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Development of Android E-book Forms of Energy to Improve Students' Critical Thinking and Mathematical Representation Skills

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Abstract:
Critical thinking and mathematical representation skills play an important role for students, especially in physics. This research' aims are to study the feasibility and effectiveness of the android e-book forms of energy to improve students' critical thinking and mathematical representation skills. This research was developed using the ADDIE model. The experimental design was one group pre-test post-test. This research found that the E-book were feasible to be applied in physics learning. Its content has qualified the writing and content requirements for a physics E-book. The android e-book is effective for improving students' ability in interpretation and explanation, effective enough in analyze aspect, and less effectively in the inference and argument and evaluation aspects. E-book is less effective in the aspect of use pictures, graphs, tables, or diagrams to solve problems and effective enough in training students use symbols or mathematical equations in solving problems and explain data or other representations in sentence form. The global N-Gain value shows that the Android e-book forms of energy is effective enough to improve critical thinking and mathematical representation skills.

Keywords: android e-book, critical thinking, mathematical representation, forms of energy.

Introduction

Rapid technology progressions in the industrial revolution 4.0 era are predicted to have an impact on labor market needs. Labor market demand is shifting towards core skills such as analytical, critical and creative thinking abilities, operating skills, and designing technology (World Economic Forum et al., 2020). The ability to think critically differentiates a person from technology. Critical thinking is needed to act on the output of AI and automation (Loseby, 2019). Critical thinking is needed to prove an opinion, interpret the meaning of something, and find solutions to problems (Facione, 2015). Critical thinking makes someone being a superior resource who is able to master and create technology.

Critical thinking has an important role in education. Critical thinking influences a person's academic success and productivity (Suresh et al., 2023). Critical thinking plays an important role in closed creativity (Lin & Shih, 2022). In physics learning, critical thinking has a significant influence (Hikmah & Jauhariyah, 2021). Critical thinking mediates problem-solving skills and the self-efficacy (Tasgin & Dilek, 2023). When the students analyze a problem and they experience doubt, they will mobilize all their potential to overcome it (Southworth, 2022). Critical thinking helps students to complete assignments in class.

The importance of critical thinking has made it widely researched. Several studies found that students' level of critical thinking still low (Sundari & Sarkity, 2021) and need to be improved (Rahayu & Kuswanto, 2021). In problem solving process that requires critical thinking, students who solve problems with physics content show lower results than students who solve problems without physics content (Trúsiková & Velmoská, 2020). The low level of critical thinking has to be addressed immediately so as not to interfere with students' achievement of competency in physics.

Physics learning has special characteristics. Learning physics involves experimental activities, making predictions, asking questions and hypotheses, solving problems, the ability to use mathematical symbols,

and using various forms of formal representation (Mitrevski, 2019). Mathematical representation is needed when students face physical problems that must be solved quantitatively with mathematical equations (Wulandari et al., 2019). Mathematical representation includes various forms that can be utilized in learning (Mainali, 2021). Various mathematical elements are used to explain physical relationships, such as numbers and units, diagrams, geometric elements, advanced mathematical techniques, such as calculus (Pospiech, 2019). Some adjustments are required so that the mathematical representation matches the characteristics of physics (Geyer & Kuske-Janßen, 2019). Mathematical representation bridges communication between mathematical data and physical knowledge.

Several studies have been conducted to map mathematical representations. Previous research stated that students' mathematical representation was still low (Azmidar & Husan, 2022; Minarni et al., 2016; Saputra & Andari, 2024; Utami et al., 2019; Utami et al., 2023). Students understand the description of physics problems, but fail to write them in the form of mathematical equations. On the other hand, students often memorize mathematical equations, but cannot interpret them physically (Jewaru et al., 2021). Students are also weak in connecting mathematical representations to other forms of representation (Taqwa & Rahim, 2022). As a result, students fail to solve physics problems. More effort is needed for students to become proficient.

Nowdays, energy scarcity is one of global issues in the world. Education about sustainability is very important to give to students (Boca & Saraçli, 2019). This encourages the government to include alternative energy material as one of the learning outcomes in the Independent Curriculum. Before students learn about alternative energy, the basic material on forms of energy must be well mastered. Unfortunately, research has found that there are still many misconceptions about energy (Mayari, 2022). Misconceptions about forms of energy will make students fail in constructing alternative energy. Choosing appropriate learning media is important to instill the correct concept about forms of energy. The phenomenon of falling coconuts, as an example of a form of potential energy, is easier to be analyzed if presented in pictures or videos using a smartphone (Wulandari et al., 2022). Presenting the concept in an attractive representation makes students understand the forms of energy easier.

