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THE EFFECTIVENESS OF PROBLEM-BASED LEARNING PHYSICS POCKETBOOK INTEGRATING AUGMENTED REALITY WITH THE LOCAL WISDOM OF CATAPULTS IN IMPROVING MATHEMATICAL AND GRAPHICAL REPRESENTATION ABILITIES

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Abstract

This research aimed to reveal the effectiveness of using a Problem-Based Learning (PBL) physics pocketbook integrating augmented reality (AR) with the local wisdom of catapults in improving the mathematical and graphical representation abilities of high school students. This study is a quasi-experiment with a pretest-posttest control group design. The data collection was carried out in two stages, namely empirical testing and effectiveness testing stages. The empirical test was conducted on 276 grade XII students, while the effectiveness test was conducted on three science classes of grade XI students of State Senior High School (SMAN) 10 Yogyakarta. The three classes consisted of 36 students in the experimental class, 36 students in the Contrast Class 1, and 36 students in the Contrast 2 Class. The mathematical and graphical representation abilities were measured through a test instrument that passes the analysis of the empirical test using the QUEST program. General Linear Model (GLM) was utilized to analyze the effectiveness test, which was supported by the SPSS software. The result of the General Linear Model (GLM) analysis in the experimental class showed a significant value of 0.000 on the mathematical and graphical representation ability variables. The findings of this study indicate that the use of the developed Problem-Based Learning physics pocketbook integrating augmented reality with local wisdom is effective in increasing the mathematical and graphical representation abilities of grade XI students, with an effective contribution of 82.6% and 84.4% each.

Keywords – Augmented reality, Graphical representation, Local wisdom, Mathematical representation, PBL, Pocketbook.

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1. Introduction

The world of education has a major effect on increasing the potential of human resources in a nation's civilization. This increase is being complemented by the advances in science and technology. The field of science plays an important role in the advancement of science and technology. Science is classified as basic and it is important to learn; through science, we can know the benefits and applications of anything around us. One component of science that is important to learn is physics (Anwar et al., 2019; Diani, Yuberti & Syarlisjiswan, 2018).

The importance of learning physics usually does not go according to expectations. Most students consider the field of physics to be very difficult to learn, especially at the high school level (Simanjuntak, Marpaung, Sinaga & Siregar, 2021). The difficulties in secondary school physics are usually found in the materials related to material elasticity, especially in the multi-representation abilities of students (Jannah, Sarwanto & Sukarmin, 2019). Material elasticity is the basic concept of physics that is poorly mastered by students (Rosiqoh, Barus, Bohori & Suhendi, 2020; Sa'diyah, Sarwanto & Sukarmin, 2017). Research reveals that understanding of the concept of material elasticity is still low (Batlolona, Diantoro, Wartono & Latifah, 2019). The reason is none other than the difficulty of students in answering problems related to Hooke's law sub-materials, the arrangement of springs, and the modulus of elasticity (Batlolona, Diantoro, Wartono & Leasa, 2020; Sa'diyah et al., 2017).

The above research findings are supported by another finding that shows that the percentage of students who answered correctly in Hooke's legal problems was only 4%, while the other 96% answered incorrectly (Mustofa, 2018). In the sub-material of the modulus of material elasticity, the percentage of success in answering was only 57% (Sa'diyah et al., 2017). The difficulty continues, especially in the mathematical and graphical representation abilities in the material elasticity. Usually, students tend not to answer the questions with graphical and mathematical representation indicators (Jannah et al., 2019; Rosiqoh et al., 2020). This shows that there are still many students who have low mathematical and graphical representation abilities. Thus, it is necessary to strengthen students' conceptual understanding through the use of learning media that can represent abstract concepts in material elasticity.

