Indonesian Society for Science Educators
Journal of Science Learning
journal homepage: ejournal.upi.edu/index.php/jslearning

Development of Android-based Interactive Multimedia to Enhance Critical Thinking Skills in Learning Matters

Salma Almira Hamdani[1], Eka Cahya Prima[1]*, Rika Rafikah Agustin[1], Selly Feranie[2], Ahmad Sugiana[3]

[1]Department of Science Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Indonesia
[2]Department of Physics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia, Indonesia
[3]Department of Smart IT & Security, Woosong University, Republic of Korea

Corresponding Author: ekacahyaprima@upi.edu

ABSTRACT The advancement in science and technology in the 21st Century necessitates improving critical thinking skills in students. Implementing digital technology such as interactive multimedia in the learning process can encourage quality learning and teaching. This study aims to create Android-based interactive multimedia that will help students improve their critical thinking skills in learning matters. This research aims to develop android-based interactive multimedia to enhance critical thinking skills in learning matters. This research employed a developmental method that included analysis, design, development, implementation, and one group pretest-posttest to assess students' critical thinking skills. The participants were 30 students from Private Junior High schools in Bandung Barat. The instruments used were the expert's judgment rubric, students' questionnaire, and objective test. With an overall score of 88.25%, the experts' judgment score was classified as very good. Moreover, the average score of students' impressions was 84.56%, classified as very good. Based on the data analysis, the value of <g> is 0.52, which is classified as a medium enhancement. This finding indicates that students' critical thinking skills improve after applying Android-based interactive multimedia.

Keywords Student's Critical Thinking Skills, Android, Interactive Multimedia, Matter

1. INTRODUCTION

PISA or Program for International Students Assessment held every three years since 2000. Indonesia is one of the countries that have participated in the Pisa test. However, from 2000 to 2018, the average PISA test earned by Indonesian students never exceeded the global average. For example, in 2018, the average score for science was 296, while the global average score for science was 489 (Schleicher, 2018).

The PISA test score shows that Indonesia's science learning results are still relatively low. Furthermore, the low ranking received by Indonesia implies that Indonesian students' critical thinking abilities are also relatively low. According to Schleicher (2018), one of the goals of the PISA test is to help students succeed in the 21st Century. Therefore, one way to help them compete is to improve their critical thinking skills.

According to Regulation of the Minister for Education and Culture of the Republic of Indonesia Number 20 of 2016, students must have creativity, productivity, critical thinking, independence, collaboration, and communicative skills (Permendikbud RI, 2016). Critical thinking should be taught to students, and it is one of the most important goals of learning and an inseparable aspect of education at all levels (Utami, Saputro, Masykuri, & Widoretno, 2017). According to Lee et al. (2016), in 21st-century learning. Critical thinking is one of the skills that students must have. According to Facione (2011), critical thinking aims to make an argument, interpret something, or solve a problem. According to Facione (2011), there are six skills of critical thinking needed, namely interpretation, analysis, inference, evaluation, explanation, and self-regulation.

According to Sumardi, Rohman, and Wahyudiati (2020), to improve 21st-century skills such as critical thinking skills, the learning activities must include 21st-century learning features such as student-centered or constructive learning, technology integration, and HOST level questioning. In addition, Siregar and Situmorang

Received: 4 May 2021
Revised: 13 February 2022
Published: 1 March 2022

(2017) stated that critical thinking is a component of higher thinking abilities.

However, Sumardi et al. (2020) discovered that most learning activities used teacher-centered learning, relied on conventional methods, did not use technology, and students' higher-order thinking skills were underdeveloped. Furthermore, according to Utami et al. (2017), the majority of the teachers still ask questions that are slightly lower in cognitive ability than the higher-level questions. According to Sookoo-Singh and Boisselle (2018), the teacher-centered model does not enable students to use and improve their thinking skills. As a result, we must find an alternative method of assisting students in using and developing their thinking abilities to enhance their academic activities.

As we all know, the 21st Century is the age of globalization. Science, information, and technology are developing at a rapid pace. Therefore, technology can support learning activities as an additional medium (Irawan, Nyoman Padmadewi, & Artini, 2018). According to the UNESCO website, Ahmar and Rahman (2017) stated that the ICT will contribute to freedom of access to education, equity of education, and the promotion of a high-quality learning process. In addition, Sumardi et al. (2020) revealed that digital media is one of the technologies used for learning activities. Therefore, digitalization of the education process and student-centered learning are two key characteristics of 21st Century education. Consequently, ICT moves the focus of teaching and learning activities from teacher-centered to student-centered.

Interactive multimedia is one digital medium that can be used for educational purposes. According to Saputri, Rukayah, and Indriayu (2018), interactive multimedia combines some media such as audio, image, text, animation, video, and games. It allows the students to engage with the device. In addition, Hadisaputra, Gunawan, and Yustiqvar (2019) discovered that using interactive multimedia in the learning process has been shown to increase learning outcomes, critical thinking skills, conceptual comprehension, and motivation.

Mobile application is one form of interactive multimedia developed for educational purposes. According to Widodo et al. (2020), gen-Z students cannot be separated from their gadgets. 17.17 million active users utilize the gadget to access digital content. Furthermore, almost every elementary to senior high school student owns a smartphone. Referring to Kocakoyun and Bicen (2017), mobile learning is suitable for education because it is more efficient and can support the classroom's learning process outside the classroom. Bidin and Ziden (2013) discovered that mobile learning allows for student-centered learning and active participation in the learning process.

There are several higher-powered mobile operating systems, one of which is Android. Android is an open-source operating system. Furthermore, the Android application development is more user-friendly than other platforms (Walker, 2011). Furthermore, since the Android platform is open source, some programming tools are free (Ma, Gu, & Wang, 2014). Furthermore, Fajar, Safii, and Andajani (2021) revealed that Android is used by 75% of mobile users in Indonesia. This data indicates that Android users outnumber other platform users.

In this research, the subject of chemistry was selected, and the topic was the matter. According to Hadisaputra et al. (2019), critical thinking skills are related to chemistry since chemistry itself consists of macroscopic and microscopic aspects that require critical thinking skills to connect those aspects. However, since microscopic particles are invisible to the naked eye, most students still struggle with abstract concepts. Sya'bandari, Firman, and Rusyati (2017) revealed that students struggle with matter topics because they can still link abstract and concrete aspects. Furthermore, according to Yuniarti, Yeni, and Yokhebed (2017), abstract concepts can be visualized through interactive multimedia. Kotevsk and Tasevska (2017) also stated that it could develop students' cognitive abilities in learning and encourage students to understand abstract concepts.