One of the efforts to overcome the problem of critical thinking and mathematical representation is through setting appropriate learning scenarios. Learning in high school needs to present more activities that stimulate meta- cognitive skills and thinking strategies related to critical thinking (Piedade et al., 2020). Mathematical representation abilities can be improved by innovating media, strategies and instruments in learning (Putra et al., 2023). Activities, media and forms of learning assessment must be designed appropriately to enhance students' critical thinking.

The educational paradigm shifts to the use of communication and information technology now. The opportunities for using digital devices in learning (Meirbekov et al., 2022) are increasing, for example is android smartphone. Android-based learning media is proven to have a vital role in enhancing critical thinking skills (Isnaeni et al., 2021) and mathematical representation in physics learning (Priyadi et al., 2020). One of the Android-based physics learning media and resources that can be developed is e-book. E-books can trigger students' curiosity about physics (Sari et al., 2022). E-books can be a learning resource for improving critical thinking skills (Saprudin et al., 2021). Android e-books provide new learning experiences because they are completed with interesting videos and pictures (Hasbiyati et al., 2019), practice questions, menus, and page navigation (Batubara et al., 2022). Android e-books are very flexible to use. The many advantages of android e-books make them very potential to be developed to improve students' critical thinking and mathematical representation skills especially for the forms of energy.

This research explains the feasibility and effectiveness of the Android e-book on forms of energy to improve students' critical thinking and mathematical representation skills. It is hoped that the presentation of the results of this research can become a basis and enrich other relevant research references.

Materials and Methods

This research' method is a Research and Development (R&D) research. The product of this research developed with the ADDIE research model. In using the ADDIE model, the steps of the research are: 1) analyzing, 2) designing, 3) developing, 4) implementing, and 5) evaluating (Branch, 2010). The work steps of this research are presented in Table 1.

Table 1. Research Steps

No	Stages	Activity Description
1	Analyzing	- Carry out performance, student, learning objective, and material analysis.
2	Designing	- Designing material content in E-book, learning strategies, assessment plan, and E-book flow charts.
3	Developing	- Develop teaching modules, worksheets, instruments for measuring critical thinking skills and mathematical representations, and E-book products. - Validating instruments and E-book products.
4	Implementing	- Implementing the Android e-book on forms of energy in class. - Conduct pre-test and post-test to measure students' critical thinking and mathematical representation skills.
5	Evaluating	- Evaluate results at each stage and correct any deficiencies found. - Evaluate the application of the android e-book forms of energy in class.

Android e-book was developed using Smart Apps Creator Education and Canva software. E-book that has been developed and the test instruments that will be used in the research are first validated by Master of Physics Education students at Yogyakarta State University. The validation results were analyzed with the V-Aiken formula (Aiken, 1985). The V-Aiken formula is written in Equation (1).

$$V = \frac{\sum s}{n(c-1)} \quad \text{..... (1)}$$

s is the difference of an expert's value (r) and the lowest value of validity (l_o). V states the validity index of the item according to expert agreement. n is the number of experts, and c is the highest value of validity. The criteria for the V value are low validity if V is less than 0.4, medium validity if V is between 0.4 to 0.8, and high validity if V is more than 0.8. The results of the validation analysis of E-book and instruments are used to evaluate whether E-book and instruments are suitable to use in this research.

The research' population is the students in X Class of E Phase in SMA Negeri 1 Kayen. Sampling was carried out using cluster random sampling with a sample size of 68 students. The experimental design in this research is one group pre-test-post-test. The students were given essay tests about forms of energy to measure their initial critical thinking and mathematical representation abilities (O_1). Students were then given treatment in the form of physics learning assisted with an android e-book of forms of energy (X). After receiving treatment, students were given essay test as a post-test to measure their final critical thinking skill and mathematical representation (O_2).

The effectiveness of android E-book in improving critical thinking and mathematical representation skills is calculated using the N- gain formula (Hake & Reece, 1999) in equation (2). The criteria of N-gain is shown in Table 2, and the effectiveness criteria based on n-gain percentage is shown in Table 3.

$$\text{N} - \text{gain} = \frac{\text{postest score} - \text{pretest score}}{\text{maximum score} - \text{pretest score}} \text{..... ..... (2)}$$

Table 2. N-gain Criteria

N-gain Score	Criteria
gain ≥ 0.7	high
0.3 ≤ gain < 0.7	medium
gain < 0.3	low

Table 3. Effectiveness Criteria Based on N-gain Percentage

N-gain Percentage	Criteria
> 75	Effective
56 - 75	Effective enough
40 - 55	Less effective
< 40	Ineffective