Technological developments in the era of the industrial revolution 4.0 have produced many smartphone-based learning media (Aththibby, Kuswanto & Mundilarto, 2021; Bani & Masruddin, 2021; Liliarti & Kuswanto, 2018; Raras & Kuswanto, 2019; Saputra & Kuswanto, 2018; Shabrina & Kuswanto, 2018). The interest of students in accessing smartphones is one of the backgrounds for the development of the media (Sari, Riswanto & Partono, 2019). Several studies show that one of the learning media innovations by utilizing mobile technology that is being intensively used and developed is augmented reality (AR) (Fidan & Tuncel, 2019; Kholiq, 2020; López-Belmonte, Pozo-Sánchez, Fuentes-Cabrera & Romero-Rodríguez, 2020; Permana, Tolle, Utaminingrum & Dermawi, 2019; Suprapto, Ibisono & Mubarok, 2021). The application of augmented reality (AR) in learning process allows for the visualization of two-dimensional things in three dimensions. So, objects look real (Arslan, Kofoğlu & Dargut, 2020; Bakri, Permana, Wulandari & Muliyati, 2020; Khan, Johnston & Ophoff, 2019). Therefore, augmented reality (AR) technology is able to facilitate and support the explanation of abstract physics concepts to students.

The selection of learning models is also important in overcoming these problems. The Problem-Based Learning (PBL) model is one of the learning models that is proven to help deepen scientific knowledge and revise conceptual understanding (Yuberti, Latifah, Anugrah, Saregar, Misbah & Jermsittiparsert, 2019). PBL tends to stimulate students with a problem. Stimulus in Problem Based Learning (PBL) is contextual which is taken in everyday life (Haryanti, Wilujeng & Sundari, 2020). This is in line with the characteristics of physics itself.

One of the characteristics of physics concepts that can be found in everyday life is local wisdom or community traditions. This is one of the factors that contribute to students' understanding of the physics concepts being taught (Jensen, Stentoft & Ravn, 2019; Qasem, 2016). Cultural diversity in Indonesia cannot necessarily be studied in a limited time. In overcoming this issue, it is necessary to have mobile application-based learning media with several integrations in the form of culture, PBL teaching models, and augmented reality (AR) technology to become a teaching medium. Thus, the development and implementation of media with the integration of these three things were carried out in order to increase students' mathematical and graphical representation abilities.

The media that is implemented is in the form of a Problem-Based Learning physics pocketbook integrating augmented reality by adding the local wisdom in the form of a catapults. The magnitude of the elasticity of the material in this medium is explained through the 3D augmented reality (AR) animation of the catapults. This is intended to grab students' attention and support students' understanding of material elasticity. Therefore, students are able to improve their mathematical and graphical representation abilities in learning physics, especially on the subject matter of material elasticity. The theoretical framework of this research is presented in Figure 1.