Previous research has been developed on interactive multimedia and the Android-based platform. Djamas and Ramli (2019) investigated the impact of interactive multimedia on critical thinking skills in the context of studying Newton's Law. It was discovered that developing interactive multimedia with fitted games would help students improve their critical thinking skills. Another study was carried out by (Widodo et al., 2020). They created interactive multimedia for gadgets. The media will help students enhance their scientific literacy in learning pressure with medium enhancement based on the findings. Hamimi and Sari (2020) also researched developing Android-based interactive multimedia. The media was created to teach the subject of buffer solutions. This research focused on analyzing the media quality media validated by the experts and the efficacy of media in terms of learning outcomes.

Regarding the background above, interactive multimedia has increased learning outcomes, motivation, and critical thinking skills. However, there was still a lack of science learning multimedia to help students develop their critical thinking skills. Therefore, this research aims to develop Android-based interactive multimedia in Junior High School. Furthermore, this research also focuses on students' critical thinking skills, which is one of the goals of education. Therefore, this research aims to develop Android-based interactive multimedia to enhance critical thinking skills in learning matters.

2. METHOD

2. 1. Research Method

Based on the purpose of this study, the developmental research method was applied in this study. This method was appropriate for this research because, according to Sugiyono (2013), this method is used to develop new products and evaluate the effectiveness of the products. Developmental research based on Richey and Klein (2005) is the systematic study of designing, developing, and evaluating instructional programs, processes, and products that must follow internal quality and product effectiveness.

The method of this study includes several phases, including the analysis stage, product design, product development, product validation, and evaluation. And then, the product was revised following the experts' recommendations. Finally, since the media had been revised, the product was distributed to the students to analyze the media's readability and effectiveness in terms of critical thinking skills.

One group pretest and posttest were conducted to determine the product's effectiveness. According to Fraenkel, Wallen, and Hyun (2012), one group pretest-posttest is a single group that measures or observes the impact of treatment and before treatment. First, the pretest aims to determine the student's prior knowledge about a matter topic. After that, the Android-based interactive multimedia was implemented in learning matter. Furthermore, there was a posttest to investigate how students' critical thinking skills improved after applying the Android application. The posttest had the same question as to the pretest. The difference only was in the test time. The one-group pretest-posttest design is shown in Table 1.

Table 1 Experiment method

Group	Pretest	Treatment	Posttest
Experiment	O_1	X	O_2

2.2. Participants

The subjects of this study were students and experts. The experts are experts in science topics and experts on media. The location of this research was held in one private Junior High School in Bandung Barat. This school uses Indonesia Curriculum 2013 (Kurtilas). This school was selected because all of the participants have their Android smartphones. There were 30 students of 7th grade who participated in this research. The students were chosen through the convenience sampling technique.

2.3. Research Instrument

The instruments are used to gain the data in this research. There are three types of instruments used in this research:: expert's judgment rubric, student questionnaire, and objective test. An expert judgment rubric was used to validate the quality of the application. This rubric was arranged following the Learning Object Review Instrument (LORI) from the study of Leacock and Nesbit (2007). This rubric consists of six indicators: information structure, mechanical, interface, learning content, motivation, and multimedia. A student questionnaire was used to assess students' responses after applying Android-based interactive multimedia. The aspects included in the student's questionnaire are mobile connectivity, materials, project, quiz, mobile interface, and multimedia.

An objective test was used for pretest and posttest to measure the students' critical thinking skills before and after implementing interactive multimedia in learning matters. There are 20 multiple-choice questions on this test. The questions are relevant to the matter topic limited by basic competence 3.3 in curriculum 2013. The questions consist of five critical thinking aspects by Facione (2011): interpretation, analysis, inferring, evaluation, and explanation. The experts judged the questions before being distributed to the students. After revising the questions, the test was sent to 8th-grade students who studied the matter. After that, ANATES was used to analyze the validity, reliability, difficulty level, distinguish power, and distraction. Table 2 shows the distribution of test items.

Table 2 The distribution of test items

No	Critical Thinking Skills	Number	Total
1.	Interpretation	1, 2, 3, 4	4
2.	Inference	5, 6. 7. 8	4
3.	Analysis	9, 10, 11, 12	4
4.	Evaluation	13, 14, 15, 16	4
5.	Explanation	17, 18, 19, 20	4
Total			20

2.4. Data Analysis

The result expert's judgment rubric and student's questionnaire were analyzed by comparing the result with the cumulative value of the highest total score. Then, the result was converted to a percentage. Table 3 shows the interval percentage category based on (Arikunto, 2010). SPSS version 25 was used to interpret the data from the pretest and posttest. Some tests such as the homogeneity test, normality test, N-Gain test, and hypothesis test were used to analyze the data. If the data is normally distributed, the data is analyzed using a paired sample t-test. Meanwhile, if the data is not normally distributed, the data is analyzed using Wilcoxon signed-rank test.

Table 3 Percentage range

No.	Interval Percentage	Category
1.	80%<score<100%	Very Good
2.	60%<score<80%	Good
3.	40%<score<60%	Fair
4.	20%<score<40%	Poor
5.	0% - 20%	Very Poor

2.5. Research Procedure

This research consists of several stages. The first stage is analysis or called the preparation stage. This stage consists of material analysis. Software analysis and hardware analysis. The next stage is the design stage. In this stage, the flowchart and storyboard were created. The flowchart illustrates the story flow of Android-based interactive multimedia. The storyboard has a function as a visual draft of the application developed. And then, in the development stage, the application was constructed based on the flowchart and storyboard. The application was created using Articulate Storyline 3. The output of media created by Articulate Storyline 3 is an HTML file. The HTML file was converted into the Android application using Website 2 Apk Builder pro 4.0. After that, the application was validated by five experts to assess the quality and give some suggestions. The application was revised based on the expert's suggestions.

After that, the application was carried out to the student to be implemented in the learning matter. Due to this pandemic situation, the research was done through the online system. Before implementing the application, the students were asked to fill out the pretest via a google form. At the first meeting, the students were given the link to download the Android application. They learned about sub-chapter 1 and 2. At the second meeting, the students learned sub-chapter 3 and 4. At the last meeting, the students did a posttest via a google form. At the end of the learning session, the students were asked to fill out the questionnaire to gain the students' impression after implementing Android-based interactive multimedia.

