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The Development of Learning Module with Mobile Augmented Reality Based on 9E Learning Cycle to Improve Problem Solving Skills

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Abstract

The aim of this research is to produce a learning module with mobile augmented reality based on 9E Learning Cycle. This research is a type of research design. The development model used is ADDIE model which consists of five development phases namely analyze, design, development, implementation, and evaluation. The results of this study are learning modules that have been installed with QR-code and *ModulAR* apps that runs on the Android operating system. The results of validation get from experts' reviewer that consist of 4 mathematics education lecturers and 3 mathematics teachers that showed the predicate of products was valid without revision for use. Then, the module and *ModulAR* apps has been implemented at SMPN 2 Mantup, Lamongan which involved 68 students who were divided into experimental and control classes. The module and *ModulAR* apps has received a practical predicate based on the analysis of the practicality questionnaire filled out by experimental class's students. The use of learning modules with mobile augmented reality based on 9E Learning Cycle is also effective to improve problem solving skills. It can be seen from the average n-gain score obtained 61.10% which is include in the moderate category and the results of the independent-samples t test show that the average of problem solving skills improvement in the experimental class is significantly higher than the control class.

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INTRODUCTION

Problem solving is very valuable skills in the real world, both in work and daily life (Chaudhry & Rasool, 2012). So that is way, it becomes the reason why problem solving skills must be integrated into various learning topics, especially mathematics (Demirel et al., 2015; Tambychik & Meerah, 2010).

Nowadays, problem solving is a main topic in mathematics education curricula for many countries such as Singapore, Hong Kong, England, the Netherlands, and Turkey (Anderson, 2009; Karatas & Baki, 2013). The intensity of problem solving skills training will affect students' mathematics achievement as happened to Japanese students who are superior then USA and Canada students in mathematics (Karatas & Baki, 2013).

Moreover, the curriculum in Indonesia also applies problem solving as one of the competencies that will be achieved in mathematics education (Prabawa & Zaenuri, 2017). However, based on the results of the PISA 2018 (OECD, 2019, p. 107), Indonesia ranks is on 71st out of 77 countries in math proficiency. Then, based on the publication of TIMMS 2015 (Mullis et al., 2016), Indonesia's ranked is on 44 out of 49 countries and many students are still reaching the intermediate level from 4 levels (advanced, high, intermediate, and low). Based on the indicators of mathematics achievement of TIMMS 2015 level, Indonesian students are still unable to apply their understanding and knowledge to complex situations.

The teaching complex material requires more attention. Delivering a complex material by applying visualization in a new dimension such as by adding images, graphic, or video information can make the students easier to understand and comprehend the complex material (Markamah et al., 2018). Furthermore, the technology that is able to accommodate the addition of digital information to real objects is Augmented Reality (AR) (Azuma et al., 2001). AR has been developed to run on a variety of smartphone operating systems (Figueiredo et al., 2014).

Mobile devices are very close to students life, but their integration in the education world is very limited (Bokhove et al., 2018). Meanwhile, the use of mobile devices has many benefits for learners. The research that conducted by Fabian & Topping (2019) show that students who use mobile devices while learning math have better performance. This statement is in line with Etcuban & Pantinople (2018) Hwang et al., (2019) and Wijers et al., (2010) studies that examines about the use of mobile devices in mathematics learning.

Mobile Augmented Reality (AR) is useful for adding information from the digital world into the physical world via mobile device (Craig, 2013). The use of AR in learning can support various things used in learning support materials, including images, text, sound, video, 2D and 3D animation (Bal, 2018). The study that conducted by Astuti et al. (2019) and Karagozlu (2018) show that the use of AR can improve students' problem solving skills. Thus, integrating AR in learning mathematics is needed to improve students' problem solving skills. This is consistent with education in Indonesia, where the most of students have smartphones that run on the most popular operating systems, namely Android and iOS. (Cahyono, 2018, p. 58).