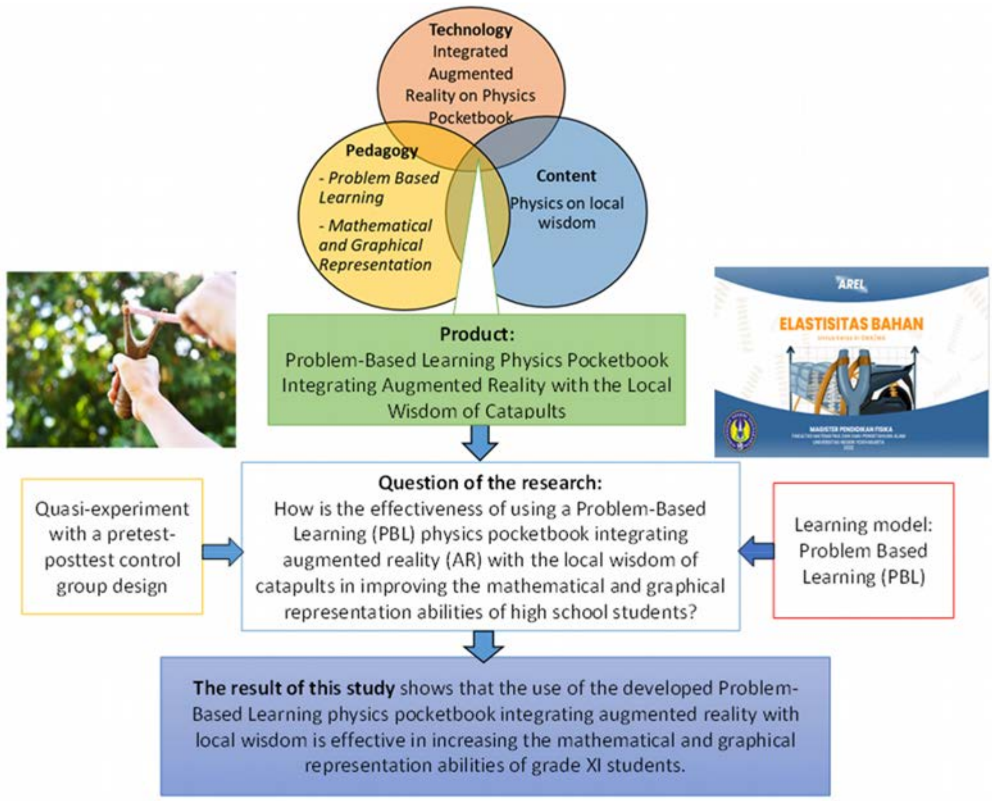

Figure 1. Theoretical Framework

2. Research Method

2.1. Research Design

This study is a quantitative quasi-experimental that involves three different classes using a pretest-posttest control group design. The three classes consist of one experimental class, and two contrast classes (comparison). The experimental class is a class with treatment in the form of physics learning using a Problem-Based Learning physics pocketbook integrating augmented reality. Contrast Class 1 is a class that uses power-points media (PPT), while in Contrast Class 2, learning is carried out using school textbooks. The detailed can be seen in Table 1.

Group	Pretest	Treatment	Posttest
Experimental Class	O_1	X_1	O_2
Contrast Class 1	O_1	X_2	O_2
Contrast Class 2	O_1	X_3	O_2

Notes: O_1: Pretest; O_2: Posttest; X_1: Physics teaching by applying PBL physics pocketbook integrated with augmented reality (AR); X_2: Physics teaching by applying PowerPoint media; X_3: Physics teaching by applying textbooks used by teachers

Table 1. Research Design

2.2. Research Sample

This study used two stages of testing with different samples. The empirical test phase aimed to determine the items of the material elasticity test that were valid and reliable, before being implemented in the research design class. The empirical test involved 276 grade XII students of three different high schools, namely State Senior High School (SMAN) 1 Comal, SMAN 2 Pemalang (Taman), and SMAN 3 Pemalang. Grade XII students were used as an empirical test sample because they had been given material elasticity lessons. The empirical test instrument consists of 15 questions. The details of these question indicators are shown in Table 2.

Indicator of mathematical representation ability	Item number	Question Indicator
Reading mathematical symbols according to the problem	1	An event is presented when a child pulls a rubber catapult to shoot mangoes in his father's garden. Students were asked to determine the increase in length, the symbols of known quantities (stress, and modulus of elasticity).
	2	2 springs used in an experiment are subjected to different forces and it is known that one of them increases in length. Students were asked to examine influential magnitude symbols and other spring length increase values
	3	Students were asked to determine the symbol of the quantity that has an effect and examine the value of the increase in the length of the spring that occurs in parallel arrangements, when there is a picture and description about spring arrangements
Determining mathematical equations according to the problem	4	A description of the problem regarding two types of elastic materials to make a catapult's rope has the same length, and the diameters of the two elastic materials are known. Students were asked to analyze the equation to find the overall increase in length of the elastic material, if the two elastic materials are connected as a slingshot rope with a stone load of w.
	5	A problem regarding 4 family members who get into a car so that the springs of the car are compressed or experience a certain increase in length is presented. Assuming the spring is single. Students were asked to analyze the equation to find the spring constant of the car and the value of the spring constant in question
	6	Students were asked to come up with the right equation in determining the ratio of length increases from spring arrangements carried out by students in an experiment
Operating numbers or symbols in mathematical equations correctly	7	An event is presented about a rock climber who falls and hangs from a rope with a known initial rope length, diameter and length increase. Students were asked to analyze the Young's modulus of the rope if the mass of the rock climber is known.
	8	A problem is presented about a group of students conducting a Hooke's law experiment on a spring suspended by a load. With the experiment table containing the force value and the known length of the spring. Students were asked to assess the spring constant or spring rate based on the Hooke's law experiment table presented.
	9	A picture of 3 springs arranged in parallel and in series is presented. The spring constant of each spring is known. Students were asked to analyze the mass of the load suspended in the arrangement of the 3 springs in the picture if the increase in length is known after being loaded.

