Benthik Android Physics Comic Effectiveness for Vector Representation and Crtitical Thinking Students' Improvement

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This research aims to reveal the effectiveness of the use of Kofie GeBoL media in improving (1) vector representation ability and (2) critical thinking ability in physics instruction. It is a descriptive quantitative study with the quasi-experiment design. It was conducted in two stages: empirical try out and implementation of Kofie GeboL to see the media effectiveness. It was conducted in four high schools in Sleman Regency, including State Senior High School (SSHS) 1 Mlati with 64 students, SSHS 1 Ngaglik with 96 students, SSHS 1 Ngemplak with 56 students, and SHS Bina Umat with 46 students on the learning materials of Parabolic Movement in October, Semester 1 of the academic year 2019/2020. The research instrument is a vector representation and critical thinking ability test which is valid and dan reliable according to the empirical test. The data analysis used the QUEST application to see the validity and reliability of the test items and the MANOVA test to see the media effectiveness. The research finding shows that the Kofie GeBoL is effective in improving students' vector representation and critical thinking abilities with the *Cohen's* value in each variable being 0.46 and 0.57 interpreted as *Large Effect Size*. This can also be seen in the *N-gain* scores of vector representation and critical thinking abilities of 0.7 and 0.8 respectively, which are in a high category. So similar research can be done for other physics theory to improve students' scientific abilities.

Keywords: android, *Benthik*, critical thinking, Kofie GeBoL, physics comic, vector representation

INTRODUCTION

Physics is a science which is general in nature, in the form of theory, law, regulation, and principles which are reliable. As a science, physics is used as the basis for developing technology, so that physics theory needs high accuracy in learning it (Puspita, Kaniawati, & Suwarna, 2018). Physics is one of the school subjects which plays an important role in education, and therefore physics subjects have to be improved

continually and to be enjoyed by students (Putranta, 2018). One of the problems in education is the weakness in teaching (Sutrisno, Handayanto, & Supriana, 2018).

Neslihan & Eser (2014) showed physics instruction mostly emphasizes the aspects of knowledge and concept understanding, which makes students less trained in improving their reasoning in applying physics concepts, and thus their critical thinking skill is not well developed. Critical thinking skills have to be mastered by students because some of the thinking competence lies on a high level, but at present that competence is still low (Zubaidah, Corebima, Mahanal, & Mistianah, 2018). Through critical thinking is also needed for academic succes in higher education (Alkharusi, et al, 2019). Vector representation is one of the representations in physics. Vector representation ability is very important for students to have in physics instruction, especially on the materials of parabolic movement, because in that material there is a physical quantity which is defined as vector (Widianingtiyas, Siswoyo, & Bakri, 2018).

The students' low ability to learn physics can be seen in the National Examination (NE) scores which are below the minimum criterion. According to the data from the National Education Standards Agency, the result of physics examination in the last five years has been in the low category (Mutakinanti & Anwari, 2018). The assessment includes knowledge, reasoning, and application. This is related to the aspects of students' critical thinking skill and higher order skill, both of which do not develop (Zhou, Huang, & Tian, 2013).

Sutrisno (2018) showed that the global development nowadays is in the era of Industrial Revolution 4.0 (I.R 4.0), in which information technology is used as basic necessities in human's life. In the ever developing industries nowadays, there is a need for human capabilities including critical thinking, systemic, lateral, and higher order abilities (Ahmad & Qasem, 2016). In Indonesia, the impact of I.R 4.0 on education is the digitalization of the education system in order to adapt to changes, followed by teachers and students. In coping with the I.R 4.0 era, students have to have critical thinking ability (Lee, 2017). Therefore, there need to be innovative instructional media in information technology-based schools, which stimulate students to develop their vector representation and critical thinking skills (Bollen, Van Kampen, & De Cock, 2015).

Chavarria (2019) showed comics are visual media for expressing ideas through pictures combined with texts as information. The application of digital comics has a positive impact on students; besides being interested in them, they are also motivated to learn (Ntobuo, Arbie, & Amali, 2018). In this era, students access media not only through personal computer (PC) but also through mobile phones such as iPad, netbook, and smartphone, so that the use of digital comics gives a clear direction related to the applicable teaching processes (Liliarti & Kuswanto, 2018). Learning using multimedia based on multiple representation increase the mastery of science (Syahri, et al, 2021).

