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Development of 2-D augmented reality integrated physics e-book to improve students' problem-solving skills

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Abstract: This study aims to produce an augmented reality integrated e-book that is feasible to improve the problem-solving skills of 11th graders; identify the improvement of 11th graders' problem-solving skills after using the augmented reality integrated e-book. Problem-solving is a way of obtaining solutions to difficulties and is divided into four indicators, which are: understanding the problem, making plans, implementing plans, and reviewing solutions. Data collection techniques consist of tests, questionnaires, observations, and documentation using instruments that support the Research and Development (R&D) technique with a 4D model. Research subjects were selected by simple random sampling with 34 students of 11th graders. In this study, questionnaires were used for validation, observations were made to determine the condition of students, and documentation was used as evidence in conducting research. The data were analyzed quantitatively based on the results of the validation and analysis of pretest and posttest items. The results showed that the augmented reality integrated e-book is feasible to use based on the results of validation using the average value conducted by a very high category validator and the validation value obtained is 3.79. The improvement of problem-solving skills was analyzed using Normalized Gain and the improvement of problem-solving skills got a score of 0.8 in the high category.

Keywords: E-Book; Augmented Reality; Problem-Solving

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Introduction

Physics is a subject that requires an understanding of concrete and abstract concepts (Ismail et al., 2019). Physics in its use is generally limited to natural phenomena but may produce general laws or basic principles to explain them (Dewi et al., 2019; Madu, 2020). Therefore, physics is necessary and important to study. However, physics is considered a difficult subject for students because students still have difficulty determining the solution to a problem if the problem is different from the previous example (Ince, 2018). Students are still learning to memorize formulas and less visualize concepts in solving problems (Docktor & Mestre, 2014). One of the objectives of learning physics is to create students who can solve problems by applying knowledge and understanding in everyday life. Problem-solving as a way to obtain solutions to difficulties is divided into four indicators, namely: (1) understanding the problem; (2) making plans; (3) implementing plans; and (4) reviewing solutions (Pólya, 2014).

Currently, research related to physics problem-solving skills is still dominated by mechanical and electric-magnetic materials (Caleon & Subramaniam, 2010) as well as temperature and heat (Leinonen et al., 2013). Physics education research that examines students' problem-solving skills on optical instrument materials is quite rare. The optical instrument is a material that discusses objects

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in the form of optical instruments that are scarcely owned by schools, so that visualizations need to be made in the form of animation. Therefore, a media with capability to visualize various optical instruments and understand each part of the optical instrument is necessary. The optical instruments studied for 11th graders consist of the eye, camera, microscope, telescope, and loupe.

Advances in technology offer the possibility of using mobile devices to enrich the learning environment with multimedia content that includes audio-visual (Becker et al., 2020). One of the renewable technologies that is experiencing significant development at this time is Augmented Reality (AR) (Hamzah et al., 2021). AR technology makes two-dimensional and three-dimensional virtual objects appear real. It is a technology that utilizes mobile phones and allows students to interact with digital information (Bower et al., 2014; Elfeky & Elbyaly, 2021; Koutromanos et al., 2015) which can develop and contribute to problem-solving skills. AR is interesting to use in learning because it can provide moving images or virtual videos related to real objects that are scanned using a smartphone. By developing AR, students are allowed to learn and understand material that are unexplainable by still images.

AR has attracted the attention of researchers with its use as an effective learning and teaching tool in physics (Akçayir et al., 2016); (Cai et al., 2017); (Cai et al., 2014); (Ibáñez et al., 2014) since the technology is able to understand the typical concepts of physics (Ibáñez et al., 2014). The use of AR in physics is very helpful in visualizing abstractions of physics (Kravtsov & Pulinets, 2020). It can also provide experiences that evoke attention, motivation, thereby enhancing student learning experiences (Harun et al., 2020). In addition, learning using AR can improve students' problem-solving skills (Astuti et al., 2019); (Karagozlu, 2018); (Guntur et al., 2020).