Results

Analysis Stage

Table 4. Results of Analysis Stages

Aspect	Analysis Results
Performance analysis	- Teachers implement learning activities according to government teaching modules. - Teachers still use learning resources that have not been integrated into one media.
Student analysis	- Students have good cognitive and communication skills, but the formative test results are still unsatisfactory. - Students are responsive, but some of them are not yet focused. - Students enjoy learning using colorfull learning resources, completes with pictures, videos, easy to understand and not boring. - The learning resources used by students in learning physics are independent curriculum package books from the government, conventional worksheets, YouTube, and articles from the internet. - All students use android smartphones and bring it to school. In learning, smartphones are used for browsing to find answers of their assignment. Students have never used android e-book.
Learning Objectives Analysis	- The learning objectives to be achieved refer to the Learning Outcomes in Physics Phase E Class X, Alternative Energy material, sub-material forms of energy.
Material Analysis	- Facts, concepts, principles, law, and theory about forms of energy

Design Stage

The forms of energy content in the android e-book includes: Definition of Energy, Forms of Energy: Kinetic Energy, Potential Energy, Electrical Energy, Thermal Energy. Learning activities are designed using Problem Based Learning with the group discussion method. The assessment instrument used to measure critical thinking skills and mathematical representation is planned to use a essay test. The development of the android e-book forms of energy was carried out according to the flowchart in Figure 1.

Development Stage

The appearance of the android e-book forms of energy is presented in Figure 2. The instruments which will be used to measure the students' critical thinking and mathematical representation skills are assessed by the validators to see the feasibility of the items. The results of validation of critical thinking instruments are shown in Table 5, and the results of validation of mathematical representation instruments are shown in Table 6.

Implementation Stage

In implementation stages, students are taught with the assist of android e-book forms of energy. Before and after the learning process, the students are given a test namely pre-test and postest to measure the effectiveness of the android e-book. The results of the test are analyze with normality test, which the results are shown in Table 7.

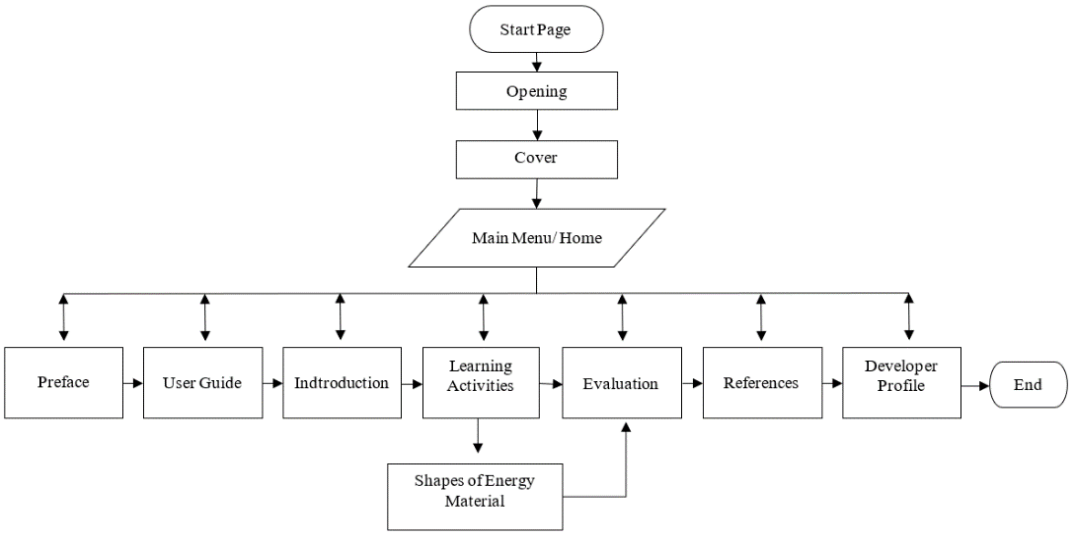
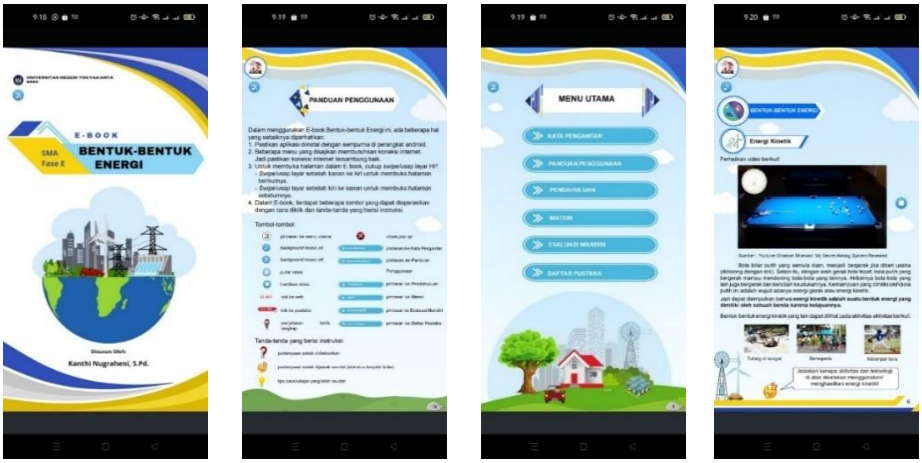


