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The Influence of Problem-based Learning with the STEM using Mobile Learning Toward Problem Solving Physics Ability and Self-directed Learning Student in Dynamic Electricity Subject Matter

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Abstract

The application of a learning model can affect students' ability to solve problems, independence, and student learning interactions. The purpose of this study was to determine the effect of the problem-based learning model through the STEM approach with mobile learning on problem-solving skills, independence, and student interaction in class XII student learning at SMA Negeri 3 Balaesang. The research method is quasi-experimental with a population of all students in class XII and a sample of 57 students, 29 students in the experimental class, and 28 students in the control class. The research instrument was a written test, questionnaire, observation sheet, and documentation. Data on the ability to solve physics problems, independent learning questionnaires, and problem-solving interactions, and student learning independence using the SPSS software application with a significance value of 0.05. the results showed that students can: 1) solve problems; 2) have independence; and 3) interacting between problem-solving skills and independence in solving physics problems. The conclusion is that there are: 1) a significant effect of the application of problem-based learning on solving skills; 2) a significant effect of the application of problem-based learning on students learning independence; and 3) there is a significant interaction between problem-solving skills and student learning independence.

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Introduction

Physics learning is intended to pay attention to the order of the universe and emphasize providing direct experiences that can help students gain a deeper understanding of the natural surroundings. So that physics learning is not only delivered so that students understand the concept, but also students are directly involved in the process of finding knowledge. So, in the learning process, the teacher does not only convey information but also helps students to able to face the challenges of the globalization era by providing problem-solving skills.

Anticipating this global competition requires quality human resources who master the skills and attitudes that support development in all fields, are able to take advantage of various opportunities, and are resilient in facing challenges. The strategy to increase the competence of human resources in all fields is one of the efforts that must be made for the creation of quality human resources, who have the power to innovate and adapt to environmental changes and are able to carry out a continuous learning process.

Problem-based learning (PBL) is a student-centered teaching approach that allows students to be active participants in solving problems, answering questions, collaborating on learning, working in teams on problems or projects, and taking more responsibility for learning (Ates & Eryilmaz, 2011). In the PBM model, students are directed to take the initiative for their own knowledge (Lee et al., 2010). Meanwhile, according to Taufik (2008), PBM accustoms students not to get stuck in solutions to narrow thoughts. PBM in the process has a close relationship with independent learning (Tan, 2003). In independent learning skills, students can plan, conceptualize, conduct, and evaluate learning. Independent learning is presented in education in various types of action including reading, collaboration, debating, accessing resources, research, and development. Using time to prepare for their learning and deep learning is expected of students in independent learning Deepwell & Malik (2008). As a result, independent learning is a part of the ability to name sources, select and implement appropriate educational strategies, and evaluate the results of instruction and learning experiences. In addition, through independent learning, one takes the main responsibility and initiative to plan and diagnose the conditions of learning (Deepwell & Malik, 2008).

Learning models that have the potential to be used to accommodate students in developing their potential such as problem-solving skills and independent learning include PBM models. This is reinforced by the opinion of Suyanto & Jihad (2013) that the PBM model is not designed to help teachers provide as much information as possible to students, but to (1) help students develop thinking skills and problem-solving skills (2) learn the role of authentic adults and (3) become independent learners. Based on the results of the analysis above, the researcher intends to conduct research by applying the PBM model with the science technology engineering, and mathematics (STEM) approach using mobile learning so that students are familiar with physics problems and find a way to solve them and of course, it is expected that it will affect students' independent learning skills. The expansion of the usefulness of science technology engineering and mathematics (STEM) using mobile learning arises because after being implemented in learning, it turns out that this approach is able to increase knowledge mastery, and apply knowledge to solve problems, this is in line with the results of research by Siew et al. (2016) which show that the approach STEM-EDP can be applied as a means to encourage creativity, problem-solving skills and thinking skills of students

Previous studies on PBM in its relationship to problem-solving skills include Atan et al. (2005) show that students who follow the PBM method can develop scientific reasoning, and problem-solving skills and show advantages in conceptual learning, attitudes, and interests. Another study by Dwi et al. (2013) shows that there are significant differences in problem-solving abilities between students who are taught using ICT-based PBM strategies and PBM strategies.

