International Journal of Instruction *July 2020 ● Vol.13, No.3*
e-ISSN: 1308-1470 ● www.e-iji.net *p-ISSN: 1694-609X*
pp. 17-30

Received: 11/07/2019
Revision: 30/12/2019
Accepted: 03/01/2020
OnlineFirst:02/04/2020

Development of Smartphone App as Media to Learn Impulse-Momentum Topics for High School Students

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One popular advanced technology nowadays is smartphone. Smartphones allow various functions beyond the traditional function of mobile phones as communication devices. The technology in smartphones has potential applications in many areas including education. In this study, we report our research which aims to: (1) produce a smartphone app as media for learning Impulse-Momentum; (2) determine the appropriateness and quality of the app; and (3) describe the effectiveness of the smartphone app to help students in learning the concept of Impulse-Momentum. We use developmental research method within 4D (define, design, develop, disseminate) model. The smartphone app is reviewed by physics education expert and teacher. The field testing involves a group which consists of 26 high school students. The students are given pre- and post-tests before and after they use the developed learning media, respectively. It aims to investigate the impact of the media to students' conceptual understanding. The normalized gain (N-gain) score of their pre- and post-tests is 0.74 which can be categorized as high improvement.

Keywords: smartphone, learning media, impulse-momentum, high-school, physics

Citation: Wirjawan, J. VD., Pratama, D., Pratidhina, E., Wijaya, A., Untung, B., & Herwinarso. (2020). Development of Smartphone App as Media to Learn Impulse-Momentum Topics for High School Students. *International Journal of Instruction*, 13(3), 17-30. https://doi.org/10.29333/iji.2020.1332a

INTRODUCTION

Impulse-momentum is a topic in high school physics subject which is closely related to our daily life. Some students have difficulties when learning Impulse-Momentum. One of the difficulties is relating the concept to the application in sophisticated problem solving (Lawson & Mcdermott, 1987). Students face difficulties in interpreting the basic concept of momentum and employing the concept in physical situation (Singh & Rosengrant, 2003). Impulse-Momentum topic also involves vector analysis, however some students are unaware with the vector nature of momentum (Sekercioglu & Koakulah, 2018).

Interpreting basic concept and relating concept to physical situation are usual problems faced by students when they are learning any topics in physics. Visualizations may help students to get physical interpretation, to highlight the element that is important in physics concept, and to convey abstract information (Dervic, Glamocic, Gazibegovic-Busuladzic, & Mesic, 2018). Through visualization, students can relate the result of mathematical modelling and the real phenomenon in daily life. Moreover, visualizations are also able to guide intuition and help to comprehend physical phenomena beyond direct experience (Sanders, Senden, & Springel, 2008)

Learning media, including multimedia, play an important role to provide visualization in physics. Some studies have shown that multimedia give a good impact in physics classroom (Bennett & Brennan, 1993; Chen, Stelzer, & Gladding, 2010; Jian-hua & Hong, 2012). Multimedia could concretize abstract concept, break complex problem and visualize concept which difficult to be explained by chart (Liu & Li, 2011). A study by Casperson & Linn (2006) indicates that multimedia with simulation helps students make connections between microscopic and macroscopic views of electrostatics phenomena. In other study by Pratidhina et al. (2019), multimedia is effective to improve students' conceptual understanding of ideal gas properties from macroscopic and microscopic views. Instruction using interactive computer software has affected students' conceptual learning on motion and vector analysis better than that of traditional way (Jasmy, Rahman, Arif, Ismail, & Nasir, 2014). Multimedia in the form of physics virtual laboratory that includes advanced physics experiment such as photoconductivity and Franck-Hertz experiments enhance learning and teaching experience (Daineko, Dmitriyev, & Ipalakova, 2016). Using multimedia containing physics simulation in student centred physics classroom is also effective in developing students' ability to solve quantitative problem (Dervic et al., 2018).