3. RESULTS AND DISCUSSION

The results show the process to develop the Android application, the quality of media that have validated by the expert, the student's responses after implementing Android-based interactive multimedia in learning matter, and the data analysis obtained from pretest and posttest to determine the effectiveness of Android-based interactive multimedia in improving students' critical thinking skills.

3.1. The Development of Android-based Interactive Multimedia

There are several stages to develop Android-based interactive multimedia: analysis, design, and development.

Analysis Stage

The first stage is the analysis stage, also called as preparation stage. Content, software, and hardware were analyzed before creating the application. Content analysis is essential to creating Android applications for educational purposes. In this research, the matter topic was selected. This topic is limited by Indonesian Curriculum 2013, which stated basic competence 3.8 and 4.8. This analysis is also conducted to decide the sub-chapter included in the application. The sub-chapters included in this application are the characteristics of matter, the properties of matter, the states of matter, single substance, mixture, the changes of matter, and separation of matter.

The software necessity analysis was conducted to decide the software used to construct the application. In this research, Articulate Storyline 3 was used to create interactive multimedia. The output of this software is HTML type. After that, the HTML file was converted to an Android application using Web 2 Apk Builder Pro 4.0. Hardware must be analyzed because the specification must meet the software's minimum requirements.

Design Stage

In this stage, a flowchart and storyboard were created. The flowchart shows the narrative flow of interactive multimedia. The flowchart is started from the beginning of interactive multimedia until the end by the user. And then, the process continued with designing the storyboard. The storyboard provides the visualization and an overview of the application produced. It has a function as a visual blueprint.

Development Stage

After designing the flowchart and storyboard, the Android-based interactive multimedia was developed. First, the application was created using Articulate Storyline 3. Inserting objects, adding action, giving button effects, making navigation, adding games, inserting audio and video, creating animation, and showing pop up are all part of the application development process. The output of interactive multimedia constructed by Articulate Storyline 3 is an HTML file. And then, Web 2 Apk Builder Pro 4.0 was used to convert the HTML file into an Android application. After constructing the Android application, it is ready to be validated by the experts. The example of application interface was done as follow:

1) First Page

When the user opens the application, the first page will appear. The user should click the button to go to the next page. Figure 1 shows the interface of the first page.

Figure 1 The First page of the application

2) Loading Page

This page appears after the first page. When the loading bar is completed, it will go to the main menu page. Figure 2 shows the interface of the loading page.

3) Input Name and Choose Character

Figure 2 The Interface of Loading Page

On this page, the user should fill the textbox with their name. After that, they should select the character depending on their gender. Figure 3 shows the interface of the input username. After they choose the character, the

Figure 3 The interface of choosing character and input name

welcoming page will appear. Next, they should click "*Ayo Mulai Belajar*" on the main menu page. Figure 4 shows the interface of the welcoming page.

Figure 4 The interface of the welcoming page

4) Main Menu

On the main menu page, there are some buttons. For example, the sound button has a function to turn in and turn off the music and an exit button to end the program. There are four menus, which are *petunjuk*, *kompetensi*, *profil*, and *materi*. Figure 5 shows the main menu.

5) Learning Content Menu

On this page, there are four sub-chapter. The first sub-chapter is the characteristics and properties of matter. The second is the changes of matter. The third is a single

Figure 5 The interface of the main menu

substance and mixture. Furthermore, the last is the separation of matter. The user has the option of selecting which sub-topic will be played first. The home button has a function to go to the main menu. Figure 6 shows the interface of the learning content page.

Figure 6 The interface of the learning material menu

6) Learning Content

The learning content in this application is related to a matter topic. Figure 7 and 8 shows the example of the learning content page.

Figure 7 The example of learning content

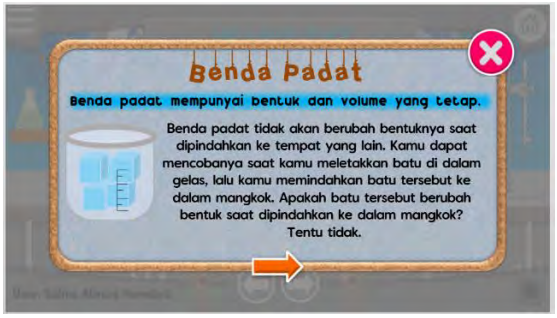

Figure 8 The example of pop up information

7) Multiple Choice Quiz

Multiple quizzes will appear in each sub-chapter. Most of the multiple-choice are used for analyzing something. Figure 9 shows the example of multiple choice.

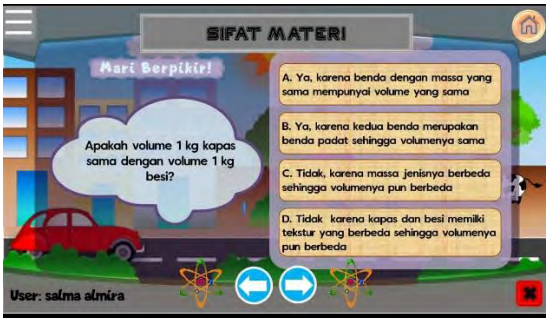

Figure 9 The example of Multiple quizzes

8) Pick Much Game

In this game, the user should pick more than one of the correct answers. The color of the option selected by the user will change. They have three chances to play this game until they answer the correct answers. If they still lost, the correct answer will appear at the third chance. Figure 10 shows the interface of this game.

Figure 10 The interface of "Pick many game"

9) Drag and Drop Game

This game requires the user to categorize something by dragging and dropping the object to the empty column. This game also provides three chances. Figure 11 and 12 shows the example interface of the drag and drop game.

Figure 11 The interface of drag and drop game

10) Matching Quiz

This game requires the user to match the types of the separation of mixture with the correct example in daily life. Figure 13 shows the interface of the matching quiz.

Figure 12 The interface of drag and drop game

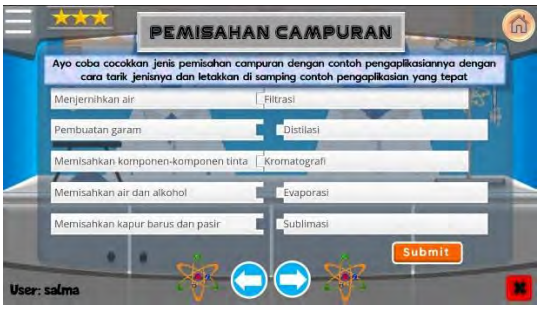

Figure 13 The interface of matching quiz

11) The Animation of Particle Movement

This page shows the particle movement of solid, liquid, and gas. This page aims to visualize an abstract concept. Figure 14 shows the interface of this page.