Several other studies also show the effect of the PBM model on learning independence including research conducted by Saleem et al. (2014) revealed that PBM without or with the lecture method improved independent learning skills better than conventional teaching methods. Furthermore, Sharon & Petra's (2014) research shows that introducing students to the PBM approach can promote a more meaningful learning pattern characterized by critical processing of subject matter and independent learning processes.

In this research, the science technology engineering, and mathematics (STEM) approach using mobile learning is a learning approach that encourages students to design, develop and utilize technology, can hone cognitive, manipulative, and effective, and apply knowledge. The integration of the Science Technology Engineering and Mathematics (STEM) approach using mobile learning helps students analyze and solve problems that occur in real life so that students are ready to carry out the learning process.

The use of mobile learning as a learning medium, which is a type of E-learning that uses a mobile device, shows that mobile learning has a significant influence on academic achievement and student achievement in speaking skills. These findings are recommended for use in classroom learning (Elfeky & Masadeh, 2016). Learning mobile applications in the form of a simulation lab as a learning medium for schools can be used because it has eligibility criteria for use (Astra et al., 2015).

In my research, I adopted a learning device that had previous research in developing STEM-based learning tools assisted by mobile learning carried out by Ansar, M.A (2019) which met the quality criteria and included 3 (three) aspects, namely validity, practicality, and aspects. The effectiveness has gone through expert validators and this learning tool can be used.

Based on the explanation above, science technology engineering, and mathematics (STEM) using mobile learning is very suitable to collaborate with problem-based learning (PBM). Thus, all achievements in learning facilitated by physics subjects are expected to be realized through the problem-based learning (PBL) model with the science technology engineering, and mathematics (STEM) approach using mobile learning towards students' ability in solving physics problems and learning independence of students. Dwi et al. (2013) in class X SMA Negeri 1 Bangil in the academic year 2012/2013 showed that there were significant differences in problem-solving abilities between students who were taught using ICT-based PBM strategies and PBM strategies. Atan et al. (2005) show that students who follow the PBM method can develop scientific reasoning, and problem-solving skills and show advantages in conceptual learning, attitudes and interests. Saleem et al. (2014) in University of Baghdad students revealed that there were no significant differences between PBM and PBL with the lecture method. This PBM without or with the lecture method improves independent learning skills better than conventional teaching methods. Sezgin et al. (2013) at a State University in Turkey revealed that no significant difference between the two experimental groups (problem-based versus strategy-based instruction) was found. Sharon & Petra (2014) in students of the Faculty of Education, Canterbury Christ Church University in South Africa show that introducing students to the PBM approach and promoting more meaningful learning patterns is characterized by critically processing subject matter and independent learning processes. Furthermore, Sharon & Petra (2014) stated that independent learning skills are questionable if students' beliefs in this approach do not support the activities used. Introducing PBM becomes the basis for developing independent learning skills in the student learning process and moving the growth process toward lifelong learning. Abdullah (2014) states that learning with the PBM model allows students to be involved in learning things including: (1) real-world problems, (2) higher-order thinking skills, (3) problem-solving skills, (4) learning between disciplines, (5) independent learning, (6) learning to explore information, (7) learning to work together, (8) learning communication skills Wahyuni (2019) application of the PBL (problem-based learning) learning model based on STEM (Science Technology Engineering and Mathematic) which has been applied in the experimental class (VII F), it is known that the pre-test-post-test average value of scientific literacy that has been obtained higher than the control class. Research by Farwati et al, (2015), "integration of problem-based learning in stem education is oriented towards actualization of environmental literacy and creativity". The results of this study can be concluded that STEM education is very likely to be collaborated with problem-based learning. Wijaya et al. (2018) research the impact or influence of the PBM model on problem-solving abilities and student learning independence as well as the interaction between the ability to solve physics problems and student learning independence. The results of these studies can be concluded that there is a significant effect of the application of PBM on the ability to solve physics problems and student learning independence. PBM is basically an educational method that develops students' thinking and important problem-solving skills in addition to developing an understanding of important concepts through analysis of real-life problems. The entire learning process takes place when learners try to solve real-life problems in groups of seven to eight people. Barrows in Sezgin et al. (2013) stated that the main characteristic labels of PBM are as follows: (1) learning is student-centered, (2) learning requires forms in small groups of students, (3) teachers must act as moderators and facilitators, (4) problems provide motivation for learning and organizational focus, (5) problems are given on the basis of improving problem-solving skills, (6) self-directed learning helps the acquisition of new information. Currently, problem-based learning approaches are used in various fields of education, especially in medical education (Hughes et al., 1997), engineering, law, teacher training, and science education (Folly & Sulaiman, 2013; Hillman, 2013). After that, PBL is now becoming more popular. Although the literature on PBL supports the benefits and effectiveness of this approach in various fields, it has been noted that there have been several studies on physics education through PBM (Sulaiman & Folly, 2014; Folly & Sulaiman, 2013; Folashade, et al., 2009). The scope of this research is physics discipline and this research is based on related studies on PBM.