In other hand, due to the limited time in class, sometimes teacher also does not emphasis the physical interpretation. To fully understand the material, students need to do independent study outside classrooms. Traditionally, students learn from their textbook. Disadvantages of traditional book are lack of visualization and cannot be brought conveniently. A study also shows that multimedia is better than traditional books (Stelzer et al., 2013)

Nowadays, tremendous development of smartphone technology allows various features not only for communication but also multimedia. Most of young people in Indonesia are familiar with smartphones, according to survey 66% of young people own a smartphone (Taylor & Silver, 2019). Although smartphones have bad impact such as causing addiction, smartphones are potential to engage students' participation in learning activity (Gikas & Grant, 2013). Smartphones are devices that can visualize physical phenomenon. Unlike traditional personal computer based multimedia, smartphones can be brought anywhere. Thus, learning resources in the form of smartphone app is suitable for independent study outside classroom. According to our preliminary study, although most of students in Indonesia have smartphone, they rarely use it for educational purpose because of the limited number of educational app published in Indonesian. In addition, they say that they need an interactive learning media which is interesting, convenience, and providing understandable-clear explanation and exercises.

Recently, few studies also have been conducted to develop learning resource in smartphone app. Smartphone app has been developed as physics learning media on the topics of classical mechanics (Arista & Kuswanto, 2018; Kurniawan & Kuswanto, 2019; Simanjuntak & Budi, 2018), thermodynamics (Astra, Nasbey, & Nugraha, 2015; Ratnaningtyas, Wilujeng, & Kuswanto, 2019), optics (Billah & Widiyatmoko, 2018), electricity (Yasin, Prima, & Sholihin, 2018) and so on. Astra et al. (2015) developed smartphone app in the form of simulation lab that feasible to be used as learning media to learn kinetic theory of gas. Other study indicated that the use of smartphone app can improve learning independence and conceptual understanding in rotational dynamics topics (Arista et al., 2018). Kim (2012) also has developed smartphone app in the form of games to increase interest in science and improve problem solving ability in elementary school students.

Although few works on developing and implementing smartphone app as physics learning media have been conducted, it is still limited. Moreover, so far, an application about Impulse-Momentum which is designed for high school students to do independent study cannot be found in digital distribution service. In this study, we develop a learning media in the form of smartphone app to assist high school students in learning Impulse-Momentum. This learning media includes material with figures and animation, simulation, problem example, and exercise. The material in the app is expected to overcome students; common difficulties on understanding Impulse-Momentum concept, especially related to the nature of momentum as a vector quantity.

METHOD

This study is developmental research which uses 4D models (Thiagarajan, Sammel, & Melvyn, 1974). The 4D model consists of four phases i.e. define, design, develop, and disseminate. The components of each phase is described in the Figure 1. The define phase includes front-end, learner, task, and concept analysis. The front-end analysis is done to gather the necessity of media. It is done by interviewing teachers and students about the desired learning media. We conduct task and concept analysis based on Indonesian national curriculum 2013 (revised version). Based on the task and concept analysis, the learning objective is specified.

After several analyses, we design physics learning media in the form of Android app. According to our observation, Android smartphone is the most popular phone among high-school students. The Android app is constructed using Adobe Flash CS 6 software. The app can be operated in smartphone with Android Operating System version 4.1 or above.

The develop phase involves expert appraisal and field testing. Expert in physics education review the developed smartphone app. Reviewing process is also done by a high school physics teacher. After going through some reviewing process, the smartphone app is revised according to suggestions from the expert and physic teacher until it is ready for the field testing.

Field testing is conducted involving 26 students in tenth grade from a private school in Surabaya. Students in this school are very familiar with smartphone and most of them bring an Android phone to school. We use one group pre-test and post-test design in the field testing to investigate the use of smartphone app effect on students' conceptual understanding. The interval between pre- and post-test are 2 weeks. Furthermore, we also collected students' response on the use of the media though questionnaire.