AR features can be added to learning media such as e-book. Digital books/e-books are electronic versions of printed books and can be read with a computer device or device for certain purposes (Siegenthaler et al., 2010). This makes an e-book is one of the most attractive and interactive learning media compared to the printed one (Mohammed & Rahman, 2015). An e-book can serve as a learning resource for students to increase student motivation and provide better learning outcomes (Ambarwati et al., 2019). The use of e-book can also improve students' problem-solving skills (Lieung et al., 2021). Based on the above literature sources, AR and e-books are able to improve students' problem-solving skills. This innovation offers independent learning that can be controlled by educators (teachers) in online and offline learning with technology. Therefore, in this research, an integrated physics e-book of 2-dimensional AR will be developed. Based on the explanation above, the aims of the research are producing an augmented reality integrated e-book that is feasible to improve the problem-solving skills for 11th graders and identifying the improvement of 11th graders' problem-solving skills after using the AR integrated e-book.

Methods

The method used in this research is Research and Development (R&D) with a 4D model namely define, design, develop, and disseminate adapting from Thiagarajan (Rani et al., 2017). The research procedure shown in Figure 1.

The research was conducted in April 2021 at Senior High School. This research was conducted on 34 students of 11th graders at Senior High School. Research subjects were selected by simple random sampling. This research consists of two stages, namely modeling and implementation. Modeling is learning using AR integrated e-book conducted by researchers and implementation is learning using AR integrated e-book conducted by teachers of 11th graders at Senior High School. The modeling stage and implementation stage use class XI MIPA 3.

The research instruments are divided into two parts, namely learning instruments and data collection instruments. The learning instruments consist of the AR integrated e-book and lesson plans. The data collection instrument consisted of instrument validation sheets and pretest-posttest questions for problem-solving skills with a total of 10 essay questions. Problem-solving skills questions were developed by the author based on indicators of problem-solving skills and indicators of optical instrument material.

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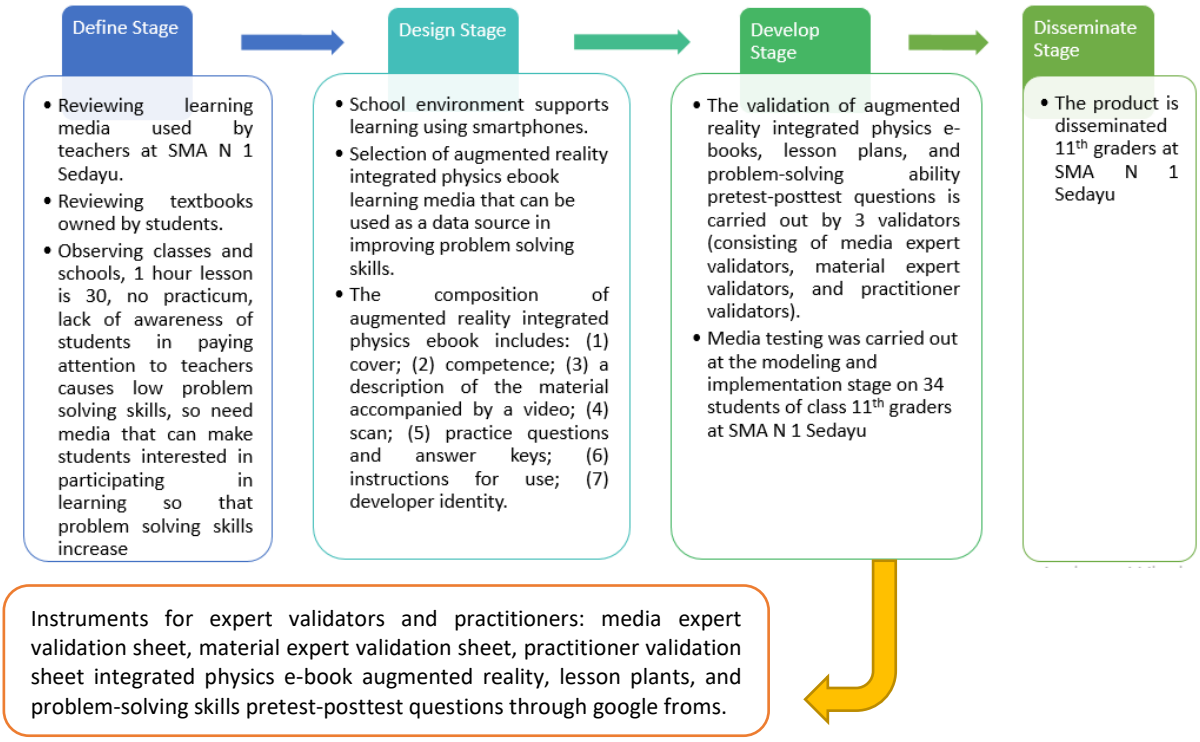