Materials and Method

This study used a quasi-experimental research method with a pre-test-post-test research design without random control groups, namely research conducted in two classes, namely one experimental class that received learning with problem-based learning models and one control class that received conventional learning. Meanwhile, according to Sugiyono (2007), the pretest-posttest design of the control group without being random can be described in accordance with Table 1.

Table 1 Research design

class	initial test	Treatment	Final test and questionnaire
Eksperiment	O_1	X	O_2
Control	O_1	-	O_2

Source: Sugiyono (2007)

O_1 = pre-treatment test given to the experimental group and control group.

O_2 = the final test and questionnaire after the treatment was given to the group experimental and control groups.
X = learning treatment based on problem based learning model.
Research location and time

The research location is Balaesang 3 Public Senior High School which is located at Jl. Palu Sabang Km. 129 Sibayu Village, Balaesang District, Donggala Regency. The research was conducted on 27 July - 24 August 2020. Odd Semester of the 2020/2021 school year.

Population, sample and sampling technique

The population in this study were students of class XII SMA Negeri 3 Balaesang with 84 students divided into 3 classes. 29 students of class XII IPA 1, class XII IPA 2 28 students and class XII IPS 27 students. The research sample chosen was students of class XII IPA 1 and XII IPA 2 SMA Negeri 3 Balaesang. The sampling technique in this study was purposive sampling. Determining the experimental group and the control group in this case is done by considering the abilities of students who are relatively the same in both groups and the number of students is also relatively the same so that internal and external validity can be maintained.

Normality test

The normality test can be calculated by applying the Kolmogorov-Smirnov and Shapiro-Wilk equations. The general Kolmogorov-Smirnov and Shapiro-Wilk. The general Kolmogorov-Smirnov and Shapiro-Wilk equations are as follows:

1) *Kolmogorov-Smirnov*

$$F_n(x) = \frac{1}{n}\sum_{i=1}^{n} I_{X_i \leq x}, \quad (1)$$

$$D_n = S_x[F_n(x) - F_x]. \quad (2)$$

2) *Shapiro-wilk*

$$T_3 = \frac{1}{D}\left[\sum_{i=1}^{k} a_i(X_{n-i+1} - X_i)\right]^2 \quad (3)$$

$$D = \sum_{i=1}^{n}(X_i - \bar{X})^2 \quad (4)$$

$$G = b_n + C_n + ln\left(\frac{T_3 - d_n}{1 - T_3}\right) \quad (5)$$

Hidayat (2014)

Where D = coefficient test. X n-i + 1 = nth digit - i + 1 in data. Xi = number i in data. X = mean of data. G = identical to the normal Z value distribution and bn, cn, dn = statistical conversion to the normal distribution approximation.

Homogeneity test

The homogeneity test is used to see the variance of the data between the two data samples analyzed. The formula that can be used is the F-test. The homogeneity test is used to see the data variance between the two data samples analyzed. The formula that can be used is the F-test. The F-test equation is as follows:

$$F = \frac{S_1^2}{S_2^2} \quad (6)$$

Sugiyono (2009)
S1 = largest variance.
S2 = smallest variance.
The real level (α) = 0.05 and dk = n-1, the data testing criteria are homogeneous if. $F_{(1-\alpha)(n1-1)} < F \leq F_{1/2\alpha(n1-1,\ n2-1)}$.