Indicator of graphical representation ability	Item number	Question Indicator
Connecting graphs and mathematical formulas	10	A graph of the force relationship with the increase in length of an elastic rope on a catapult is presented. Students were asked to conclude at which point the rope changes its properties to become plastic based on the mathematical equation.
	11	A graph of the relationship between the force and the increase in length of the three springs is presented. Students were asked to interpret which spring constant value is the largest of the three springs through the information on the graph.
Modelling real objects or situations into graphics	12	Illustrations and descriptions of the problem of a child pulling a catapult are presented, but over time the catapult rope is no longer elastic. Students were asked to display a graph of the relationship between stress and strain when the applied stress exceeds the elasticity of the slingshot rope.
	13	A table is presented with the results of Hooke's law experiment. The table contains information about the mass of the load suspended at the end of the spring and the increase in length. Students were asked to make a graph of the relationship between force and length increase according to the information in the table, and conclude.
Processing information from a graph and calculating the physical quantity in question	14	A graph of the relationship between force and length increase is presented. Students were asked to analyze the value of the spring constant based on the information in the graph.
	15	A graph of the relationship between force and length gain is presented in an experiment on Hooke's law. Students were asked to analyze the potential energy of the spring based on the information on the graph.

Table 2. 15 Questions on Instrument of Empirical Test

The next stage was the effectiveness testing by involving 108 grade XI science students of SMAN 10 Yogyakarta. The sample was divided into three treatment classes. Each treatment class consisted of 36 students. The three classes were experimental class (grade XI Science 1), Contrast Class 1 (grade XI Science 3), and Contrast Class 2 (grade XI Science 2). The sample was established by using the random sampling technique.

2.3. Research Instrument

There are two types of research instruments, namely the teaching instrument and the data collection instrument. Teaching instrument is in the form of lesson plans and student worksheets, while the data collection instrument is in the form of a test. The essay test of the material elasticity to improve the mathematical and graphical representations abilities consists of three variable indicators with details presented in Table 3.

Variable	Indicators	Treatment
Mathematical Representation	Determining mathematical equations according to the problem	Analyzing the equation to find the increase in the overall length of the elastic material, if the two elastic materials are connected as a catapult rope with a rock weight weighing w.
	Reading mathematical symbols according to the problem	Determining the influential quantity symbol and examining the value of the increase in the length of the spring arrangement that occurs through image illustrations and stimulus descriptions.
	Operating numbers or symbols in mathematical equations correctly	Assess the spring constant or spring constant based on Hooke's law experimental table presented.

Variable	Indicators	Treatment
Graphical Representation	Connecting graphs and mathematical formulas	Comparing Young's Modulus of the two catapult rope materials with mathematical equations by presenting a graph of the relationship between stress and strain on the two catapult ropes.
	Modelling real objects or situations into graphics	Making a graph of the relationship between style and length increase according to the information in the table, and drawing conclusion
	Processing information from a graph and calculating the physical quantity in question	Analyzing the potential energy of a spring based on the information on the graph

Table 3. Indicators of Mathematical and Graphical Representation Matrix

2.4. Data Analysis

The analysis of empirical test was carried out on each item of the test using the QUEST program. The empirical test analysis with QUEST aimed to determine the validity and reliability of the test that was used. The result of the validity of the test items is seen through the Infit Mean of Square (INFIT MNSQ) value. The test items are said to meet the quality of the Rasch model and have INFIT MNSQ values in the range of 0.77-1.30 (Adams & Kho, 1996; Raymond & Siek-Toon, 1996). The summary of item estimates and the summary of case estimate values provide information about the test's reliability. The result of the two estimates was then interpreted using the criteria shown in Table 4 (Sumintono & Widhiarso, 2015).

Reliability Coefficient (R)	Interpretation
$R < 0.67$	Low
$0.67 \leq R < 0.80$	Adequate
$0.80 \leq R < 0.90$	Good
$0.90 \leq R < 0.94$	Very Good
$R > 0.94$	Outstanding

Table 4. Reliability Interpretation Coefficient

Prior to the analysis of the effectiveness test, the prerequisite testing was conducted. The prerequisite test consisted of a normality test (Shapiro-Wilk) and a homogeneity test (Levene Statistics). The data that were proven to be homogeneous and normally distributed were then tested for effectiveness. The analysis of the effectiveness test in this study used the General Linear Model (GLM) technique assisted by the SPSS Program Version 25.

In general, the effectiveness test is useful to find out the magnitude of the effect of the use of the Problem-Based Learning (PBL) physics pocketbook integrating augmented reality with the local wisdom of catapults to improve students' mathematical and graphical representation abilities. The increase in mathematical and graphical representation abilities was analyzed using the General Linear Model (GLM) technique at the output of Pairwise Comparison based on the pretest-posttest scores in each treatment class. An increase in the pretest-posttest score can be seen through the significance value and the Mean Difference in the Pairwise Comparison output.