Indigenous knowledge is closely related to students' lives, so that it can give direct experience or context to them (Baquete, Grayson, & Mutimucuio (2016). The teaching which integrates technology, science, and culture makes science instruction more inclusive, by utilizing the relevance of the curriculum to culture (Mungmachon, 2012).

The teaching which is based on indigenous knowledge or traditional game is effective in improving students' competence (Morales, 2017). The story of *Benthik* game packaged in the form of a digital physics comic presents the material about parabolic movement. The *Benthik* game is one of the traditional games popular among the students in Yogyakarta and its surrounding, so that it can give direct experience in analysing the material in parabolic movement (Ragil, 2018). The effectiveness of learning physics by directly applying the material to traditional games is considered better, because students can more easily analyze what they experience in the game (Saputra, M., & Kuswanto, H, 2019).

Based on the background of the problem above, this research was conducted about the effectiveness of a physics comic through the Android-assisted *Benthik* game (Kofie GeBoL) in improving the vector representation and critical thinking abilities of senior high school students. The research aims to reveal the effectiveness of the use of Kofie GeBoL media in improving the vector representation and critical thinking abilities of senior high school students.

METHOD

Type of Research

This research is a quantitative study with the quasi-instrumental design. It uses two classes: the control class and experimental class. The instructional media used in the experimental class is Kofie GeBoL, while those used in the control class is the Power Point Text (PPT). The research design is presented in Table 1.

Table 1
Research design

Group	Pretest	Treatment	Posttest
Control Class	O_1	X_1	O_2
Experimental Class	O_1	X_2	O_2

Notes:
O_1 : pretest before treatment
O_2 : posttest after treatment
X_1 : physics instruction using PPT
X_2 : physics instruction using Kofie GeBoL media

Research Sample

The research sample for the try-out of vector representation and critical thinking ability test items is 262 grade XI science students of four senior high schools in Sleman Regency. This try-out aims to reveal the feasibility of the test items in terms of their validity and reliability. The four senior high schools are State Senior High School (SSHS) 1 Mlati with 64 students, SSHS 1 Ngaglik with 96 students, SSHS 1 Ngemplak with 56 students and SHS Bina Umat with 46 students. The effectiveness of Kofie GeBoL media on the parabolic movement material for grade X science students in their first semester aimed at improving vector representation and critical thinking abilities was tried out at SSHS 1 Mlati. The sample for the try-out of Kofie GeBoL media is two

classes consisting of 30 students in the control class and 30 students in the experimental class. The sample was established using the cluster random sampling technique, in which the students' abilities vary.

Research Instrument and Procedure

The instrument used in this research is a teaching kit and data collecting instrument. The teaching kit is in the form of Kofie GeBoL media, and Power Point Text (PPT). The research data were collected using a test which is in the form of the test items to measure vector representation and critical thinking abilities. The vector representation and critical thinking ability test consists of a pretest and posttest. The test analysis was developed based on the core competence, basic competence, and indicators of physics instruction of the revised edition of Curriculum 2013. Prior to its administration, the test was validated by experts (Kusumawati, Marwoto, & Linuwih, 2015).

The data collecting instrument is in the form of an essay test consisting of four items on vector representation ability and six items on critical thinking. This instrument was prepared by the research team themesleves, from synthesizing the opinions of experts on these two abilities. The indicators of the test items on vector representation and critical thinking abilities are presented in Table 2 dan Table 3.

Table 2
Indicator of Vector representation ability

Basic Competence		Test Item Indicator	Item No.
3.5	Analyzing parabolic movement by using vector together with its physical meaning, and its application in everyday life	Provided with a picture of the trajectory of a *janak* pushed with a *benthong* at the *nyuhat* stage of the *Benthik* game and the known speed and angle of the throw, the students analyze the maximum height of the *janak*.	7,8
		Provided with a picture showing a *janak* hit with a *benthong* at a certain height, students can analyze the maximum height the elevation angle, initial velocity, and horizontal distance from the initial position of the *janak* are known.	9,10

Table 3
Indicator of Critical thinking ability
The research procedure is presented in Figure 1 below