Hypothesis testing

The relationship between the two dependent variables and the extent to which the independent variable contributed to the two dependent variables was used the multivariate analysis or multi-analysis of variate (MANOVA). In MANOVA, the dependent variable is more than one, while the independent can only be one or more than one (Wijaya, 2010). According to Santoso (2004), multivariate analysis can be defined simply as a method of processing a large number of variables to seek their effect on an object simultaneously. Statistical analysis that can be used is the t-test with the following equation:

$$t_{count} = \frac{\overline{x_1} - \overline{x_2}}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}} \quad (7)$$

Sugiyono (2009)
With:
n_1 and n_2 = the number of samples 1 and 2
$\overline{x_1}$ and $\overline{x_2}$ = sample mean 1 and 2
s_1^2 and s_2^2 = variance of sample deviation 1 and 2
The t-test results obtained are used to make a decision on acceptance of the hypothesis.

Results and Discussion

Normality test

The main requirements that must be met in the parametric analysis of research on the effect of problem-based learning are normally distributed data. To use parametric analysis such as comparison analysis of means and so on, it is necessary to test the normality of the data first. The data normality test aims to determine whether the data on problem-solving skills and learning independence are normally distributed or not.

The data normality test was performed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The advantage of this test is that it is simple and does not cause differences in perception between one observer and another, which often occurs in normality tests using graphs. The basic concept of the Kolmogorov-Smirnov and Shapiro-Wilk normality tests is to compare the data distribution (which will be tested for normality) with the standard normal distribution. The results of the Kolmogorov-Smirnov and Shapiro-Wilk tests can be seen in Tables 2 - 3.

1) The normality of the data is the ability to solve problems and the independent learning of the experimental class.

Table 2 Normality of experimental class data

Component	Problem-Solving Ability	Independent Learning
Kolmogorov-Smirnov (sig)	0.200	0.200
Shapiro-Wilk (sig)	0.302	0.208
Conclusion	Normal	Normal

2) The normality of data is the ability to solve problems and the independent learning control class.

Table 3 Normality of control class data

Component	Problem-Solving Ability	Independent Learning
Kolmogorov-Smirnova (sig)	0.059	0.200
Shapiro-Wilk (sig)	0.474	0.836
Conclusion	Normal	Normal

The results of data normality testing that have been carried out through SPSS obtained data according to Tables 2 and 3. From this table, it can also be explained for the variable problem-solving ability the sig value of 0.200 > 0.05. The learning independence variable has a sig value of 0.200> 0.05. This data was obtained using the Kolmogorov-Smirnov analysis (sig). Meanwhile, for testing with the Shapiro-Wilk analysis (sig), the data obtained from the variable analysis of the problem-solving ability sig value 0.302 > 0.05. The learning independence variable is sig value 0.208 > 0.05. So it can be stated that the null hypothesis is accepted, which means that the two data samples have both the ability to solve problems and the learning independence of students in the experimental class with the application of PBM with the STEM approach using mobile learning comes from a normally distributed population.

Homogeneity test

The pre-test results showed a difference in the mean score of the experimental class (29.31) and control (26.75). However, it needs to be tested using statistical techniques to obtain applicable inferences in the study population. The results of the test requirements show that the assumptions of parametric statistical techniques are fulfilled so the parametric statistical technique used to test the difference in the mean pre-test results is the independent sample t-test. Data from the pre-test results with the independent sample t-test were analyzed through the SPSS program. The test results for the difference in the mean score of the pre-test results of the experimental class and the control class are presented in Table 4.

Table 4 Pre-test homogeneity analysis

		Pre-test	
		Equal variances assumed	Equal variances not assumed
Levene's Test for Equality of Variances	F	6.782	
	Sig.	0.12	
t-test for Equality of Means	T	0.868	0.873
	df	55	50.942
	Sig. (2-tailed)	0.389	0.387
	Mean Difference	2.56034	2.56034

The results of the homogeneity analysis in Table 4 provide two significant values (sig). The sig with a value of 0.389 is the sig of the pre-test homogeneity of the control class and the value of 0.387 is the pre-test homogeneity of the experimental class. The sig values 0.389 and 0.387 > 0.05 probability, it can be said that the two data population variances are homogeneous or the same. The second sig value is Anova analysis with the calculated F value. This analysis gives a sig value of 0.12 > 0.05, which means that the mean pre-test scores of the experimental class and control class are the same.