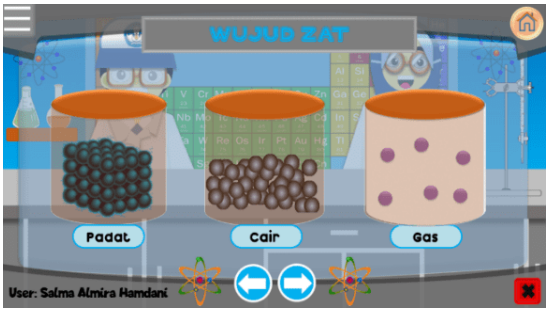

Figure 14 Particle movement animation

12) Appreciation Page

At the end of each sub-chapter, there is a page to appreciate the students who have finished the learning activity. For example, figure 15 shows the interface of particle movement animation.

Figure 15 The interface of the appreciation page

This interactive multimedia consists of texts, images, videos, animations, simulations, quizzes, and games. In this application, the users read the material, but they are also invited to think and analyze something before learning a new concept. For example, they have to analyze the different characteristics of metals and non-metals before learning about metals and non-metals. After that, they can conclude it. According to Facione (2011), analyzing is one of the critical thinking indicators that must have by students. Moreover, students are also required to enhance their skills in analyzing something.

This media is also equipped with games to improve students' critical thinking skills and comprehension of the concepts taught. The games that are used in this application are "pick many" games, "drag and drop" games, and "matching" games. In addition, it is also equipped with multiple-choice quizzes. The previous research conducted by Yang and Chang (2013) has suggested digital game effectiveness in developing critical thinking capabilities. After using digital game-based learning, they discovered a significant enhancement in critical thinking skills and learning outcomes.

It also presents abstract concepts such as solid, liquid, and gas-particle movement animation. This is intended to assist students in making connections between macroscopic and microscopic aspects. According to Yuniarti et al. (2017), interactive multimedia will make abstract concepts easier to visualize and understand. The Lestari, Basri, Yusuf, Suciati, and Masykuri (2019) study supports it, which found that interactive multimedia would help students understand abstract concepts better.

3.2. Expert's Judgment Validation

Five experts validated the Android application. The result of the expert's judgment can be seen in Table 4.

Table 4 Expert judgment result

No.	Students' Respond Aspect	Average Scale	Percentage
1	Mechanical	3.48	87%
2	Multimedia	3.60	90%
3	Information Structure	3.50	87.50%
4	Motivation	3.40	85%
5	Mobile Interface	3.40	85%
6	Learning Content	3.80	95%
Average		**3.53**	**88.25%**

Based on Table 4, six aspects were assessed by the experts. The average score is 3.53, with a ratio of 88.25%. Since the score was higher than 80%, the result was excellent. Furthermore, the learning content has the highest average score of 95%, considered very good. Therefore, it can be concluded that the quality of learning content is excellent. Furthermore, it is determined that the learning material meets the Indonesian curriculum 2013, the content is specifically explained, the scientific terms are correctly written, the learning content is quite deep, the learning objective matches the learning experience with the Android smartphone, and it can be used to exercise critical thinking skills.

Ozdamli and Cavus (2011) mentioned that one of the essential elements of mobile learning is content. According to Cairncross and Mannion (2001), the application's content should be integrated with the curriculum. Furthermore, they suggested that the depth of learning materials affects students' comprehension. Ambarwati and Suyatna (2018) stated that critical thinking is a skill that must be learned and incorporated into curriculum contents in order for students to engage in constructive learning.

The multimedia aspect has the second-highest average score of 90%, which is considered very good. The multimedia in the Android application, such as images, videos, text, animation, and graphics, can help promote the learning content because it is representable, accessible, and consistent with the learning materials. Ozdamli and Cavus (2011) revealed that the graphics, video, and multimedia components could support mobile learning. Furthermore, Nordin, Embi, and Yunus (2010) claimed that multimedia representation should be used in mobile learning practices. It ensures that the text, audio, video, animation, video, and 3D object must provide learning content.

The third-highest average score is information structure with 87.50%, categorized as very good. It indicates that overall the information is well-structured. It also indicates that the learning materials are well organized. Ozdamli and Cavus (2011) stated that mobile learning should be systematized. According to Parsons, Ryu, and Cranshaw (2007), the most fundamental mechanisms of the learning experience are the structure of information and the systematic content distribution. Furthermore, Nordin et al. (2010) found that well-organized learning material can help students understand and retain the information.

And then, mechanical has an average score of 87%, which is categorized as very good. This finding shows that the navigation, interactivity, and buttons are considered very good. Dalle, Hadi, Baharuddin, and Hayati (2017) revealed that navigation is used to carry out the layout, create the grid system and division, and connect one page to the next or previous page. According to Hamimi and Sari (2020), interaction is the key feature of digital media. The interactive feature allows the users to interact with media.

With a score of 85 percent, motivation and interface aspects receive the lowest rating. Although those aspects have the lowest score, they are still considered very good. It means that the interface is quite attractive nice enough to entice students to read, increasing students' learning motivation. Overall, the application's evaluation has yielded a positive outcome. According to Parsons et al. (2007), the

Table 5 Experts' suggestions for application improvement

Indicator	Suggestions/Comments
Mechanical	1. There are some button that does not work
	2. The media is ready to use
	3. There are a few typos of text
	4. The sub-menu buttons at the top of the slide is not eye-catching
Multimedia	1. Font in competency menu is less clear
	2. The video animation about boiling water and alcohol, there are no bubbles
	3. Atomic size and color consistency for all slides
	4. The image of the stone in a beaker is not like a stone
	5. In the compound section, the molecular description is inconsistent because some are listed in the atom's name, and some are not.
	6. The animation of a mixture of water and condensed milk chocolate is not neat spoon movement
Information Structure	1. Please add the instruction to click the elements and compounds section to get the information
Motivation	-
Interface	1. Put the source of images that are taken from the internet
	2. There is a text that is not very clear
	3. The car movement as a background is disturbing
	4. The image on the properties of matter page is not very clear because it overlaps the background
	5. It is better to change the title color so that it contrasts with the background
	6. the color of filtrate during the filtration process is not clear
Learning Content	1. It is better to make the content about air into multiple slides.
	2. For the difference between metal and non-metal, please make it like a quiz again
	3. Added Berzellius-based element naming rules
	4. Add crystallization process because some students are still confused with differentiating between crystallization and evaporation
	5. The distillation page explains the process of separating water and alcohol, so it is better to show the video about that process.
	6. In the sublimation video, it should be added the ice on the top of the petri dish

interface is one of the essential features of the mobile environment, and it must satisfy the needs of the user. Saputri et al. (2018) supported it, who claimed that an attractive interface would entice the students to learn by interactive multimedia. Hamzah, Ali, Saman, Yusoff, and Yacob (2015) revealed that the interactive feature of e-learning is one of the features to increase students' motivation.