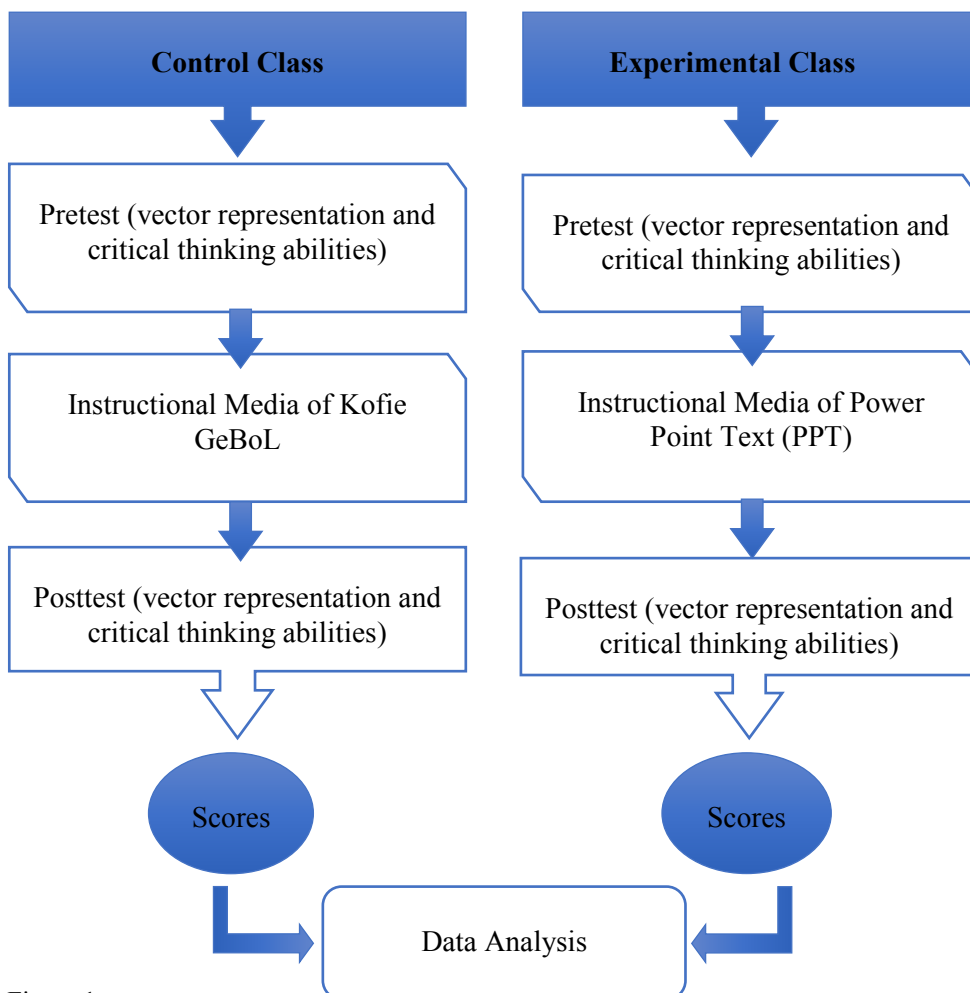| Basic Competence	Test Item Indicators	Item No.
3.6 Analyzing parabolic movement by using vector together with its physical meaning, and its application in everyday life	Provided with a picture of the trajectory of the motion of a *janak* pushed with a *benthong* at the *nyuhat* stage of the *Benthik* game and the speed and angle of the throw are known, the students analyzed the maximum height of the *janak*.	1
	Provided with a picture showing a *janak* being hit using a *benthong* at a certain height, students can analyze the maximum height, if the elevation angle, initial velocity, and horizontal distance from the initial position of the *janak* are known.	2
	Provided with a picture showing the motion of a *janak* after being pushed by the *benthong*, if the angle of the throw, the maximum height, and the time are known, students can solve the initial velocity problem by connecting several quantities.	3
	Students can analyze an equation to find the magnitude of the angle formed by a *janak*, if the initial velocity, maximum height and farthest range are known.	4
	Students can describe the parabolic movement trajectory by calculating the maximum height and the farthest range experienced by a *janak*, if the initial velocity, elevation angle, and time are known.	5
	Provided with a description of two children playing *Benthik* with different elevation angles, students can conclude the child whose throw of the *janak* reaches the farthest point (assuming the velocity is the same).	6