Activity analysis

The results of the analysis of teacher and student activities obtained from teacher observation sheets and student observation sheets can be seen in Table 5.

Table 5. Analysis of teacher activities

No	Meeting	Percentage/meeting	Criteria
1	First	89.13	Very good
2	Second	86.96	Very good
	Average	88.05	Very good

Table 6. Analysis of student activities

No	Meeting	Percentage/meeting	Criteria
1	First	92.39	Very good
2	Second	91.30	Very good
	Average	91.85	Very good

The data from the analysis of teacher and student activity for each of the above meetings were obtained using the calculation standards issued by the Kementrian (2003). Some of the meetings above are meetings outside the meeting for the implementation of the exam.

Based on the analysis of teacher activity data in Table 5, the percentage at the first meeting was 89.13%, the second meeting was 86.96%. The average percentage of all meetings was 88.05% with very good criteria. While Table 6 shows the percentage of student activity at the first meeting was 92.39%, the second meeting was 91.30%. The average percentage of all meetings is 91.85% with very good criteria

Multivariate analysis

Multivariate analysis or often called MANOVA (multi-analysis of variates) is used as an analysis tool to test whether there is a difference in the mean of a certain variable with more than one predicted factor. In multivariate the dependent variable is more than one, while the independent variable can be only one or more than one. In this case, there are three variables that will be used for this test, namely the learning model variable, the variable physics problem-solving ability, and the learning independence variable. The test criteria for this test, namely if the significance of the F test < 0.05 then Ho is rejected and H1 is accepted. The results of the analysis assisted by SPSS obtained the results of the multivariate analysis as in Table 7 and Table 8. Table 9, shows the value of the F significance test for Wilks' Lambda of 0.00 and Hoteling's Trace of 0.00. This means that there is a relationship between the ability to solve physics problems and students' learning independence.

The value of the multivariate test in Levene's test in Table 8 shows the significant value of the F test for the problem-solving ability of 2.199 and student learning independence of 1.245. This fulfills Manova's assumption of the same variance so that it can be passed into data analysis.

Table 7 Multivariate test between the ability to solve physical problems and learning independence

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	.995	4996.911[b]	2.000	54.000	.000
	Wilks' Lambda	.005	4996.911[b]	2.000	54.000	.000
	Hotelling's Trace	185.071	4996.911[b]	2.000	54.000	.000
	Roy's Largest Root	185.071	4996.911[b]	2.000	54.000	.000
Class	Pillai's Trace	.380	16.555[b]	2.000	54.000	.000
	Wilks' Lambda	.620	16.555[b]	2.000	54.000	.000
	Hotelling's Trace	.613	16.555[b]	2.000	54.000	.000
	Roy's Largest Root	.613	16.555[b]	2.000	54.000	.000

a. Design: Intercept + class

b. Exact statistic

Table 8 Multivariate test results in Levene's test

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Problem-Solving Ability	2.520	1	55	.118
Independent Learning	1.267	1	55	.265

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + class

The results of the multivariate test to see the extent to which the contribution of the learning model in explaining the ability to solve physics problems and student learning independence can be seen in Table 7. This table shows that the F-calculated significance value of the ability to solve physics problems is 0.00, which means that there are differences in problem-solving abilities based on the applied learning model.

Table 9. Multivariate test results of between-subject effects

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	Problem-Solving Ability	1718.320[a]	1	1718.320	24.882	.000
	Independent Learning	704.527[b]	1	704.527	14.618	.000
Learning model	Problem-Solving Ability	1718.320[a]	1	1718.320	24.882	.000
	Independent Learning	704.527[b]	1	704.527	14.618	.000

a. R Squared = .311 (Adjusted R Squared = .299)

b. R Squared = .210 (Adjusted R Squared = .196)

Table 9 shows that the significant f value of the ability to solve physics problems is 0.00, which means that there are differences in problem-solving abilities based on the applied learning model. The contribution of the learning model in explaining problem-solving ability was 31.1%. The significance value of the F count of the independent learning of students is 0.00 which means that there are differences in student learning independence based on the learning model applied. The contribution of the learning model to students' learning independence is 21%.