Overall the application's validation yielded an outstanding response because, based on Figure, the score of each indicator is greater than 80%. And then, the overall average is 88.25%, which is considered very good. Therefore, the results obtained by the expert judgment are considered to be valid, and the application is appropriate for educational purposes. In addition, the experts gave some recommendations for enhancing the quality of the application. Table 5 presents several recommendations and remarks from the experts. All recommendations were responded to to improve the quality of learning media.

3.3. Students' Responds after Implementing Android-based Interactive Multimedia

The students' responses toward the application were obtained from the questionnaire. The result of students' responses is tabulated in Table 6.

Table 6 Students' responses towards interactive multimedia

No.	Students' Respond Aspect	Average Scale	Percentage
1	Mobile Connectivity	3.36	84.08%
2	Materials	3.42	85.42%
3	Projects	3.25	81.25%
4	Quiz	3.37	84.17%
5	Mobile Interface	3.43	85.75%
6	Learning Experience	3.45	86.25%
7	Multimedia	3.40	85.00%
Total		23.68	591.92%
Average		**3.38**	**84.56%**

Table 6 shows that the student's response has an average score of 84.56%, which is considered very good because the percentage is more significant than 80%. It indicates that students have responded positively to the Android application. The learning experience got the highest score, with 86.30%, considered very good. It indicates that the application is fun, motivates students to learn through it, and allows them to learn independently.

This aspect consists of motivation and learning independently. It means that the use of android-based interactive multimedia can increase motivation. This result is in line with Adrizal and Pahlifi (2020). They discovered that Android-based learning improved the students' motivation in the learning process.

The second-highest result is the interface aspect, with a score of 85.75%, classified as an excellent response. It means that the design is appealing and quite attractive, the text is readable, the images and the other media are accessible. These findings align with the previous research by Adipat and Zhang (2005), which stated that the purpose of designing a mobile learning interface is to make it easier for the users to engage with the application. According to binti Ayob, Hussin, and Dahlan (2009), the user interface is one of the essential features of an application. A good interface will entice users to use the application.

And then, materials aspect as the third-highest result with 85.42% is considered an outstanding response. It can be indicated that the materials are easily comprehendible, the explanations are clear, and the contents are well-organized. This result is in line with the previous study by Nordin et al. (2010), which found that students are more able to interpret or comprehend the information if it is well-organized.

The quiz's percentage is 84.17 %, categorized as very good. The quiz's percentage result indicates that the question and game will help the students improve their understanding of the topic. According to Ozdamli and Cavus (2011), quizzes or interactive games may be used as an additional or supplementary method of presenting content to assist the users in obtaining required knowledge. Ariani and Festiyed (2019) claimed that students' motivation and critical thinking abilities could be improved using game-based learning. It can also be used to make studying more enjoyable for students and to improve their concentration.

As seen in Figure, the percentage of mobile connectivity is 84.08%, which is an outstanding response. It means that the application is user-friendly, the buttons are easy to use efficient, and the application is easy to connect. According to Parsons et al. (2007), mobility is the core function of the mobile learning environment. One of the general criteria for mobile learning, according to Nordin et al. (2010), is that it be user-friendly. The application's connectivity should be easy to utilize and should not cause technophobia.

With an 81.25%, the project aspect receives the lowest score. However, even though it has the lowest score, the percentage result shows it is classified as a very good response. Also, it indicates that the project in the Android application is entirely interactive. Furthermore, the average students' impression score shows that students positively respond to the application. According to Huang (2005), the successful interactive multimedia design allowed students to imagine complex concepts, facilitate problem-solving, constructive learning, critical thinking, and engage with the contents and quizzes.

On the blank space provided by the researcher, the students also wrote their impressions and suggestions regarding the application. In general, the students showed positive responses toward the application. The majority of them stated that the application is attractive, has a nice appearance, helps study, the learning content is easy to comprehend, the application makes them happy because it provides them with much new knowledge. In addition, they can learn while playing, it provides them with new insight, increases their enthusiasm for learning, is enjoyable to play, and they would like an application similar to "Funter" for other topics.

Some students also have offered their suggestions to improve the application's quality. For example, they recommended that the file size be reduced, some bugs must be fixed, and the animation being played should be reduced. Overall, students' suggestions are helpful and acceptable. The suggestions would be taken into consideration for the finalization of the application.

3.4. The Effectiveness of Android-based Interactive Multimedia towards The Improvement of Student's Critical Thinking Skills

This study aims to develop Android-based interactive multimedia that will help students enhance their critical thinking skills. First, the results obtained from the pretest and posttest were used to analyze the effectiveness of the application in improving students' critical thinking skills. After that, the normality, homogeneity, hypothesis, and normalized gain of the pretest and posttest results were tested using the SPSS version. The results of the homogeneity test can be seen in Table 7.

According to Table 7, the pretest posttest's significance (Sig.) value is 0.887. Since the value of Sig. is more significant than 0.05 (0.887>0.05), the variance of the data pretest and posttest can be assumed to be homogeneous.

The normality test is then used to determine the next step in the statistical analysis. Table 8 shows the results of the normality test data review. Since the number of students who participated in this study was less than 50, the Shapiro-Wilk test used in the SPSS application analyzed the

Table 7 Homogeneity test of variance

Levene Statistic	Sig	df2	Sig.
.020	1	58	.887

Table 8 Test of normality

Test	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	Df	Sig.	Statistic	Df	Sig.
Pretest	.195	30	.005	.925	30	.037
Posttest	.184	30	.011	.896	30	.007

normality test. According to Mishra et al. (2019), the Shapiro-Wilk test can be used to test the normality of a small sample size where the sample is less than 50 (n<50) because it has more ability to detect the non-normality.