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┌─────────────────────────┐          ┌─────────────────────────┐
│      Control Class      │          │    Experimental Class   │
└─────────────────────────┘          └─────────────────────────┘
            │                                    │
            ▼                                    ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Pretest (vector         │          │ Pretest (vector         │
│ representation and      │          │ representation and      │
│ critical thinking       │          │ critical thinking       │
│ abilities)              │          │ abilities)              │
└─────────────────────────┘          └─────────────────────────┘
            │                                    │
            ▼                                    ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Instructional Media of  │          │ Instructional Media of  │
│ Kofie GeBoL             │          │ Power Point Text (PPT)  │
└─────────────────────────┘          └─────────────────────────┘
            │                                    │
            ▼                                    ▼
┌─────────────────────────┐          ┌─────────────────────────┐
│ Posttest (vector        │          │ Posttest (vector        │
│ representation and      │          │ representation and      │
│ critical thinking       │          │ critical thinking       │
│ abilities)              │          │ abilities)              │
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            └──────────►  Data Analysis  ◄───────┘
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Figure 1
Research procedure diagram

Data Analysis

The data obtained in the empirical test analyzed using the QUEST program were in a fit condition (reliable and valid) to the PCM or they are feasible. The scores of infit mean square (INFIT MNSQ) ranged from 0.83 to 1.20 and they fell in a good category or fit to the model, where items 1.2,3,4,5, and 6 are critical thinking items and items 7, 8,9, and 10 are vector representation items.

The type of the data in this research is quantitative. The data were obtained by using the critical thinking and vector representation ability test. The quantitative analysis of the

data was done in order to reveal the improvement of vector representation and critical thinking abilities of the students. The improvement in vector representation and critical thinking abilities was measured using the pretest and posttest. The result of the pretest and posttest was considered in the standard gain.

The result of the analysis of the *N-gain* or standard gain is in accordance with Table 4 below:

$$standar\ gain\ (g) = \frac{\bar{x}posttest - \bar{x}pretest}{x - x\ pretest}$$

Table 4
Gain score criteria

Score (g)	Classification
g≥ 0.7	High
0.7 >g≥0.3	Medium
g<0.3	Low

Notes:

$\bar{x}pretest$ = pretest average score

$\bar{x}posttest$ = posttest average score
x = students' scores, and
x pretest = pretest scores.

The normalized advantages (g) are as follows: high if g> 0.7; medium if $0.3 \le g \le 0.7$; low if g < 0.3. In addition, the descriptive advantage in the advantage is explained by the normalized gain.
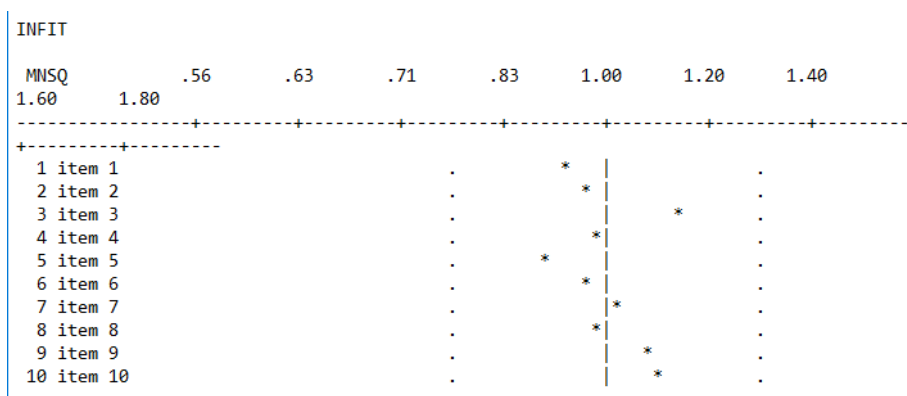
Prior to the statistical analysis of MANOVA, there needs to be a prerequisite statistical analysis. The prerequisite analysis consisted of a normality test using Shapiro-Wilk and homogeneity analysis using Box's M test.