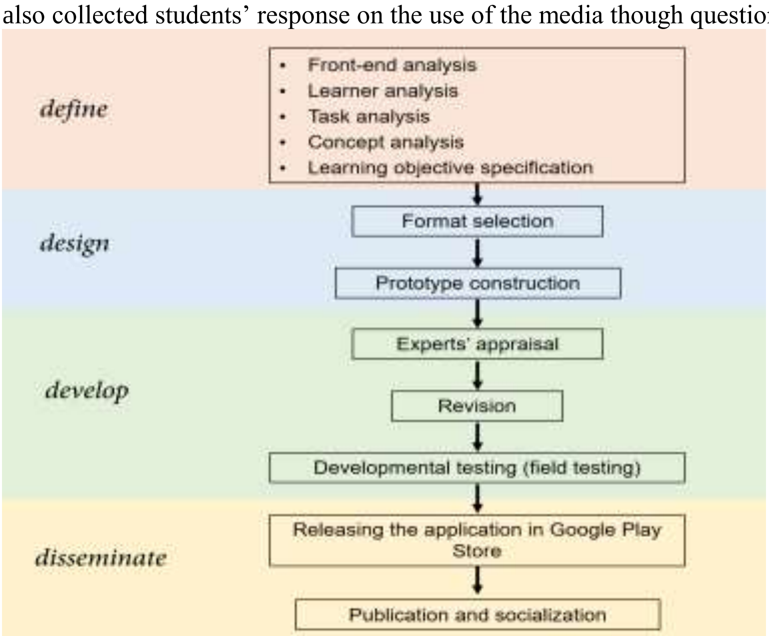

Figure 1
The 4 Phases in the 4D Model

Research Instrument

The quality of the smartphone app is determined through expert's appraisal, teacher's evaluation, and student's feedback. Before implemented in the class, the app is evaluated through expert's appraisal and teacher's evaluation. The instruments used for expert's appraisal, teacher's evaluation, and student's feedback are questionnaire. The expert's appraisal is given by an expert in physics education. We revise the media according to the expert's and teacher's suggestions several times. The questionnaire for expert's appraisal and teacher evaluation includes several items, which gather information about four aspects, i.e. appropriateness for instructional purpose, material/content, layout, and accessibility. The questionnaire is developed using Likert scale of 1-5. Qualitatively, 5=Very Good, 4= Good, 3=Fair, 2=Poor, and 1=Very Poor.

The questionnaire for gathering students' feedback contains several statements about the usefulness for learning purpose, material, layout, and accessibility aspect. Students are asked to choose answers such as "Strongly Agree" (4), "Agree" (3), "Disagree" (2), and "Strongly Disagree" (1).

The effectiveness of the smartphone app on improving students' conceptual understanding in Impulse-Momentum concept is determined through pre-test and post-tests. We give a pre-test and a post-test to students before and after they use the smartphone app to learn Impulse-Momentum concept. Pre- and post-tests are conducted in the form of paper and pencil test. Pre- and post-tests consist of four essay problems. Problems given in the pre- and post-test have the same indicators and difficulty level. In this research, we do not conduct empiric validation of items in pre- and post-tests. However, the items in pre- and post-tests are contextually and constructively validated by our 2 colleagues who are experts in physics education.

Technique of Data Analysis

Descriptive technique is used in the data analysis. The evaluation scores from each aspect given by expert are averaged. The average scores are interpreted according to quality classification in Table 1. The classification is constructed using ideal average score (Xi) and ideal standard deviation score (SDi) as basis (Widoyoko, 2016). For the students' feedback questionnaire, we convert students' answer to quantitative score (1-4). The scores are averaged for each aspect. Each aspect's score is interpreted according to classification in Tabel 2.

Table 1
Conversion of Actual Average Score to Qualitative Criteria (5 Scale)

No	Score	Score Interval	Criteria
1	$\overline{X} > \overline{X}_i + 1.8SDi$	$\overline{X} > 4.2$	Very Good
2	$\overline{X}_i + 0.6SDi < \overline{X} \le \overline{X}_i + 1.8SDi$	$3.4 < \overline{X} \le 4.2$	Good
3	$\overline{X}_i - 0.6SDi < \overline{X} \le \overline{X}_i + 0.6SDi$	$2.6 < \overline{X} \le 3.4$	Fair
4	$\overline{X}_i - 1.8SDi < \overline{X} \le \overline{X}_i - 0.6SDi$	$1.8 < \overline{X} \le 2.6$	Poor
5	$\overline{X} \le \overline{X}_i - 1.8SDi$	$\overline{X} \le 1.8$	Very Poor

$\overline{X}$: average score of each aspect

$\overline{X}_i$: 1/2 (maximum ideal score + minimum ideal score)

SDi = 1/6 (maximum ideal score - minimum ideal score)

Table 2
Conversion of Actual Average Score to Qualitative Criteria (4 Scale)