If the significance value is more significant than 0.05, the data is considered normally distributed (Mishra et al., 2019). According to Table 8, the Shapiro-Wilk test has a significance value of 0.037 for the pretest and 0.007 for the posttest. According to the results, the significance value of the pretest is less than 0.05 (0.037<0.05), and the significance value of the posttest is also less than 0.05 (0.007<0.05). Therefore, it can be assumed that both the pretest and the posttest are not normally distributed. This study was continued with a Non-Parametric test using the Wilcoxon signed-rank test since the data is not normally distributed. The hypothesis was analyzed using the Wilcoxon to see whether it was accepted or rejected. The Wilcoxon test result is shown in Table 9.

Based on Table 9, the value of negative ranks has 0, indicating that all students' scores increased from pretest to posttest. It means that there was no score decrease. The value of positive ranks is 30. It indicates that 30 students improved their learning outcomes from the pretest to posttest so that all of the students' scores were increased. The average rank is 15.50, and the total ranking is 465,000. Based on the result, the value of ties is 0, indicating that the pretest and posttest scores are not the same. The hypothesis research results can be seen in Table 10.

As seen in Table 10, the Asymph. Sig. (2-tailed) is 0.00 which is less than 0.05 (0.00<0.05). It can be assumed that the H1 is accepted and H0 is rejected. It can be inferred that there is a significant difference in students' critical thinking skills after applying the Android-based interactive multimedia. It can also be concluded that students' critical thinking skills have improved after applying Android-based interactive multimedia in learning matters. This finding aligns with the previous research by Ariani and Festiyed (2019), which found that interactive multimedia would help students develop their critical thinking abilities. Table 10 shows the descriptive statistics of students' critical thinking.

According to Table 10, the average pretest score is 46.50 and 70.50 for the posttest. Since the posttest score is greater than the pretest, it can be concluded that the score has improved as a result of the use of Android-based interactive multimedia. And then, the normalized gain (N-gain) based on Hake's Rule was used to analyze the improvement. N-gain was used to determine whether or not students' critical thinking skills have improved as a result of the implementation of the application, as well as the level of improvement.

Based on Table 10, the value of N-Gain is 0.52, which is considered a medium improvement. According to Hake's Rule, if the score 0.30<g≤0.70 is classified as a medium improvement. It denotes medium improvement from the pretest to the posttest. It indicated that students' critical thinking abilities had improved moderately due to implementing the application in learning matter. The improvement of students' scores indicates that the features and media used in Android-based interactive multimedia will assist the students in training and improving their critical thinking skills. These findings are relevant to the previous research by Jeno, Grytnes, and Vandvik (2017). They discovered that the test scores improved after applying for the smartphone program in learning activities. The other research conducted by Hamimi and Sari (2020) found that Android-based interactive multimedia can enhance learning achievement in learning chemistry.

This study also analyzes each critical thinking aspect to determine the improvement of each aspect of critical thinking. This analysis aims to assess the effectiveness of interactive multimedia in enhancing critical thinking in each of its aspects.

As seen in Figure 16, the explanation has the greatest N-Gain score of 0.55. It can be assumed that the implementation of Android-based interactive multimedia can enhance the student's ability to state results, explain processes or procedures, present arguments or claims,

Table 9 Wilcoxon signed-rank test

Test	Posttest-Pretest
Z	-84.816
Asymph. Sig. (2-tailed)	.000

Table 10 Descriptive statistics of students' critical thinking skills

Component	Pretest	Post-Test
N	30	30
Average Score	46.50	70.50
Standard Deviation	19.790	19.775
Highest Score	90	100
Lowest score	20	45
Gain	24	
N-Gain	0.52	

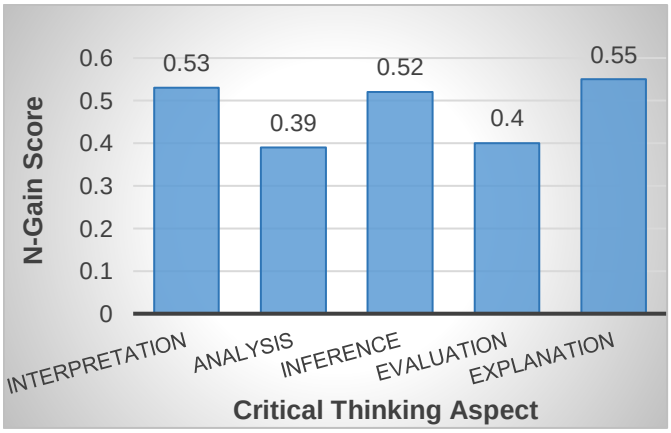

Figure 16 N-gain score of critical thinking aspect

provide reasoning. Then, followed by interpretation with a score of 0.53, indicating that the student's ability to express the meaning, categorize, and decode significance has improved. The N-gain score of the inference aspect is 0.52, indicating that students' ability to draw logical conclusions, query evidence, and conjecture alternatives have improved. Next, the evaluation aspect has a score of 0.40. It can be assumed that students' ability to evaluate the credibility of claims and evaluate or judge the argument has improved.

Moreover, with a score of 0.39, the analysis aspect has the lowest N-gain score. Last is analysis has the lowest N-Gain score. Despite having the lowest N-gain score, students' ability to examine ideas or theory, identify arguments, and identify reasons and claims has improved. Larson and Miller (2011) revealed that the students must be encouraged to apply knowledge, interpret it, analyze it, synthesize it, and constantly evaluate it. Those abilities can be combined with the use of technology.

This finding aligns with the previous study conducted by Amir, Hasanah, and Musthofa (2018). They discovered that interactive multimedia significantly increased students' ability to conclude, analyze evidence, make conjecture alternatives, examine and validate arguments or claims, reasoning skills, present results with information and scientific knowledge, and even evaluate the arguments' claims. Furthermore, Lestari et al. (2019) found that using multimedia in the learning process will help students improve their ability to think critically, interpret information, analyze facts, make decisions, and judge a statement or argument. According to Sari, Aryana, Subarkah, and Ramdhani (2018), interactive multimedia enhanced the student's ability to explain the meaning.