Integrating AR in learning process can be done with learning modules to add more information related to learning materials. It can be seen from Figueiredo et al. (2014) and Lytridis & Tsinakos (2018) studies that showed the learning textbooks are very suitable to integrate with AR technology. Infact, AR integrated learning modules and textbooks rarely provided in Indonesia's education. Therefore, based on that statements, AR integrated learning module needs to be applied in Indonesia education.

Learning module are complete, systematic, and planned set of learning that guides students learn independently or with minimal assistance. (Lestari & Handayani, 2018; Muljoatmodjo, 1979). So that is way, the

integration of AR can be done in the material giving section. The use of modules in learning is an effective way to improve problem solving skills (Cabrera, 2016; Lim, 2016; Silk et al., 2017). However, there is still need a basis for learning steps in the learning module.

Furthermore, 9E Learning Cycle model is intended to improve the competences and skills of students (Kaur & Gakhar, 2015). 9E Learning Cycle is very supporting and accommodating education technology well (Kaur & Gakhar, 2015). Thus, 9E Learning Cycle is suitable and supportive mutually if it is integrated with mobile augmented reality.

Based on the description above, it can be concluded that it is necessary to produce a learning module with mobile augmented reality based on 9E Learning Cycle which is valid, practice and effective in improving students' problem solving skills.

METHOD

The type of this research is research design with ADDIE development model (Analyze, Design, Develop¸Implement and Evaluate) because it is presenting a series of workable systems for complex situations and it is suitable for developing learning products and other learning resources (Branch, 2009, p. 2).

The first phase of the ADDIE development model is the analyze phase. The concept of this phase is to look for gaps between the expected achievements and the attainments obtained, with general procedures namely needs analysis, determining learning objectives, confirming research subjects, identifying required sources, determining systems for realization, and draw up a project plan (Branch, 2009).

The second phase is design phase. It is carried out by determining the learning material and product development design. The design begins with making a flow chart of the learning module and ModulAR apps. For more details, see figure 1.

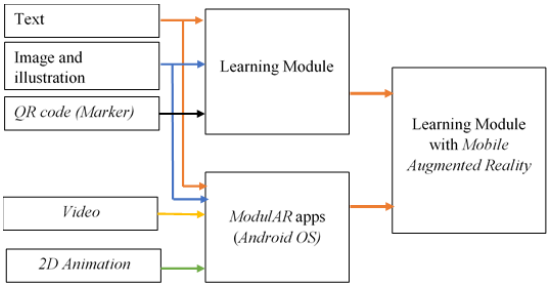

Figure 1. Design of Product

The third phase is the development phase. This phase is the stage of implementing the development plan into a complete product. In this phase, the validity test was also carried out by 7 experts' reviewers that consist of 4 mathematics education lecturers and 3 mathematics teachers. The product has a valid predicate if 8 aspects of validity have the valid without revision or valid enough with few revisions category. The validity category can be seen in table 1.

Table 1. Validity Categories

Percentage	Categories
$\mathbf{75\% \leq \%VC \leq 100\%}$	Valid without revision
$\mathbf{50\% \leq \%VC < 75\%}$	Valid enough with few revisions
$\mathbf{25\% \leq \%VC < 50\%}$	Less valid and many revision
$\mathbf{0\% \leq \%VC < 25\%}$	Not valid and totally revision

Information:

$\%VC$ = percentage of validity score

The fourth phase is implement phase where the products have been produced are implemented in class using a quasi-experimental design with a non-equivalent (pretest-posttest) control group design. (Creswell, 2009, p. 160). There are two classes chosen, they are the experimental class (learning using a learning module with mobile augmented reality based on 9E Learning Cycle) and the control class (conventional learning). Both classes took the problem solving skills test as a pretest and posttest. While, the experimental class students

were asked to fill out a student response questionnaire after learning process.