No	Score	Score Interval	Criteria
1	$\bar{X} > \bar{X}_i + 1.8SDi$	$\bar{X} > 3.4$	Very Good
2	$\bar{X}_i + 0.6SDi < \bar{X} \leq \bar{X}_i + 1.8SDi$	$2.8 < \bar{X} \leq 3.4$	Good
3	$\bar{X}_i - 0.6SDi < \bar{X} \leq \bar{X}_i + 0.6SDi$	$2.2 < \bar{X} \leq 2.8$	Fair
4	$\bar{X}_i - 1.8SDi < \bar{X} \leq \bar{X}_i - 0.6SDi$	$1.6 < \bar{X} \leq 2.2$	Poor
5	$\bar{X} \leq \bar{X}_i - 1.8SDi$	$\bar{X} \leq 1.6$	Very Poor

The improvement of students' conceptual understanding in Impulse-Momentum after using the smartphone app are investigated though pre- and post-tests. We calculate the N-gain score to determine how significant the improvement is. The formula of N-gain score is given in equation (1), whereas the interpretation is given in Table 3.

$$\text{N} - \text{gain} = \frac{\%\text{posttest score} - \%\text{pretest score}}{100 - \%\text{pretest score}} \quad (1)$$

Table 3
The Criteria of N-Gain Score (Hake, 1998)

N-gain	Criteria
Above 0.7	High
0.3 - 0.7	Medium
Bellow 0.3	Low

FINDINGS

This study is developmental research which employs 4D model. The four phases of 4D are define, design, develop, and disseminate. So far, we already conducted up to develop phase.

Define Phase

The define phase involves task analysis, concept analysis, students' analysis, and learning objective determination. The task and concept analysis are done based on Indonesian national curriculum 2013 (revised version). After the task and concept analysis, we set the learning indicators and material. The material is presented as a concept map in Figure 2.

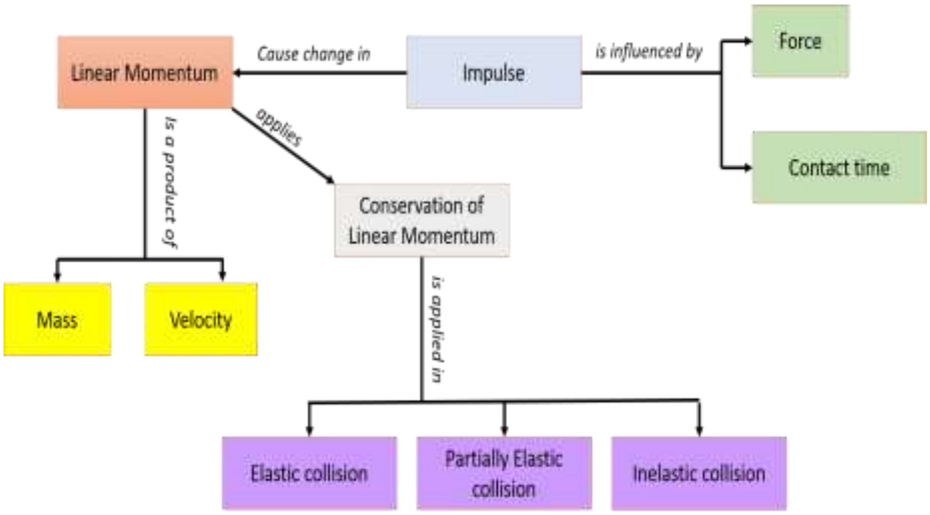

Figure 2
The Concept Map of the Material Developed in the Mobile App

We do students' need analysis by asking students about what kind of learning resource that most likely use, is that helpful when they learn physics, is individual study necessary for them, and are they use mobile phone often. According to majority, they use traditional textbook as learning resource. They also state that they actually face difficulty in learning physics from traditional book due to the lack of visualization. On the other hand, they are familiar with recent mobile phone technology. In addition, they believe that individual study outside the classroom is necessary to deepen their understanding on physics material. A multimedia platform to support this individual studies is necessary. Other study conducted by Stelzer et al., also indicates that multimedia module provided better introduction to basic physics content compared to traditional textbook (Stelzer et al., 2013).

Design Phase

In the design phase, we determine the learning media platform and construct the prototype of the learning media. Based on the students' analysis, we decide to develop the learning media in the form of smartphone application. The reason is it can provide more visualization to help students understand the concept easily, can be interactive, and can be brought anywhere comfortably so that students can do individual study anywhere.