Figure 1. Research procedures and instruments

Data collection techniques consisted of tests, questionnaires, observations, and documents in the form of photos and videos. The test consists of pretest and posttest to determine the improvement of students' problem-solving skills. The questionnaire consists of an instrument validation sheet consisting of an augmented reality integrated physics e-book media, lesson plan, and pretest posttest problem-solving skills. Observations made before the research was conducted. They were observing the state of the school and the learning process. Documentation was done to keep the research data. The validation results were averaged and categorized based on the feasibility of the AR integrated physics e-book that has been developed, lesson plans, and pretest-posttest problems of problem-solving skills.

In this research, the validated instrument consisted of an integrated e-book of augmented reality, lesson plans, pretest-posttest questions of problem-solving skills. Validation was carried out by three physics teachers from 3 different schools who are holding a master's degree in physics education. They are material expert validators, media expert validators, and practitioner validators. The results of the validation of the lesson plans instrument, AR integrated e-book, pretest questions, and posttest questions were analyzed using V Aiken. The steps to analyze it using Equation 1.

$$V = \frac{\sum r - l}{N(c-1)} = \quad (1)$$

From the Equation 1 it can be explained that *r* is the value given by the validator, *l* is the lowest number of validity assessments, *c* is the highest number of validity assessments, and *N* is the number of validators. The value of the V Aiken index calculation of an item can be categorized based on its index into three categories, namely high, medium, and low. For the division of the index category V Aiken can be seen in Table 1.

Table 1. Categories of V Aiken

Index V Aiken	Category
$V \leq 0.4$	Low
$0.4 < V \leq 0.8$	Medium
$0.8 < V \leq 1$	High

Source: (Kowsalya et al., 2012)

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The test results of students were analyzed with N-gain (normalized gain) which aims to determine the magnitude of the increase in learning outcomes and problem-solving skills of students from pretest to posttest (Hake, 1999). Based on the results of the analysis using the N-gain, the value obtained was converted using the N-gain category table to determine the increase in the problem-solving skills of students. There are three categories of identifying the N-gain, namely high, medium, and low. The distribution of N-gain category can be seen in Table 2.

Table 2. N-Gain Category

N-Gain	Category
$\langle g \rangle > 0.7$	High
$0.3 \leq \langle g \rangle \leq 0.7$	Medium
$\langle g \rangle < 0.3$	Low

Source: (Hake, 1999)

Data from the pretest and posttest results of students' problem-solving skills were also analyzed using paired t-test. Paired t-test is one method of testing the hypothesis in which the data used are not independent (pairs). The characteristics that are most often found in paired cases are that one individual (object of research) gets 2 different treatments. Even though using the same individual, researchers still obtained 2 kinds of sample data, namely data from the first treatment and data from the second treatment (Xu et al., 2017).

Results and Discussion

The AR integrated physics e-book that was developed was then tested to measure students' problem-solving skills. The developed e-book contains material on optical instruments. There are two images that become marker images in the book, namely an eye image and a microscope image. The eye image and microscope image contained in the e-book can be scanned using the Artivive application. When the eye and microscope image is scanned, it will show a video of the shadow formation that occurs in the eye and the microscope. In addition, the video also contains presentation material regarding the process of forming shadows on the eye and the microscope. The AR feature in the form of educational videos can help students understand the material independently. In addition, there are images that can be scanned, the e-book also contains material on optical devices, sample questions, and practice questions. Therefore, the e-books can be read anywhere and anytime by students. Figure 1 is an image of the contents of an e-book that is integrated with AR.