Then, for the evaluate phase, the results of the student's response questionnaire were analyzed to determine the practicality level of each of 6 practicality aspects. The product has a practice predicate if every practical aspect is categorized as very good or good. The practicality category is presented in table 2.

Table 2. Practicality Categories

Categories	Predicate
$75\% \leq \%\boldsymbol{PS} \leq 100\%$	Very good
$50\% \leq \%\boldsymbol{PS} < 75\%$	Good
$25\% \leq \%\boldsymbol{PS} < 50\%$	Moderate
$0\% \leq \%\boldsymbol{PS} < 25\%$	Poor

Information:

$\%\boldsymbol{PS}$ = percentage of practicality score

Then, an analysis of the results of the problem solving skills improvement is also carried out using n-gain test which refers to the normalized gain (n-gain) with the following formula (Hake, 1999):

$$\langle g \rangle = \frac{(\%\langle S_f \rangle - \%\langle S_i \rangle)}{(100 - \%\langle S_i \rangle)} \quad (1)$$

Information:

$\langle g \rangle$ = N-gain

$\%\langle S_f \rangle$ = *posttest* score

$\%\langle S_i \rangle$ = *pretest* score

Formula (1) is used to calculate n-gain individually, while calculating the average n-gain is done by summing up the n-gain score of each individual divided by the number of individuals. The interpretation of the n-gain score is presented in table 3.

Table 3. N-gain Score Interpretation

Gain Score	Interpretation
$\mathbf{g} \geq \mathbf{0.7}$	High
$\mathbf{0.3} \leq \mathbf{g} < \mathbf{0.7}$	Moderate
$\mathbf{g} < \mathbf{0.3}$	Low

Source: (Hake, 1999)

After the score improvement of problem solving skills from control and experimental class students was obtained, it was continued with an independent samples-t test.

RESULT AND DISCUSSION

This research design produces two products. The first is in the form of a learning module that consist of 44 pages, with congruent and similarity materials, which is divided into 4 sub-materials, namely congruency of flat shapes, congruency of trangle, similiarity of flat shapes, and similiarity of trangle. The learning module developed has a QR-code installed that are ables to display a 2D animation videos when users scan it (Figure 2).

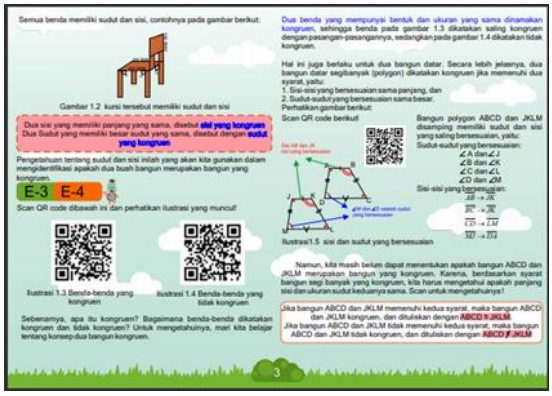

Figure 2. QR-code in the learning module

The basis of learning steps in the module is 9E Learning Cycle which is marked by giving the code E-1 until E-8, and the integrating mobile augmented reality technology as E-9.

The second product is a smartphone application that runs on the Android operating system called *ModulAR* apps which has functions to scan the QR-code in the learning module. The main page displaies the *ModulAR* application containt of 4 buttons that represent each of sub-materials in the learning module (figure 3), and an exit button. *ModulAR* apps use the camera features on a smartphone, which automatically activates when users press the one of the sub-material button (figure 3).