Furthermore, the statistical multivariate test (MANOVA) was conducted to see the effect of the use of Kofie GeBoL media on the improvement of vector representation and critical thinking abilities using the SPSS. The output of the SPSS on Hotteling Trace shows that the higher the score, the bigger the effect of Kofie GeBoL media on the improvement of the two abilities. The MANOVA analysis using the SPSSprogram through the analysis of General Linier Model (GLM) to see the improvement of vector representation and critical thinking abilities of the students. The result of the GLM analysis in the form of eta square scores was converted into Cohen's f scores to see the effect size of Kofie GeBoL media.

FINDINGS AND DISCUSSION

Validity and reliability of vector representation and critical thinking ability test

The data from the empirical test analyzed using the QUEST program were in a fit condition (reliable and valid) to PCM or they are feasible to use. The scores of infit mean square (INFIT MNSQ) range from 0.83 to 1.20 and they are in a good category or fit to the model, as presented in Figure 2.

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INFIT

 MNSQ          .56      .63      .71      .83      1.00      1.20      1.40
1.60     1.80
----------------+---------+---------+---------+---------+---------+---------+---------
+---------+---------
  1 item 1                                    .         *  |              .
  2 item 2                                    .        *   |        *     .
  3 item 3                                    .            |      *       .
  4 item 4                                    .          * |              .
  5 item 5                                    .     *      |              .
  6 item 6                                    .         *  |              .
  7 item 7                                    .            |* |           .
  8 item 8                                    .          * |              .
  9 item 9                                    .            |     *        .
 10 item 10                                   .            |       *      .
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Gambar 2
Result of item fitness analysis

Based on the output of QUEST application in the it.out section aimed at showing the fitness of each item, all test items can be used as assessing instrument as shown in Table 5.

Table 5
Interpretation of vector representation and critical tthinking test items

Item No.	Delta	Difficulty Level Criteria	INFT MNSQ	Criteria	Outfit t	Criteria	Item Quality
Item 1	-0.64	Good	0.93	Fit	-1.1	Valid Item	Good
Item 2	-0.09	Good	0.97	Fit	0.0	Valid Item	Good
Item 3	0.01	Good	1.13	Fit	0.5	Valid Item	Good
Item 4	0.10	Good	0.99	Fit	0.4	Valid Item	Good
Item 5	0.13	Good	0.90	Fit	-1.3	Valid Item	Good
Item 6	0.01	Good	0.96	Fit	-0.7	Valid Item	Good
Item 7	-0.38	Good	1.02	Fit	0.3	Valid Item	Good
Item 8	-0.50	Good	0.98	Fit	0.4	Valid Item	Good
Item 9	0.68	Good	1.09	Fit	0.4	Valid Item	Good
Item 10	0.67	Good	1.10	Fit	0.7	Valid Item	Good

The item difficulty level is determined through the score of *difficulty* in the QUEST output. The result of the analysis of the difficulty level shown in Table 5 shows the

difficulty level of all of the vector representation and critical thinking test items is in a good category because they range from -2 to +2. Based on this result, the test items are feasible to use.

The item reliability can be seen in the output of the summary of item estimates and summary of case estimates. The reliability coefficients of the items are 0.64, which is in the high reliability category, and 0.46 which is in the medium reliability category This result is presented in Table 6.

Table 6
Analysis result of test item reliability

Category	Summary of item estimates	Summary of case estimates
Mean	0.18	0.60
SD	0.41	0.31
SD (adjusted)	0.33	0.21
Realiability of Estimate	0.64	0.46

Improvement in Vector representation and critical thinking abilities

The improvement of students' vector representation and critical thinking abilities can be seen in their test result before and after they used the Kofie GeBoL media and PPT. The test result was analysed, known as prerequisite test, i.e. normality and homogeneity tests. The field try out data were tested for their normality using the SPSS. The result of the normality test is based on Shapiro-Wilk formula. It can be seen in Table 7 and Table 8.