The lesson plans contain the learning steps to be applied in the learning process. The lesson plans include core competencies and basic competencies that follow the syllabus of the revised 2013 curriculum. The indicators and learning objectives that have been made by the researcher are also included in the lesson plans. The indicators achieved in learning using augmented reality integrated e-books are: being able to explain the anatomy of the eye and its function in the formation of images in the eye, explain the formation process in the eye, analyze the condition of the lens when the eye is not accommodated and accommodate maximum, explain the formation of shadows in people with eye defects, explains the formation of the camera, explains the working principle of the eye with the camera, analysis of the formation by the lens in the accommodated and non-accommodating eye, analysis of the shape by a microscope in the eye that accommodates and does not accommodate, explains the various types of binoculars, explains the difference in the formation of shadows by binoculars and binoculars Earth, conducting experiments to determine the formation of the eye, conducting experiments to determine the working principle of a loupe and microscope, and making simple binoculars. The learning model used in this lesson plan is Discovery Learning with discussion, lecture, and question and answer methods.

The lesson plans were tested for feasibility by three validators before being used in the study. Lesson plans validation is reviewed based on feasibility aspects. The results of the lesson plan validation are presented in Table 3.

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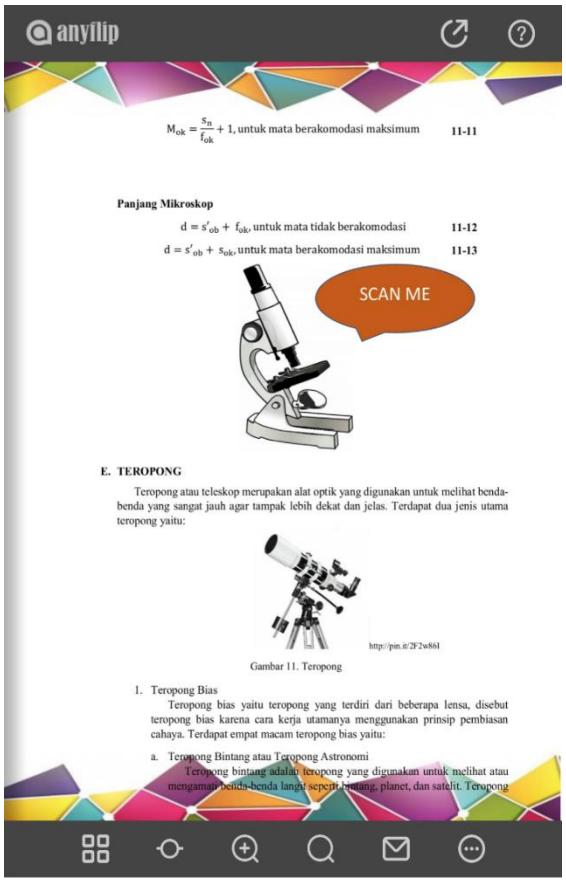

Figure 1. Augmented Reality 2D Integrated E-Book View

Table 3. Validation Result of Lesson Plan

Indicator	Validator			Index V Aiken	Category
	1	2	3		
Identity	4	4	4	1.00	High
Learning objectives	4	4	4	1.00	High
Core Competencies and Basic Competencies	4	4	4	1.00	High
Indicators of Competence Achievement	4	4	4	1.00	High
Learning materials	4	4	4	1.00	High
Learning Activities	4	3	4	0.89	High
Assessment Instrument	3	4	3	0.78	Medium
Language	4	4	4	1.00	High
Time Allocation	3	4	4	0.89	High
Average				0.89	High

Based on the assessment of the three validators, the items given in the lesson plan can be interpreted as very good. This is evidenced by the index v Aiken obtained from the total result indicators of 0.89, so that the RPP is feasible to use. This is in line with the comments given by the validator about the lesson plans that are in accordance with the syllabus, the competencies, and the basic competencies of optical instrument materials. The allocation of learning time is also appropriate. In addition, the use of communicative language is very appropriate to the level of student development.

AR integrated e-book contains material, sample questions, practice questions, and AR integrated videos that will be used in learning, namely optical instrument material. The e-book was tested for feasibility by three validators before being used in the study. The validation of the augmented reality integrated e-book is reviewed based on several aspects consisting of construction, content, language. The validation result for AR integrated e-book is presented in Table 4.