Figure 1. Android e-book Flowchart of Forms of Energy



(a) (b) (c) (d)

Figure 2. Appearance of the Android e-book Forms of Energy (a) Cover, (b) Usage Guide, (c) Main Menu, (d) Materials

Table 5. Results of Validation of Critical Thinking Instruments

Item	V Value	Category	Item	V Value	Category
1	0.75	medium	**8**	0.83	high
2	0.67	medium	**9**	1.00	high
3	0.92	high	**10**	0.92	high
4	0.67	medium	**11**	0.92	high
5	0.92	high	**12**	0.83	high
6	0.92	high	**13**	0.83	high
7a	1.00	high	**14**	0.92	high
7b	0.92	high			

Table 6 . Results of Validation of Mathematical Representation Instruments

Item	V Value	Category	Item	V Value	Category
1a	0.83	high	**4a**	1.50	high
1b	1.42	high	**4b**	1.50	high
2a	1.33	high	**5**	1.42	high
2b	1.17	high	**6**	1.50	high
3	1.42	high			

Table 7. Normality Test Results

	Critical thinking		Mathematical Representation	
	Statistics	Sig.	Statistics	Sig.
Pre-test	0.974	0.158	0.984	0.513
Post-test	0.981	0.393	0.965	0.053

Evaluation Stage

After the results are normally proven, the effectiveness of the android book is calculated with N-gain equation. Critical thinking' N-Gain each indicator can be read in Table 8 and mathematical representation' N-Gain each indicator can be read in Table 9. Global N-gain of critical thinking skills and mathematical representation is shown in Table 10.

Table 8. Critical Thinking N-Gain Each Indicator

Indicator	N Gains	N Gain %	N Gain Criteria	Interpretation of N-Gain Effectiveness
1	0.8914	89.14	high	effective
2	0.7536	75.36	high	effective enough
3	0.4213	42.13	medium	less effective
4	0.5203	52.03	medium	less effective
5	0.8095	80.95	high	effective

Note: indicator 1) interpretation , 2) analysis , 3) analysis , 4) argument and evaluation, and 5) explanation

Table 9. Mathematical Representation' N-Gain Each Indicator

Indicator	N Gains	N Gain %	N Gain Criteria	Interpretation of N-Gain Effectiveness
1	0.4881	48.81	medium	less effective
2	0.6704	67.04	medium	effective enough
3	0.6503	65.03	medium	effective enough

Note: indicator 1) using pictures, graphs, tables or diagrams in solving problems , 2) use symbols or mathematical equations in solving problems, and 3) explain data or other representations of sentences

Table 10. Global N-gain of Critical Thinking Skills and Mathematical Representation

Parameter	N Gains	N Gain %	Criteria	Effectiveness Interpretation
Critical thinking	0.6712	67.12	medium	effective enough
Mathematical Representation	0.5759	57.59	medium	effective enough

Discussion

The selection of learning resources used in physics learning at the analysis stage can be assessed from two sides. Students think digital books can improve learning performance. But there are some students who prefer printed books because they have difficulties in reading and browsing digital books (Kisno & Sianipar, 2019). In fact, in terms of content, the independent curriculum physics textbook published by the government actually fulfills all the aspects needed to improve critical thinking skills (Sebastian et al., 2023). Therefore, innovation was carried out by adopting the advantages of the independent curriculum physics package book in terms of content into an android e-book and complementing its shortcomings. This can also accommodate the use of students' smartphones which are not yet optimally used as learning resources.