The smartphone app contains features such as material, experiment simulation, problem example, and exercise. As learning media, the learning objective is written in the introduction. The scope of the material is also given through a concept map, such as depicted in Figure 2. The material is accompanied with introduction, explanation, figure, and animation to visualize the physical concepts, as shown in Figures 3-5.

Figure 3
Screenshot of the Material in the Smartphone App

We include simulation of experiment so that students can do virtual experiment. The simulation is about collision between a ball and the floor. In the simulation, students are asked to investigate the restitution coefficient between the floor and the ball. Even though it is not the same as a real experiment, however, through simulation, students can practice some science process skills such as data collecting, data analysis, and drawing conclusion. Figure 4 shows the layout of the simulation about collision between a ball and floor.

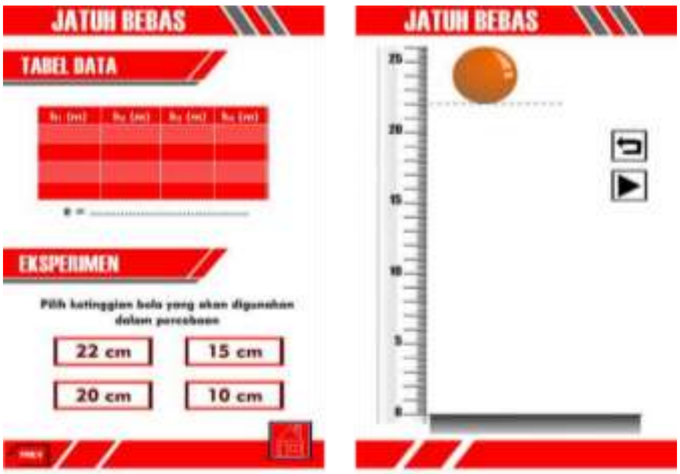

Figure 4
Screenshot of the Simulation about Collision between a Ball and the Floor. The Ball is Released from a Certain Height without Any Initial Speed. Students are Asked to Determine the Restitution Coefficient

The smartphone app is also equipped with Problem Example and Quiz. Problem Example allows students to apply some concepts that have been studied in the material and practice their problem solving skill. The solutions of each problem example are provided. Students are also able to evaluate their study themselves by doing the Quiz. If the students finish doing the Quiz, they will get their score and feedback.

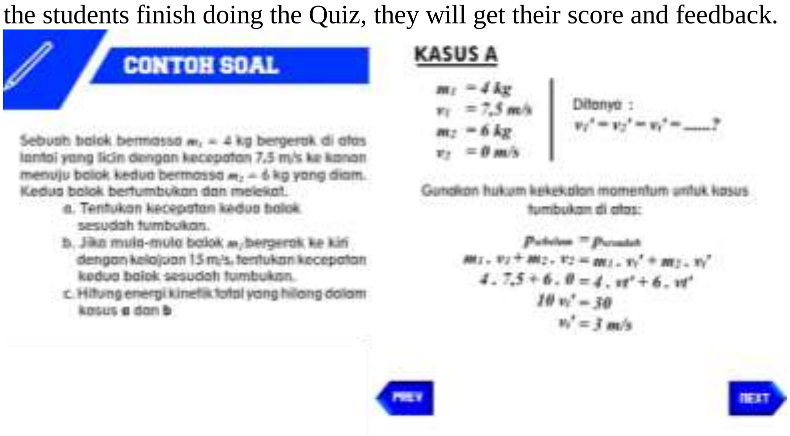

Figure 5
Screenshot of Problem Example

Develop Phase

The develop phase involves expert's appraisal, teacher's evaluation, and field testing. Before going through the field testing to students, the learning media is evaluated by an expert in physics education, and by high school physics teacher. The learning media is revised several times based on the expert's and teacher's suggestions. After being revised for several times, overall according to the evaluation, the smartphone app is very good in terms of appropriateness for instructional purpose, content, layout, and accessibility (see Table 4).