Overall, students' critical thinking skills improved after implementing the Android-based interactive multimedia in learning matters. Therefore, it can be concluded that Android-based interactive multimedia is quite effective in enhancing students' ability to think critically in learning matters. This result is relevant to the previous study conducted by Rahmawati, Labibah, and Kuswanto (2020), which showed that using Android-based learning media would help students develop their critical thinking skills. It also relates to the previous research conducted by Ariani and Festiyed (2019), which showed that interactive multimedia effectively enhances students' critical thinking skills. According to Djamas and Tinedi (2021), learning media helps students effectively engage, such as deciding how they must learn to develop their critical thinking skills.

CONCLUSION

Android-based interactive multimedia can be developed in several steps. The first stage is the analysis stage which consists of content analysis, software, and hardware analysis. The second step is the design stage, including learning materials, making a flowchart, and designing the storyboard. The third stage is the development which consists of interface construction and application development. After finishing the application, it is validated by the experts. Based on experts' validation, the average score of all indicators is 88.25%, which indicates that the application was categorized as very good and ready to be used. After that, the application was carried out to the student to be implemented in the learning matter. Students gave a positive response to the application. It is proved by the average score of the students' questionnaire with 84.56%, which is a very good response. It also can be indicated that the application is feasible to be used as learning media. After implementing Android-based interactive multimedia, students' critical thinking skills have improved. The pretest and posttest score data analysis obtained the N-Gain score of 0.52, which can be categorized as a medium improvement. It can be concluded that the Android-based interactive multimedia is quite effective in enhancing students' critical thinking skills in learning matters.

ACKNOWLEDGMENT

This work was supported by Penelitian Terapan Unggulan Perguruan Tinggi, Ministry of Education and Culture, Republic of Indonesia 2021.

REFERENCES

Adipat, B., & Zhang, D. (2005). Interface design for mobile applications. *Association for Information Systems - 11th Americas Conference on Information Systems, AMCIS 2005: A Conference on a Human Scale*, *3*, 1157–1166.

Adrizal, M., & Pahlifi, D. M. (2020). The use of android media in improving students' motivation in learning sports physiology. In *Journal of Physics: Conference Series* (Vol. 1440, No. 1, p. 012075). IOP Publishing.

Ahmar, A. S., & Rahman, A. (2017). Development of teaching material using an Android. *Global Journal of Engineering Education*, *19*(1), 72–76. https://doi.org/10.26858/gjeev19i1y2017p7376

Ambarwati, D., & Suyatna, A. (2018). Interactive design for self-study and developing students' critical thinking skills in electromagnetic radiation topic. *Journal of Physics: Conference Series*, *948*(1). https://doi.org/10.1088/1742-6596/948/1/012039

Amir, M. F., Hasanah, F. N., & Musthofa, H. (2018). Interactive multimedia based mathematics problem solving to develop students' reasoning. *International Journal of Engineering and Technology(UAE)*, *7*(2.14 Special Issue 14), 272–276.

Ariani, R., & Festiyed, F. (2019). Analisis landasan ilmu pengetahuan dan teknologi pendidikan dalam pengembangan multimedia interaktif. *Jurnal Penelitian Pembelajaran Fisika*, *5*(2).

Arikunto, S. (2010). *Management Penelitian*. Jakarta: Rineka Cipta.

Bidin, S., & Ziden, A. A. (2013). Adoption and application of mobile learning in the education industry. *Procedia-social and behavioral sciences*, *90*, 720-729.

binti Ayob, N. Z., Hussin, A. R. C., & Dahlan, H. M. (2009). Three layers design guideline for mobile application. In *2009 International Conference on Information Management and Engineering* (pp. 427-431). IEEE.

Cairncross, S., & Mannion, M. (2001). Interactive multimedia and learning: Realizing the benefits. *Innovations in Education and Teaching International*, *38*(2), 156–164. https://doi.org/10.1080/14703290110035428

Dalle, J., Hadi, S., Baharuddin, & Hayati, N. (2017). The development of interactive multimedia learning pyramid and prism for junior high school using macromedia authorware. *Turkish Online Journal of Educational Technology*, 2017(Special Issue 2017), 714–721.

Djamas, D., & Ramli, R. (2019). Learning model based on discovery learning equipped with interactive multimedia teaching materials assisted by games to improve critical thinking skills of high school students. In

Journal of Physics: Conference Series (Vol. 1185, No. 1, p. 012054). IOP Publishing.

Djamas, D., & Tinedi, V. (2021). Development of interactive multimedia learning materials for improving critical thinking skills. In *Research Anthology on Developing Critical Thinking Skills in Students* (pp. 507-525). IGI Global.

Facione, P. A. (2011). Critical thinking: What it is and why it counts. *Insight assessment*, *2007*(1), 1-23.

Fajar, C., Safii, M., & Andajani, K. (2021, January). Video-Based Android Application Development as an Educational Facility for E-Journal Users at the Library of Universitas Negeri Malang. In *The First International Conference on Social Science, Humanity, and Public Health (ICOSHIP 2020)* (pp. 14-18). Atlantis Press.

Fraenkel, J. R., Wallen, N. E., & Hyun, H. H. (2012). *How to Design and Evaluate Research in Education*. New York: McGraw-Hill.

Hadisaputra, S., Gunawan, G., & Yustiqvar, M. (2019). Effects of Green Chemistry Based Interactive Multimedia on the Students' Learning Outcomes and Scientific Literacy. *Journal of Advanced Research in Dynamical and Control Systems (JARDCS)*, *11*(7), 664-674.

Hamimi, L., & Sari, R. P. (2018). The Development Of Proof Teaching Materials For High School Students. In *ICON-ESS 2018: Proceedings of the 3rd International Conference on Economic and Social Science, ICON-ESS, 17–18 October 2018, Banda Aceh, Indonesia* (p. 407). European Alliance for Innovation.

Hamzah, W. M. A. F. W., Ali, N. H., Saman, M. Y. M., Yusoff, M. H., & Yacob, A. (2015). Influence of gamification on students' motivation in using e-learning applications based on the motivational design model. *International Journal of Emerging Technologies in Learning (iJET)*, *10*(2), 30-34.

Huang, C. (2005). Designing high-quality interactive multimedia learning modules. *Computerized Medical Imaging and Graphics, 29*(2-3), 223-233.

Irawan, A. G., Nyoman Padmadewi, N., & Artini, L. P. (2018). Instructional materials development through 4D model. In *SHS Web of Conferences* (Vol. 42, p. 00086). EDP Sciences.

Jeno, L. M., Grytnes, J. A., & Vandvik, V. (2017). The effect of a mobile-application tool on biology students' motivation and achievement in species identification: A Self-Determination Theory perspective. *Computers & Education*, *107*, 1-12.