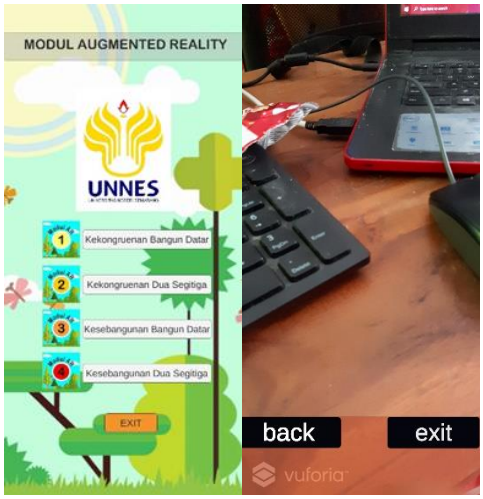

Figure 3. *ModulAR*'s Main Menu

The product of this study namely *ModulAR* apps are very simple and easy to use. It can be proved by the users only need to install the application, open it and select the sub-materials being studied, then after the camera is active, the camera is directed at the QR-code available in the learning module, and the animation as a means of clarifying the visualization will appears automatically as shown in Figure 4. Besides, it is only take 174 MB of smartphone internal storage.

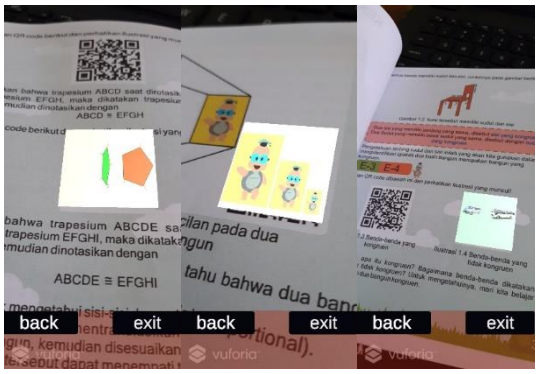

Figure 4. Mobile Augmented Reality in *ModulAR* Apps

The products in this study were validated by 7 expert reviewers consisting of 4 mathematics education lecturers and 3 mathematics teachers. All expert reviewers validate the learning module and ModulAR apps. There are 8 aspects of validity assessed by experts, namely: quality of content, self contained, self instructional, alignment with learning objectives, stand alone, presentation design, user interaction and reuse. The validation results can be seen in Figure 5.

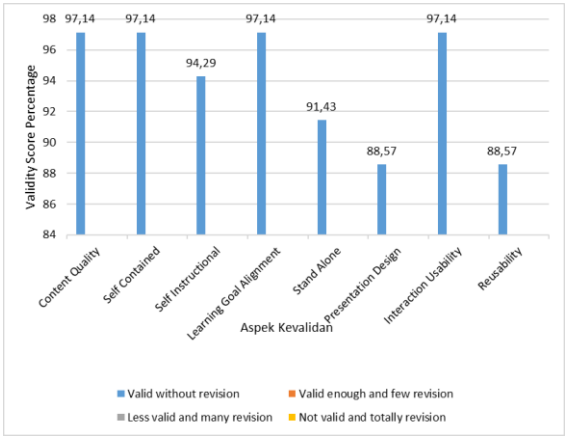

Figure 5. Validity Test Results

Validation results of experts' review show that 8 aspects of validity get a percentage at least 88.57% validity score which means that all aspects are categorized as valid without revision. Based on the results of the validity test by experts review, the learning module with mobile augmented reality based on 9E learning cycle got a valid predicate.

After that, the product is implemented in learning process to test the practicality. The practicality test is based on the students' response questionnaire in experimental class of grade IX that consist of 34 students after learning process using the products. The practicality test results can be seen in Figure 6.

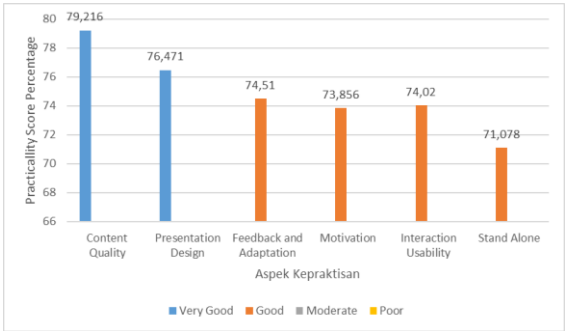

Figure 6. Practicality Test Results

The results of the practicality test showed that from 6 practicality aspects, 2 aspects are called as content quality and presentation design

were in very good category. While, 4 other aspects get good category. Thus, it was found that the learning module with mobile augmented reality has received a practice predicate.