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Table 4. Validation Result of Augmented Reality Integrated E-Book

Indicator	Validator			Index V Aiken	Category
	1	2	3		
Identity	3	4	4	0.89	High
Introductory presentation	3	4	4	0.89	High
Material presentation	4	4	4	1.00	High
Appearance	4	3	4	0.89	High
Material according to Basic Competence	4	4	4	1.00	High
Material according to purpose	4	4	3	0.89	High
Fact accuracy	4	3	4	0.89	High
Image suitability	4	4	3	0.89	High
Material collapse	4	4	4	1.00	High
Evaluation questions	4	3	3	0.78	Medium
Language use	4	4	4	1.00	High
Communicative language	4	4	4	1.00	High
Does not lead to double interpretation	4	4	4	1.00	High
Average				0.93	High

Based on the assessment of the three validators, the index of V Aiken was 0.93. Therefore, the AR integrated physics e-book was categorized very good and the e-book developed was feasible to use. For evaluation questions, the results obtained are the lowest because, based on the validator's suggestions, there are questions that are not in accordance with the indicators of problem-solving skills.

The assessment of the problem-solving skills test items is reviewed based on the material, construction, and language aspects. The assessment of the problem-solving skills test items was tested for feasibility by three validators before being used in the study. The validation result for assessment of the problem-solving skills test items is presented in Table 5.

Table 5. Validation Result of Number of Item

Indicator	Number of Item									
	1	2	3	4	5	6	7	8	9	10
The suitability of the question indicators	3.67	4	4	2.67	3.67	4	2.67	3.67	4	3.67
Clarity of question and answer boundaries	4	3.67	3.67	4	4	3.67	4	4	3.67	4
The suitability of the formulation of the question indicator	3.67	2.67	2.67	2.67	3.67	2.67	2.67	3.67	2.67	3.67
Statements are clearly formulated	3.67	2.67	4	3.67	3.67	2.67	3.67	3.67	4	3.67
Clarity of instructions for working on questions	4	4	4	2.67	2.67	4	2.67	4	4	2.67
Clarity of scoring guidelines	3.67	3.67	2.67	4	4	3.67	4	3.67	2.67	4
Clarity of pictures, graphs, and the like presented	2.67	3.67	2.67	3.67	3.67	3.67	3.67	2.67	2.67	3.67
The formulation of the sentence used is communicative	2.67	2.67	2.67	3.67	3.67	2.67	3.67	2.67	2.67	3.67
The sentences used are good and correct	3.67	3.67	3.67	2.67	2.67	3.67	2.67	3.67	3.67	2.67
Do not use the local language	3.67	4	3.67	4	4	4	4	3.67	3.67	4
Index V Aiken	0.89	0.90	0.90	0.88	0.90	0.90	0.88	0.89	0.90	0.90
Category	High	High	High	High	High	High	High	High	High	High

Based on the assessment of the three validators, the items of the pretest-posttest problem-solving skills were very well prepared. This is evidenced by the index value obtained from the total indicators with an average result of 0.89, so that the pretest posttest problem-solving skills is feasible to use. This is in line with the comments given by the validator about the questions that are in accor-

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dance with the indicators of problem-solving skills. The time allocation for the work is also appropriate. In addition, the use of communicative language greatly facilitates students in solving problems.

The aspect studied in this augmented reality integrated e-book development research is about improving student problem-solving skills. Measurement of improvement in problem-solving skills is done by giving pre-test and post-test questions before and after using augmented reality integrated e-books. The problem-solving skills question contains 10 essay questions that have been validated by the validator and have been declared valid. Based on the analysis using N-gain, it was found that all 34 students of class XI MIPA 3 had a high value of increasing problem-solving skills.

The average problem-solving skills pre-test score was 40.3 while the problem-solving skills post-test average was 85.1. Based on the analysis using the N-gain of the two scores, the result of an increase in the problem-solving skills of students is 0.8. This value is in the interval ($\langle g \rangle$) ≥ 0.7 so that it is included in the high category. This data illustrates that the use of augmented reality integrated e-books can improve student problem-solving skills. The comparison of the average pre-test and post-test scores of problem-solving skills using an integrated augmented reality e-book is shown in Figure 2.