Kocakoyun, S., & Bicen, H. (2017). Development and Evaluation of Educational Android Application. *Cypriot Journal of Educational Sciences*, *12*(2), 58-68.

Kotevsk, Z., & Tasevska, I. (2017). Evaluating the Potentials of Educational Systems to Advance Implementing Multimedia Technologies. *International Journal of Modern Education and Computer Science*, *9*(1), 26–35. https://doi.org/10.5815/ijmecs.2017.01.03

Larson, L. C., & Miller, T. N. (2011). 21st century skills: Prepare students for the future. *Kappa Delta Pi Record*, *47*(3), 121-123.

Leacock, T. L., & Nesbit, J. C. (2007). A framework for evaluating the quality of multimedia learning resources. *Journal of Educational Technology & Society*, *10*(2), 44-59.

Lee, H., Parsons, D., Kwon, G., Kim, J., Petrova, K., Jeong, E., & Ryu, H. (2016). Computers & Education Cooperation begins : Encouraging critical thinking skills through cooperative reciprocity using a mobile learning game. *Computers & Education*, *97*, 97–115. https://doi.org/10.1016/j.compedu.2016.03.006

Ma, L., Gu, L., & Wang, J. (2014). Research and development of mobile application for android platform. *International Journal of Multimedia and Ubiquitous Engineering*, *9*(4), 187–198. https://doi.org/10.14257/ijmue.2014.9.4.20

Mishra, P., Pandey, C. M., Singh, U., Gupta, A., Sahu, C., & Keshri, A. (2019). Descriptive statistics and normality tests for statistical data. *Annals of Cardiac Anaesthesia*, *22*(1), 67–72. https://doi.org/10.4103/aca.ACA_157_18

Nordin, N., Embi, M. A., & Yunus, M. M. (2010). Mobile learning framework for lifelong learning. *Procedia-Social and Behavioral Sciences*, *7*, 130-138.

Lestari, N., Basri, I., Yusuf, S. M., Suciati, & Masykuri, M. (2019). Effect of interactive multimedia based on PBL on critical thinking ability and science literacy VII junior school student at Kupang. In *6th ICRIEMS Proceedings*. Faculty of Mathematics and Natural Sciences, Yogyakarta State University.

Ozdamli, F., & Cavus, N. (2011). Basic elements and characteristics of mobile learning. *Procedia - Social and Behavioral Sciences*, *28*, 937–942. https://doi.org/10.1016/j.sbspro.2011.11.173

Parsons, D., Ryu, H., & Cranshaw, M. (2007). A design requirements framework for mobile learning environments. *J. Comput.*, *2*(4), 1-8.

Permendikbud RI Nomor 20 Tahun 2016 (2016). https://jdih.kemdikbud.go.id/arsip/Salinan%20Permendikbud%20Nomor%2020%20Tahun%202016.pdf

Rahmawati, L., Labibah, U. N., & Kuswanto, H. (2020). The implementation of android-based physics learning media integrated with landslide disaster education to improve critical thinking ability and disaster preparedness. *Journal of Physics: Conference Series*, *1440*(1). https://doi.org/10.1088/1742-6596/1440/1/012042

Richey, R. C., & Klein, J. D. (2005). Developmental research methods: Creating knowledge from instructional design and development practice. *Journal of Computing in Higher Education*, *16*(2), 23–38. https://doi.org/10.1007/BF02961473

Saputri, D. Y., Rukayah, R., & Indriayu, M. (2018). Need assessment of interactive multimedia based on game in elementary school: A challenge into learning in 21st Century. *International Journal of Educational Research Review*, *3*(3), 1-8.

Sari, S., Aryana, D. M., Subarkah, C. Z., & Ramdhani, M. A. (2018). Multimedia Based on Scientific Approach for Periodic System of Element. *IOP Conference Series: Materials Science and Engineering*, *288*(1). https://doi.org/10.1088/1757-899X/288/1/012137

Schleicher, A. (2018). Insights and interpretations. *Pisa 2018*, *10*.

Siregar, J., & Situmorang, J. (2017). The Effect of Learning Models and Critical Thinking Skills on Social Science Learning Outcomes.

Sookoo-Singh, N., & Boisselle, L. N. (2018). How Does The "Flipped Classroom Model" Impact On Student Motivation And Academic Achievement In A Chemistry Classroom?. *Science Education International*, *29*(4), 201–2012. https://files.eric.ed.gov/fulltext/EJ1205443.pdf

Sugiyono. (2013). *Metode Penelitian Kuantitatif, Kualitatif dan R&D*. Bandung: Alfabeta

Sumardi, L., Rohman, A., & Wahyudiati, D. (2020). Does the teaching and learning process in primary schools correspond to the characteristics of the 21st century learning?. *International Journal of Instruction*, *13*(3), 357–370. https://doi.org/10.29333/iji.2020.13325a

Sya'bandari, Y., Firman, H., & Rusyati, L. (2017). The Development and Validation of Science Virtual Test to Assess 7th Grade Students' Critical Thinking on Matter and Heat Topic. *Journal of Science Learning*, *1*(1), 17-27.

Utami, B., Saputro, S., Ashadi, A., Masykuri, M., & Widoretno, S. (2017). Critical thinking skills profile of high school students in learning chemistry. In *International Journal of Science and Applied Science: Conference Series* (Vol. 1, No. 2, pp. 124-130).

Walker, L. (2011). My teacher is an Android: Engaging learners through an Android application. *Changing Demands, Changing Directions. Proceedings ascilite Hobart*, 1270-1274.

Widodo, W., Sudibyo, E., Suryanti, Sari, D. A. P., Inzanah, & Setiawan, B. (2020). The effectiveness of gadget-based interactive multimedia in improving generation z's scientific literacy. *Jurnal Pendidikan IPA Indonesia*, *9*(2), 248–256. https://doi.org/10.15294/jpii.v9i2.23208

Yang, Y. C., & Chang, C. (2013). Computers & Education Empowering students through digital game authorship: Enhancing concentration, critical thinking, and academic achievement. *Computers & Education*, *68*, 334–344. https://doi.org/10.1016/j.compedu.2013.05.023

Yuniarti, A., Yeni, L. F., & Yokhebed. (2017). Development of Virtual Laboratory Based on Interactive Multimedia on Planting and Painting Bacteria. *Journal of Physics: Conference Series*, *895*(1). https://doi.org/10.1088/1742-6596/895/1/012120