Table 7
Result of normality test of experimental class data

Class		Kolmogorov Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest	Vector	0.172	30	0.024	0.939	30	0.083
	Critical thinking	0.113	30	0.200	0.966	30	0.437
Posttest	Vector	0.166	30	0.034	0.926	30	0.039
	Critical thinking	0.152	30	0.076	0.954	30	0.217

Table 8
Result of normality test of control class data

Class		Kolmogorov Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Pretest	Vector	0.098	30	0.200	0.987	30	0.962
	Critical thinking	0.106	30	0.200	0.989	30	0.988
Posttest	Vector	0.144	30	0.117	0.966	30	0.432
	Critical thinking	0.226	30	0.000	0.792	30	0.000

According to Table 7 and Table 8, for the analysis of the normality test in column Shapiro-Wilk, vector representation and critical thinking abilities using the pretest and

posttest items for the experimental class and control class is obtained a significant value (sig.) higher than 0.05, and thus it can be concluded that H_0 is accepted. This means that the data from the experimental class and control class come from the population with normal distribution.

The homogeneity test was conducted to see whether or not the data were from a homogeneous population. This analysis was done by using the SPSS program with reference to Box's Test of Equality of Covariance Matrices.

Table 9
Box's test of equality of covariance matrices

Variable	Box's M	F	df1	df2	Sig.
Vector representation and critical thinking abilities	2.701	0.867	3	6.055E5	0.458

Based on the result of the homogeneity test shown in Table 9, the significance value of the variable of vector representation and critical thinking from Table Box's M is 0.458, which is bigger than 0.05, meaning that the data were from a homogeneous population.

Therefore, at the significance level of α=0.05 it can be concluded that the experimental and control classes have the similarity in the variant-covariant matrices of the same dependent variable.

The magnitude of the effect of the use of Kofie GeBoL media on the improvement of students' vector representation and critical thinking abilities can be seen in the result of the effect size test and Cohen's f calculation. This can be seen in Table 10.

Table 101
Result of effect size calculation

No.	Variable	Eta Square	Cohen's f	Interpretation
1	Vector representation	0.388	0.46	Large Effect Size
2	Critical thinking	0.453	0.57	Large Effect Size

Table 10 shows that the result of the effect size calculation shows Cohen's f value of each variable is 0.46, interpreted as *Large Effect Size* for vector representation ability, and 0.57 interpreted as *Large Effect Size* for critical thinking ability. This means that the developed Kofie GeBoL media give a large effect to vector representation and critical thinking abilities, and this is in line with previous research finding that comics have a big effect on the improvement of scientific skills (Albrecht, & Voelzke, 2015). It is concluded that Kofie GeBoL media are effective in improving students' vector representation and critical thinking abilities.

The improvement of the students' vector representation and critical thinking abilities on physics comic media through indigenous Android-assisted *Benthik* game in the operational field try out is seen from the *N-gain* scores. The data on the result of vector representation and critical thinking ability test are presented in Table 11.

Table 11
Result of vector representation and critical thinking ability test

No.	Ability	Number of students	Average Score		Average N-Gain Score	Category
			Pretest	Posttest		
1	Vector representation	30	25	79	0.7	High
2	Critical thinking		26	83	0.8	High

Table 11 shows that the *N-gain* scores in vector representation and critical thinking abilities are 0.7 and 0.8 respectively, and both scores are in a high category. The improvement of vector representation ability and critical thinking ability is presented in Figure 3.
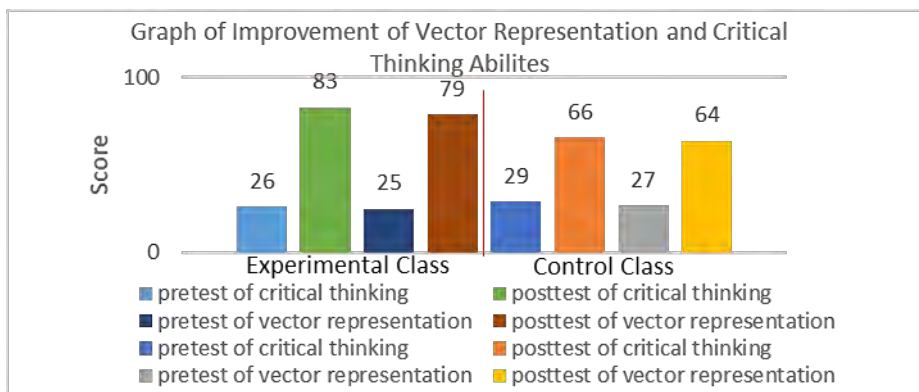
Figure 3
Improvement of vector representation and critical thinking abilities

Figure 3 shows the graph of the average scores in the pretest and posttest of vector representation and critical thinking abilities, whose increase is in a high category. This is relevant to the research finding stating that comic media can give a significant increase in physics instruction (Kurniawati, Wahyuni, & Putra, 2017).