In this study, an analysis was also carried out to find out the magnitude of the effectiveness of the use of media. The effectiveness of using the Problem-Based Learning physics pocketbook integrating augmented reality can be seen through the output of Hotelling's Trace Multivariate Test. In the output, it can be seen that the effective contribution of media use is through the Partial Eta Squared value. The greater value of Partial Eta Squared indicates that the use of the media is very effective in affecting learning.

3. Findings and Discussion

3.1 Empirical Testing Result of Mathematical and Graphical Representation Tests

The test used in the empirical test for grade XII students consists of 15 questions for the variables of mathematical and graphical representation abilities. The results of the empirical test analysis obtained the reliability value of the test instrument in the sufficient and good categories. A detailed description of the reliability coefficient is presented in Table 5.

The analysis of the validity of the mathematical and graphical representation ability test revealed 12 items that met the quality of the Rasch model having an INFIT MNSQ value in the range of 0.77-1.30. There are three items that do not fit, namely numbers 1, 2, and 12. The details of the result of the analysis of the validity of the test instruments and their categories are presented in Table 6.

The three questions that do not fit the Rasch model as shown in Table 5 can be eliminated or discarded, taking into account the form of the instrument that is described as well as the number of indicators of mathematical and graphical representation abilities, which amount to 6. Thus, it is decided that the total items used for implementation in the research design class are six items. The six items on the test represent each variable indicator and are selected based on the items that fall into the fit category on the Rasch model.

Reliability	Reliability Coefficient	Category
Summary of item estimate	0.77	Sufficient
Summary of case estimate	0.86	Good

Table 5. Analysis Result of Test Reliability

Item Number	INFIT MNSQ	Category
1	1.77	Not Fit
2	1.33	Not Fit
3	1.11	Fit
4	0.98	Fit
5	1.09	Fit
6	1.21	Fit
7	0.98	Fit
8	0.89	Fit
9	0.82	Fit
10	0.86	Fit
11	0.85	Fit
12	0.69	Not Fit
13	0.85	Fit
14	0.84	Fit
15	0.86	Fit

Table 6. Analysis Result of Test Validity

3.2. Test Result of the Effectiveness of Mathematical and Graphical Representation Ability

The data on the result of the effectiveness testing of the mathematical and graphical representation abilities were obtained by using an essay test that had passed the empirical test. The test in the form of pretest-posttest was administered to each of the 36 grade XI science students according to the treatment in the research design. Prior to the effectiveness testing, prerequisite testing was conducted. The prerequisite test consisted of a normality test and a homogeneity test. The analysis of the normality test (Shapiro-Wilk) in this study obtained data that were normally distributed. This is due to the significance value gained being more than 0.05. This statistical test analysis was derived from pretest-posttest scores of mathematical and graphical representations abilities. A summary of the range of students' pretest and posttest values along with the frequencies obtained can be seen in Table 7, 8 and 9.

The data in Table 7, 8, and 9 are input into the SPSS program according to the treatment class, namely the experimental class and the contrast class. The result of the normality test analysis in detail is presented in Table 10.

The next prerequisite test is the homogeneity test. The analysis of the homogeneity test (Levene statistic) in this study also obtained a significance value of > 0.05. This shows that there is a similarity of variance in the variable data of mathematical and graphical representation abilities, or the data are homogeneous. The result of the homogeneity test obtained can be observed in Table 11.

Pretest Score Range of Mathematical Representasion Ability	F	Posttest Score Range of Mathematical Representasion Ability	F	Pretest Score Range of Graphical Representation Ability	F	Posttest Score Range of Graphical Representation Ability	F
0 – 9	4	0 – 9	0	0 – 9	4	0 – 9	0
10 – 19	11	10 – 19	0	10 – 19	12	10 – 19	0
20 –2 9	17	20 –2 9	0	20 –2 9	16	20 –2 9	0
30 – 39	3	30 – 39	0	30 – 39	3	30 – 39	0
40 – 49	1	40 – 49	0	40 – 49	1	40 – 49	0
50 – 59	0	50 – 59	0	50 – 59	0	50 – 59	0
60 – 69	0	60 – 69	1	60 – 69	0	60 – 69	1
70 – 79	0	70 – 79	12	70 – 79	0	70 – 79	12
80 – 89	0	80 – 89	10	80 – 89	0	80 – 89	10
90 – 100	0	90 – 100	13	90 – 100	0	90 – 100	13
Total	36	Total	36	Total	36	Total	36