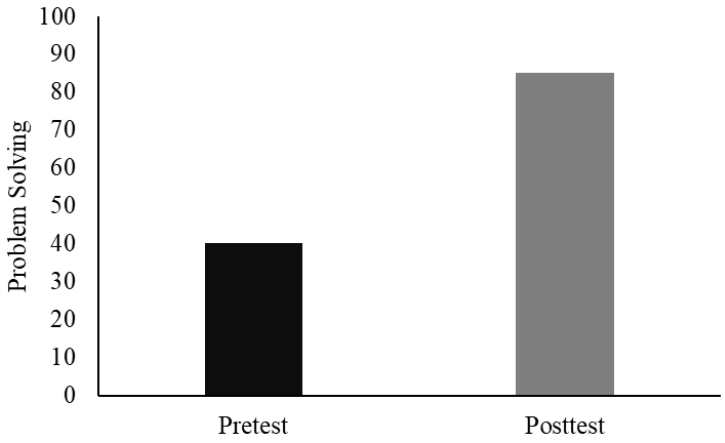

Figure 2. Average Comparison Graph

To find out whether the use of media has an effect or not in improving problem-solving skills, it can be seen through the Paired T-Test test which was previously started with the normality test first and the resulting data can be seen in Table 6.

Table 6. Test of Normality

	Shapiro-Wilk		
	Statistic	df	Sig.
pre-test	.950	34	.121
post-test	.945	34	.087

*. This is a lower bound of the true significance.
a. Lilliefors Significance Correction

The results of the normality test used are the results of normality with the Shapiro-Wilk. Based on the normality test data obtained, the sig. pretest and posttest values were 0.121 and 0.087, respectively. Both of which were > 0.05 so that the data were normally distributed. The results of the normality test are a requirement to carry out the next test, namely the Paired Samples T-Test test. The results can be seen in Table 7.

Table 7. Paired Samples Test

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
				Lower	Upper			
Pair 1 pre1 - pos1	-44.735	10.352	1.775	-48.347	-41.123	-25.197	33	.000

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The test results show the value of Sig.(2-tailed) equal to 0.00 or less than 0.05 so it can be concluded that there is a significant difference between the results obtained after the posttest and before the pretest. Thus, it can be concluded that the use of AR integrated e-books is effective in improving problem-solving skills.

Based on the results of the analysis, it was found that the improvement of students' problem-solving skills had a high category so that using an augmented reality integrated physics e-book could improve students' problem-solving abilities. This is also in line with previous research which states that the use of augmented reality applications has a positive effect on students' problem-solving abilities (Astuti et al., 2019). Problem-solving abilities can be increased because using augmented reality can directly provide learning wherever and whenever students want to carry out the learning process (Carbonell Carrera & Bermejo Asensio, 2017). By utilizing AR media, it can increase students' interest in learning because AR combines the virtual world which can increase students' imagination with the real world directly (Turan et al., 2018).

The use of e-books will also stimulate students' problem-solving skills and an attitude of caring for the environment. Research conducted by (Lieung et al., 2021) also states that e-books will make it easier for students to understand the material presented. E-books can stimulate students to learn because they are presented in an attractive manner so that it can have a positive impact on student achievement. It can be concluded that E-books can make it easier for students to learn so that they have an effect on increasing student learning outcomes, and can improve students' problem-solving abilities (Lieung et al., 2021). Based on the discussion above, AR integrated physics e-books can be used with appropriate categories for learning activities, so as to improve the problem-solving abilities of students with high categories.

Conclusion

The results of the research and development show that the AR integrated physics e-book on optical instruments is valid and feasible to use. The augmented reality integrated e-book is feasible to use based on the results of the validation using the average value carried out by the validator with a very high category. Students find the AR integrated physics e-book easy to use and practical. The use of AR integrated physics e-books in physics learning also has a positive effect on problem-solving skills. The improvement of problem-solving skills was analyzed using Normalized Gain. The score of improved problem-solving skills is considered in the high category. The next researchers are recommended to test the AR integrated physics e-book on other physics materials and see the difference in the results. Besides, the effectiveness of this AR integrated physics e-book can be tested in improving students' solving skills.

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