability	Experimental	0.000	0.949
	Control	0.000	0.912

Table 17. Contribution of effective variable of mathematical representation and critical thinking abilities

Table 17 shows the effective contribution of each class to the variables under study in Wilks' Lambda test. The effective contribution of the experimental class and control class to mathematical representation is 87.1% and 81.1% respectively. The effective contribution of the experimental class and control class to critical thinking skill is 94.9% and 91.2% respectively. Based on this result, it can be concluded that the effective contribution of the experimental class is bigger than that of the control class, and thus the developed Android-based comic media of Gajah Mungkur Dam is feasible to use to improve mathematical representation and critical thinking abilities.

6. Conclusion

The research finding shows that the developed Android-based comic media of Gajah Mungkur Dam to improve the mathematical representation and critical thinking abilities of senior high school students contains the learning materials on work and energy, learning video, discussion column, practice exercises, and it is feasible to use in physics instruction. It is operated using a smartphone with the Android operation system. It is categorized as feasible to use in physics teaching processes based on the feasibility evaluation with a score of 3.7 at the 1 – 4 scale, or in a very good category. It achieved a score of 3.1 or in a good category at the readability test. There is a difference in the improvement in mathematical

representation and critical thinking abilities between the experimental class and control class at the significance level of <0.05. The gain score of the experimental class in using the comic media to improve mathematical representation and critical thinking abilities is in the high category. This shows that the developed Android-based comic media of Gajah Mungkur Dam is effective in improving the mathematical representation and critical thinking abilities of senior high school students.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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