Table 7. Frequency Tables of Pretest-Posttest scores of Mathematical and Graphical Representation Abilities in Experiment Class

Pretest Score Range of Mathematical Representasion Ability	F	Posttest Score Range of Mathematical Representasion Ability	F	Pretest Score Range of Graphical Representation Ability	F	Posttest Score Range of Graphical Representation Ability	F
0 – 9	1	0 – 9	0	0 – 9	1	0 – 9	0
10 – 19	2	10 – 19	0	10 – 19	2	10 – 19	0
20 –2 9	4	20 –2 9	0	20 –2 9	4	20 –2 9	0
30 – 39	10	30 – 39	0	30 – 39	10	30 – 39	0
40 – 49	7	40 – 49	0	40 – 49	7	40 – 49	0
50 – 59	3	50 – 59	0	50 – 59	3	50 – 59	1
60 – 69	5	60 – 69	9	60 – 69	5	60 – 69	9
70 – 79	3	70 – 79	10	70 – 79	3	70 – 79	10
80 – 89	1	80 – 89	12	80 – 89	1	80 – 89	11
90 – 100	0	90 – 100	5	90 – 100	0	90 – 100	5
Total	36	Total	36	Total	36	Total	36

Table 8. Frequency Tables of Pretest-Posttest scores of Mathematical and Graphical Representation Abilities in Contras Class 1

Pretest Score Range of Mathematical Representasion Ability	F	Posttest Score Range of Mathematical Representasion Ability	F	Pretest Score Range of Graphical Representation Ability	F	Posttest Score Range of Graphical Representation Ability	F
0 – 9	4	0 – 9	0	0 – 9	4	0 – 9	0
10 – 19	4	10 – 19	0	10 – 19	4	10 – 19	0
20 –2 9	10	20 –2 9	0	20 –2 9	10	20 –2 9	0
30 – 39	10	30 – 39	0	30 – 39	10	30 – 39	0
40 – 49	5	40 – 49	0	40 – 49	6	40 – 49	0
50 – 59	2	50 – 59	0	50 – 59	2	50 – 59	0
60 – 69	1	60 – 69	3	60 – 69	0	60 – 69	3
70 – 79	0	70 – 79	15	70 – 79	0	70 – 79	15
80 – 89	0	80 – 89	12	80 – 89	0	80 – 89	12
90 – 100	0	90 – 100	6	90 – 100	0	90 – 100	6
Total	36	Total	36	Total	36	Total	36

Table 9. Frequency Tables of Pretest-Posttest scores of Mathematical and Graphical Representation Abilities in Contras Class 2

Variable	Treatment Class	Shapiro-Wilk		
		Statistic	df	Sig.
Mathematical Representation Ability	Experimental Class Pre-test	0.966	36	0.335
	Contrast Class 1 Pre-test	0.973	36	0.522
	Contrast Class 2 Pre-test	0.963	36	0.270
	Experimental Class Post-test	0.951	36	0.115
	Contrast Class 1 Post-test	0.959	36	0.196
	Contrast Class 2 Post-test	0.969	36	0.398
Graphical Representation Ability	Experimental Class Pre-test	0.968	36	0.379
	Contrast Class 1 Pre-test	0.973	36	0.522
	Contrast Class 2 Pre-test	0.963	36	0.270
	Experimental Class Post-test	0.951	36	0.115
	Contrast Class 1 Post-test	0.970	36	0.419
	Contrast Class 2 Post-test	0.969	36	0.398

Table 10. Analysis Result of Normality Test

Variable	Levene Statistic	df_1	df_2	Sig.
Mathematical Representation Ability	1.439	2	105	0.242
Graphical Representation Ability	1.293	2	105	0.279

Table 11. Analysis Result of Homogeneity Test

The successful prerequisite test then followed with an effectiveness test using the General Linear Model (GLM) technique facilitated by the SPSS Program Version 25. The effectiveness test in this study aimed to determine the increase and magnitude of the effective contribution of the use of the Problem-Based Learning physics pocketbook integrating augmented reality with the local wisdom of catapults on students' mathematical and graphical representation abilities. The result of the General Linear Model (GLM) analysis on the output of Pairwise Comparison obtained a significance value of <0.05, which is 0.000. The mean difference in the output has a negative value. This shows that the average post-test score in each treatment class is higher than the average of pre-test score. Therefore, from those two findings, it can be stated that each treatment class had a considerable increase in pretest-posttest scores of mathematical and graphical representation abilities. The result of the analysis in detail can be seen in Table 12.