One of the aspects of the practicality test is presentation design which gets the practicality score percentage of 76.47% which represents a very good category. This indicates that the users find the product display concise, clear and aesthetically pleasing. Besides, the augmented reality animation used is also good quality.

The use of products in learning process is also proven to be able to increase student motivation in learning. This was revealed by obtaining a good category with a practicality score percentage of 73.86% for the motivational aspect. Several studies have also revealed that students who applied augmented reality in learning process have a high level of learning motivation (Pujiastuti et al., 2020).

The results of n-gain score improvement of problem solving skills by implementing the products in learning process can be seen in Figure 7.

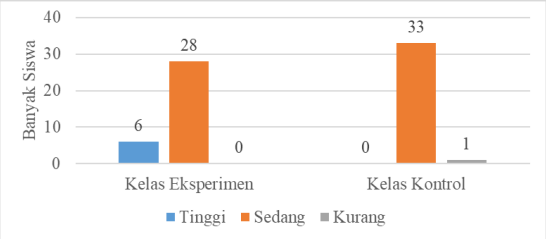

Figure 7. N-gain Results

There are 6 students who get a high category in the problem solving skills improvement. On the contrary, there was actually 1 control class student who got a low category in the problem solving skills improvement. The n-gain average of the experimental class and control class were 61.10% and 44.01%, respectively, both of which were in the moderate category. However, the experimental class was superior with the acquisition of a higher average score of problem solving skills improvement.

Then, to determine the intervention of products to improve problem-solving skills, a statistical comparison of the n-gain scores of the experimental class and the control class was carried out. Previously, the Kolmogorov-Smirnov test showed that the n-gain score was normally distributed ($sig. = 0{,}200 > \alpha = 0{,}05$) and Levene's Test showed that the n-gain score was homogeneous with $Sig. = 0{,}085 > \alpha = 0{,}05$.

Then, the results of independent-samples t test with equal variance assumed shown that the average problem-solving skills improvement in experimental class is more than the control class ($Sig. = 0{,}000 < \alpha = 0{,}05$). So it can be said that the implementation of learning module with mobile augmented reality based on 9E Learning Cycle in learning is effective for improving problem solving skills. These results are in line with several studies which showed that the implementation of mobile augmented reality in learning can improve students' problem solving skills and mathematics learning outcomes. (Astuti et al., 2019; Chao & Chang, 2018; Chiang et al., 2014; Estapa & Nadolny, 2015).

CONCLUSION

The products of this study are learning module that has been installed with a QR-code with the 9E learning cycle as the basis for the learning model and ModulAR apps that runs on a smartphone with the Android operating system integrated into a learning module with mobile augmented reality based on 9E Learning Cycle. The product developments are aimed to improve problem-solving skills. Experts have assessed that the products developed are valid in 8 aspects, they are quality content, self contained, self instructional, alignment with learning objectives, stand alone presentation design, user interaction and reuse.

The practicality test results based on the student response questionnaire in the experimental class showed that the product was considered practice category with 2 practical aspects of content quality and presentation design getting a very good category, then 4 other practical aspects, namely feedback and adaptation, motivation, interaction usability, and stand alone in good category.

The products also effective in improving problem solving skills. It can be proved by the mean n-gain score of experimental class (61.10%) greater than control class (44.01%). Then, the results of the analysis with independent-samples t test also showed that the learning module with mobile augmented reality based on 9E Learning Cycle in learning was effective for improving problem solving skills. Based on the results of this study, the learning module with mobile augmented reality based on 9E learning cycle can be an alternative to improve problem solving skills, especially in congruent and similiarity materials. Therefore, it can be use to develop the learning activities individually or grouply.

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