Table 4
Expert's Evaluation About the Smartphone App

Aspects	Score*	Criteria
Appropriateness for Instructional Purpose	4.75	Very good
Content/material quality	4.57	Very good
Layout quality	4.83	Very good
Accessibility	4.67	Very good

**score interval: 1-5*

The field testing involves 26 high school students. We measure students' initial conceptual understanding on Impulse-Momentum by giving pre-test to them. After pre-test, we distribute the smartphone app to students and let them to study Impulse-Momentum themselves through the smartphone app. At last, we give post-test to students. We analyse the score of pre- and post-tests by calculating the N-gain score given in equation (1). The average score of pre- and post-test are shown in Figure 6. The average of N-gain score from field testing is 0.74 which can be interpreted as high improvement of students' conceptual understanding.

In this study, we have found that there is significant improvement of students' conceptual understanding on Impulse-Momentum after they learn the material individually. The developed smartphone app helps students to understand the material due to the interactive visualization. This finding is in line with previous studies which indicated that the use of mobile device which provide interactive visualization and simulation as physics learning media give good impact on students' conceptual understanding (Arista & Kuswanto, 2018; Wang & Wu, 2015). Moreover, the quiz in the smartphone app also allows students to practice their problem solving skill related to Impulse-Momentum topic.

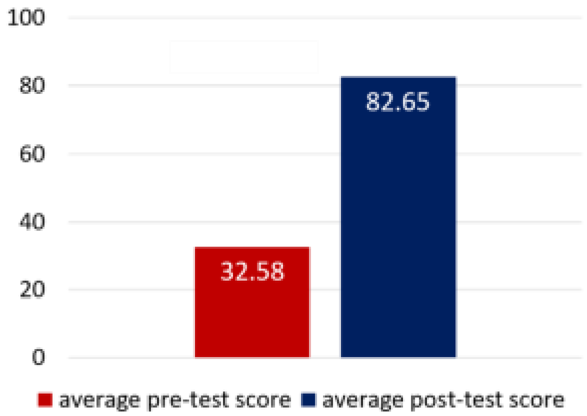

Figure 6
The Comparison of Pre- and Post- Test Scores and the N-Gain

After the post-test, students are asked to fill a questionnaire which gather their opinions about the smartphone app that they used as learning media on Impulse-Momentum topics. The students' opinion about the quality of smartphone app is summarized in Table 5. Students' response to the usefulness of learning purpose is very positive with an average score of 3.62. The material, exercise, and simulation are well structured to help students in understanding the material. Students' response to the material in the smartphone app is good with a score of 3.36. The material is understandable, motivating, and promote students' learning independence. Student do not face difficulties in reading the material. Positive responses to the aspects of usefulness and material of media are in accordance to the high N-gain in the field testing. It indicates that learning media which is well structured, appealing, motivating, providing visualization, exercise, simulation and self-evaluation is effective in improving students' conceptual understanding. This finding is in accordance to the previous study that showed virtual lab or simulation is effective in helping students learn a concept (Bajpai, 2013). Another finding in previous study indicated that virtual laboratory in smartphone app platform also can improve students' conceptual understanding in rotational kinetic energy (Arista & Kuswanto, 2018). Well-structured multimedia can also enhance students' performance (Chen et al., 2010).

Students' response to the media layout quality is very good with a score of 3.62. Background, button, font, and pictures are set well so that it is comfortable to read. The accessibility of the media is also very good with a score of 3.68. Students do not find significant obstacles or bugging during operation of the smartphone app. Overall, according to most students, the quality of the smartphone app is very good. At last, smartphone app is also convenience to be brought anywhere, it allows students to study anywhere and anytime as they want.

Table 5
Students' Response Concerning the Quality of the Smartphone App

Aspects	Average Score*	Criteria
Usefulness for learning purpose	3.62	Very good
Material	3.36	Good
Layout quality	3.62	Very good
Accessibility	3.68	Very good
**score interval: 1-4*		

CONCLUSION

In summary, we have developed Android based physics learning media in the topics of Impulse-Momentum. According to expert's appraisal and physics teacher's evaluation, the smartphone app is feasible to be used as physics learning media for high school students. The smartphone app has been tested to high school students. Based on the N-gain score analysis, the smartphone app is potential to improve students' conceptual understanding on Impulse-Momentum topics. Students' response on the smartphone app quality is also very good. This study is limited to investigation of cognitive learning outcomes. For further study, more comprehensive investigation to other domains is also needed. Wider scope of the field testing is also recommended.

ACKNOWLEDGEMENT

This work is supported by Grant from the Indonesian Ministry of Research and Higher Education with contract number 115AI/WM01.5/N/2018.

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