The concept analysis is used to arrange, determine, and identify systematically the concepts to be taught and developed in Kofie GeBoL development. The implementation of the developed product was then tried out to students in the teaching of physics in schools, which aims to reveal the improvement of students' vector representation and critical thinking abilities after the use of Kofie GeBoL media. Figure 4 and Figure 5 present the *Benthik* game activities and Kofie GeBoL media.

a)
b)

Figure 4

a) *Benthik* game and b) *Benthong* and *Janak* for *Benthik* game

a)
b)
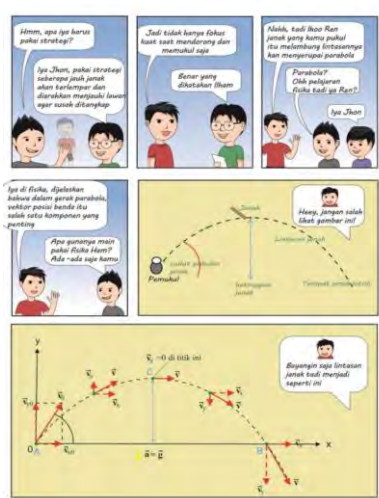
Figure 5

a) Comic Cover Display and b) Relevance of *Benthik* Game to Parabolic movement materials

Figure 4 is a part of parabolic movement which is included in Kofie GeBoL media. Figure 5 illustrates the *Benthik* game and the instruments used in the game, including two wooden sticks, the longer stick (*benthong*) and shorter stick (*janak*). Figure 5 a) presents the front cover of Kofie GeBoL media and the picture of the *janak* track which is parabolic in form analysed in each point using a vector. The competence emphasized in Kofie GeBoL media is vector representation and critical thinking abilities. The concept of parabolic motion material contained in benthic games, namely the trajectory of the janak in the form of a parabolic can stimulate students to improve their ability to represent vectors and think critically. These two abilities are presented in the form of dialogues and pictures in accordance with the storyboard based on the indicators of the two competencies. Physics comic through an android-based benthic game (Kofie GeBoL) is used for teaching vector representation and critical thinking skills on parabolic motion material. In the preparation of the comic storyline using the discovery learning method and vector material on the parabolic motion is clearly described in the comic image. This research is relevant to the use of comics in teaching and the result is that comics have good potentials as media for communicating science materials (Lin, 2015).

The developed instructional media of comic containing the teaching of vector representation facilitates students to understand the concept of vector and to solve problems with students' reasoning skills, related with Husna & Kuswanto (2018) research. The comic media were written according to the indicators of critical thinking ability. This is relevant to previous research finding that comic media can encourage students to solve problems in a logical way (Mutakinanti & Anwari, 2018). In addition, Raras & Kuswanto (2019) showed that physics instruction which integrates everyday life phenomena such as *Benthik* game is more interesting and physics instruction becomes more contextual (Ragil, 2018). This research is about the effectiveness of physics comics through the android assisted Benthik game (Kofie GeBoL) in improving vector representation and critical thinking skills, the result is that the Kofie GeBoL media used to improve vector representation and students' critical thinking skills obtained effective results in their use.

CONCLUSION

Based on the result of the study on the effectiveness of a physics comic through the Android-assisted *Benthik* game (Kofie GeBoL) in improving vector representation and critical thinking abilities, the result is that the Kofie GeBoL media used are effective in improving students' vector representation and critical thinking abilities. This is evidenced by Cohen's value of 0.46 interpreted as *Large Effect Size* for vector representation ability, and 0.57 interpreted as *Large Effect Size* for critical thinking ability. The research product in the form of physics comic media through indigenous Android-assisted *Benthik* game (Kofie Gebol) has a large effect on students' vector representation and critical thinking abilities. This can also be seen in the vector representation and critical thinking ability *N-gain* scores of 0.7 and 0.8 respectively, both of which are in the high category. This research is also relvant to the effectiveness

of Physics Mobile Learning (PML) with android-assisted to improve students' diargam representation and critical thinking skills (Saputra, M., & Kuswanto, H, 2019).

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