The effective contribution of the Problem-Based Learning physics pocketbook integrating augmented reality with local wisdom catapults and other media to physics teaching in the three treatment classes was analyzed through the General Linear Model (GLM) at the output of the Multivariate test type of Hotelling's trace. The result of the analysis obtained in detail can be seen in Table 13.

The values of partial eta squared in Table 13 show the effective contribution to the two variables from the implementation of the media for each treatment class. In the experimental class, it is known that the value of the partial eta squared of the mathematical representation ability of students is greater than that of the Contrast Class 1 and Contrast Class 2. The effective contribution is 0.826. This means that the use of the developed physics pocketbook integrating AR with local wisdom in the experimental class is able to increase mathematical representation ability by 82.6%. Meanwhile, PPT media and textbooks in Contrast Class 1 and Contrast Class 2 were able to increase mathematical representation ability by only 56.6% and 75.5%, respectively. In the variable of graphical representation ability, it is known that the partial eta squared value of the experimental class is 0.844. It can be interpreted that the use of the PBL physics pocketbook integrating AR with local wisdom in the experimental class is able to increase the graphical representation ability by 84.4%. Meanwhile, the increase in graphical representation ability in Contrast Class 1 and Contrast Class 2 using PPT media and textbooks is only 58.7% and 78.2%, respectively.

Variable	Treatment Classes	(I) Time	(J) Time	Mean Difference (I-J)	Sig.
Mathematical Representation Ability	Experimental	Pretest	Posttest	-63.722	0.000
	Contrast 1	Pretest	Posttest	-33.333	0.000
	Contrast 2	Pretest	Posttest	-51.250	0.000
Graphical Representation Ability	Experiment	Pretest	Posttest	-63.639	0.000
	Contrast 1	Pretest	Posttest	-32.583	0.000
	Contrast 2	Pretest	Posttest	-51.806	0.000

Table 12. Analysis Result of Pairwise Comparisons

Variable	Treatment Classes	F	Sig.	Partial Eta Squared
Mathematical Representation Ability	Experimental	499.440	0.000	0.826
	Contrast 1	136.665	0.000	0.566
	Contrast 2	332.064	0.000	0.755
Graphical Representation Ability	Experimental	569.928	0.000	0.844
	Contrast 1	149.405	0.000	0.587
	Contrast 2	377.683	0.000	0.782

Table 13. Analysis Result of Multivariate Test of Hotelling's Trace Type

3.3. Product of Problem-Based Learning Physics Pocketbook Integrating Augmented Reality with Local Wisdom of Catapults

In this study, elasticity topic was combined with the local wisdom of the catapult because it has the potential to attract the attention of students and increase knowledge about local wisdom in the form of the traditional catapult game. The combination is arranged in a learning media design in the form of Problem-Based Learning Physics Pocketbook Integrating Augmented Reality. The design of the media developed in this study can be seen in Figures 2 and 3.

Figure 2. Design of Problem-Based Learning Physics Pocketbook Integrating Augmented Reality with Local Wisdom of Catapults