The android e-book of forms of energy is designed according to the syntax of the Problem Based Learning (PBL) model. PBL has been proven to significantly increase the level of students' critical thinking abilities (Parno et al., 2019; Sholihah & Lastariwati, 2020). E-book assisted PBL can also improve mathematical representation (Haryanti et al., 2020). During learning, students are asked to solve problems in groups. Good team work can improve students' critical thinking skills (Sabiote et al., 2022). Student worksheets and self-evaluations are also integrated in the android e-book. This makes it easier for students because all the necessary learning tools are included in one package. The validators state that all e-book

content is in accordance with the material and criteria of an e-book. This means that E-books can be directly applied in class.

The results of the critical thinking measurement instrument stated that almost all questions were in the high category. There are only three items which get medium category. The validators also provided suggestions regarding improvements to the instrument, including: 1) selecting images whose physical events should be easier to observe according to the context of the material, 2) clearer questions referring to the critical thinking indicators that want to be measured, and 3) adding reasons questions for the answers given by students. From the suggestions provided by experts, the critical thinking instrument was revised before being used to measure critical thinking skills. It was decided not to use several questions that had a lot of revision due to consideration of test time.

The results of the mathematical representation measurement instrument stated that all questions were in the high category. This means that the instrument is suitable for measuring students' mathematical representations. The experts also give suggestions regarding improvements to the instrument, including: 1) the choice of questions should be more mathematical, not too many pictures and graphs, 2) the presentation of the pictures should be clearer, and 3) reasons need to be added to students' answers. These suggestions were used as a basis for revising the instrument for measuring students' mathematical representations. Several questions have been revised in numbering, question editing, and the form of mathematical representation.

In Table 8 it can be seen that the android e-book is effective in improving students' ability to compose questions or provide simple explanations (interpretation). E-book is also effective in increasing students' ability to explain alternative solutions to a problem (explanation). E-book is only effective enough to train students in analyzing a statement/claim (analyze). E-book is less effectively used to improve critical thinking skills in the inference and argument and evaluation aspects. This result is in line with the finding that students' level of thinking is low in aspects of evaluating (Priyadi et al., 2018) and analyzing arguments (Sutrisno et al., 2018). One of the questions in the evaluation indicator, students are asked to evaluate a climber's choice in choosing a climbing route to the peak. On average, students answered that a steeper path would require less potential energy. This shows that there are misconceptions about potential energy. Students think that the steeper the path a mountain climber takes to get to the peak, the greater the potential energy (Maison et al., 2020). In the modern labor market, inference and argumentation are the most important aspects of critical thinking skills (Jegelevičien et al., 2021). Aspects of analysis and interpretation skills are involved in the planning process. Evaluation aspects, argumentation, inference, and deduction play an important role in the decision-making process (D'Alessio et al., 2019). Therefore, an in-depth evaluation of the results of this research is very necessary, so that more effective solutions can be found to improve students' critical thinking abilities.

E-books are generally considered effective enough in improving critical thinking skills. However, there are many factors that may occur in this research that can influence the results. In short, research time can be a factor, because the length of time learning critical thinking at school has a positive impact on students' critical thinking abilities (Trúsiková & Velmoská, 2020). Other factors that may influence include mood (Lun et al., 2023), gender (Darmaji et al., 2022; Ramdani et al., 2021), and previous learning experiences (Golden, 2023). Communication skills and digital literacy should also be considered, because they also influence students' critical thinking (Amin & Adiansyah, 2023). Controlling these factors might produce better results in efforts to improve students' critical thinking.

In improving mathematical representation, the effectiveness of android e-book also differs in each indicator. Table 9 shows e-book is considered less effective in the aspect use pictures, graphs, tables, or diagrams to solve problems. Students still have difficulty reading graphs and predicting values of physical quantities that have the same graph gradient, but are not marked on the graph. E-book is effective enough in training students use symbols or mathematical equations in solving problems and explain data or other representations in sentence form. In general, android e-book is effective enough in improving students' mathematical representations. The increase in mathematical representation is not optimal yet can be affected by the way of thinking of the students (Eviyanti, 2022). The level of student self-efficacy also has a significant influence on students' mathematical representation abilities (Supandi et al., 2018). High self-efficacy encourages students to master all aspects of mathematical representation (Safrudin et al., 2021). Other factors may be reviewed so that students' representation abilities can be more optimally improved.

Conclusion

Android e-book forms of energy is feasible to use. This is seen from the results of expert validation to the e-book which is decide that android e-book is feasible to use in learning and the e-book content qualify the writing and content requirements for a physics e-book. The global N-Gain value shows the android e-book forms of energy is effective enough to improve critical thinking skills and mathematical representation. The effectiveness of e-book on critical thinking and mathematical representation varies in value, for each indicator.

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