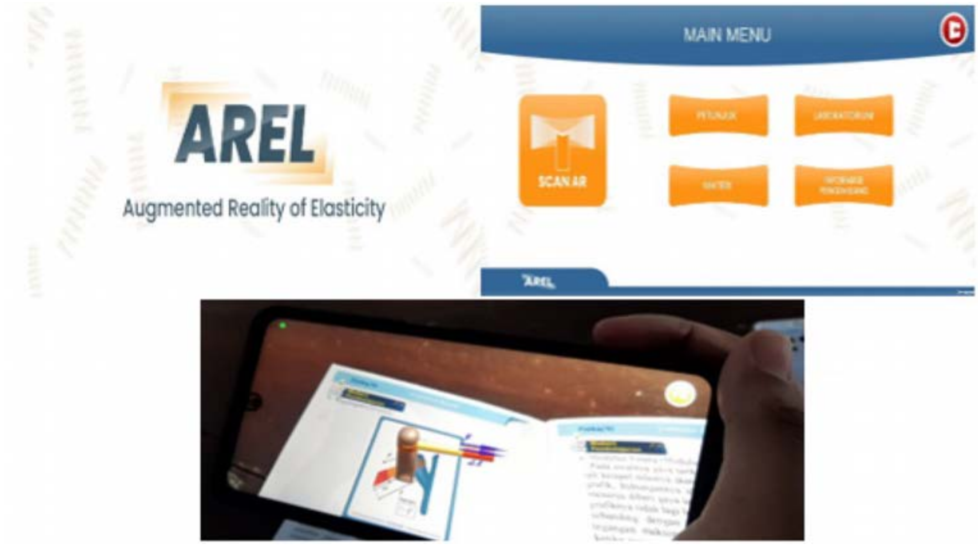

Figure 3. Application of Augmented Reality Integrated with PBL Physics Pocketbook

3.4. Discussion

In general, this current study has illustrated that in improving students' mathematical and graphical representation abilities need several stimulus factors. These stimuli include the selection of learning models. This study used Problem Based Learning as a learning model. PBL is used as a learning model in this study because its characteristics are in accordance with physics subjects. PBL syntax requires students to be able to solve contextual and complex problems in everyday life through (Haryanti et al., 2020; Jensen et al., 2019). Thus, students' understanding of physics concepts, especially the ability to represent mathematics and graphics, is also trained. Activities in the PBL model are classified as difficult and can sometimes cause boredom. So, in this study PBL combined with learning media in the form of a pocketbook that has been integrated with an application on the device. The application provides materials as well as an AR scan feature to visualize AR markers or images in the physics pocketbook on material elasticity.

Not only is the physics content combined with technology, but it is also added with a touch of local wisdom related to the material. The combination is intended to provide students with contextual problem orientation and the implementation of the application of physics concepts in accordance with the characteristics of PBL teaching models (Haryanti et al., 2020; Rahmasari, Zulaikha, Pujianto &

Jumadi, 2022; Sari, Nikmah, Kuswanto & Wardani, 2019). The results of the data analysis in this study show the role of using technology-based media integrated with augmented reality (AR) with local wisdom is able to help visualize abstract concepts of physics to be more interesting and unique in learning, especially in graphical representation ability based on Table 13. Table 13 states that the partial eta squared value of graphic representation ability is higher, than the ability of mathematical representation. Even so, both values of representational ability proved to increase after being given treatment. This study also align with the findings of the study conducted by Priyadi and Kuswanto (2023), Sari-Dewi and Kuswanto (2023), Aththibby et al. (2021), and Kurniawan and Kuswanto (2021), that the use of gadgets has a positive impact on the motivation of students, especially the integration of augmented reality and local wisdom.

The motivation is able to make it easier for students to understand abstract concepts of physics, so as to improve their mathematical and graphical representation abilities (Fidan & Tuncel, 2019; Permana et al., 2019; Saputra & Kuswanto, 2019). Thus, in this study, the use of a Problem-Based Learning physics pocketbook integrating augmented reality with the local wisdom of catapults in the subject matter of material elasticity proves effective in improving students' mathematical and graphical representation abilities. The media may also be utilized as an alternate learning resource both practitioners and students learning physics. Furthermore, this study served as extra reference information for researchers and future media developers.

4. Conclusion

The Problem-Based Learning physics pocketbook integrating augmented reality with the local wisdom of catapults is effective in improving the mathematical and graphical representation abilities of grade XI students of high school, especially in the subject matter of material elasticity. The effectiveness of the developed pocketbook is shown through the amount of effective treatment contribution (partial eta squared value). The value of partial eta squared from using Problem-Based Learning physics pocketbook integrating augmented reality with the local wisdom of catapults to the increase of the variable of mathematical and graphical representation abilities is by 82.6% and 84.4%, respectively. This study also shows the main contribution on science and technology of education is that developed problem-based learning physics pocketbook that integrates augmented reality with local wisdom can be used as a medium and alternative learning resource in physics teaching. This experience can be replicated at other educational and academic levels subjects, as well as further references for researchers and media developers in the future.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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