Difference test of pre-test mean post-test control class and experiment class

The difference in learning outcomes obtained by students in implementing PBM with the STEM approach using mobile learning and conventional learning can be known by analyzing the difference between the two mean pre-test and post-test results in both the experimental class and the control class. The pre-test mean test was carried out using the independent sample t-test. An Independent sample t-test was used to test the comparison of the two independent sample groups.

The results of the pre-test and post-test mean difference between the control class and the experimental class can be seen in Tables 10 - 11.

Table 10. Test mean difference of pre-test experiment and control class

	Levene's Test for Equality of Variances			t-test for Equality of Means		
	N	F	Sig	T	df	sig (2-tailed)
experiment	29	6.782	0.12	0.868	55.00	0,39
control	28			0.873	50.94	

Table 11. Post-test mean difference test for experiment and control class

	Levene's Test for Equality of Variances			t-test for Equality of Means		
	N	F	Sig	T	df	sig (2-tailed)
experiment	29	2.520	0.12	4.982	55.00	0.000
control	28			5.021	49.40	

The results of the analysis in Table 10 produce an F-test value of 6.782 with a significant value of 0.12. Sig 0.12 > 0.05 gives a statement that the variant pre-test data for the experimental class and the pre-test variant for the control class are the same. Because the pre-test data variants of the two classes are the same, the equal variances assumption data is collected so that the sig value for the data in the t-test for equality of means table is 0.39. This value of 0.39 > 0.05 indicates that there is no difference between the experimental class pre-test and the control class pre-test. This also shows that the two classes are suitable to be used as research samples both as an experimental class with the implementation of PBM with the STEM approach using mobile learning and as a control class with the implementation of conventional learning.

The results of the analysis of the difference between the two post-test means in Table 11 produce an F-test value of 2.52 with a significant value of 0.12. Sig 0.12 > 0.05 gives a statement that the post-test data variant of the experimental class and the post-test variant of the control class are the same. Because the data gain variances of the two classes are the same, the equal variances assumption data is collected so that the sig value for the data in the t-test for equality of means table is 0.00. This value of 0.00 < 0.05 indicates that there is a difference between the post-test in the experimental class and the post-test for the control class.

The results of the pre-test and post-test mean data description of the experimental class and control class can be seen in Figure 1. This data shows that the pre-test mean value for the experimental class is 29.31 and the pre-test mean value for the control class is 26.75. After implementing the PBM, there was a change in the average post-test score. The post-test mean score for the experimental class increased to 75.48 while for the control class, it increased to 64.50.

The ability of students to solve problems based on their initial abilities can be divided into three groups, namely groups of students with high, medium, and low initial abilities. This grouping was carried out in both the experimental class and the control class based on the acquisition scores in the pre-test to see the comparison of the obtained pre-test and post-test scores in both the experimental class and the control class. The purpose of this grouping is to see how PBM with the STEM approach using mobile learning affects the ability to solve physics problems based on categorizing students' initial knowledge as measured through the post-test and to see how the comparison of scores increases that occur in groups of students with various categories based on initial abilities.

The pre-test mean for the group of students with high initial ability in the experimental class was 45.50, which was relatively higher than the control class which had an average of 38.63. The pre-test score of the group of students with moderate initial ability in the experimental class of 30.00 was relatively higher than the control class which had an average of 24.82. Meanwhile, the pre-test score of the group of students with low initial ability in the control class was 18.56 relatively higher than the experimental class with an average of 15.60.

The mean post-test score for the group of students with high initial ability in the experimental class is 86.88, which is relatively higher than the average post-test score for the control class, namely 70.36. The average post-test group of students with moderate initial ability in the experimental class was 77.10, relatively higher than the control class, 65.25. Likewise, the group of students with low initial ability in the experimental class was 64.80 higher than the control class 56.67.

The results of the pre-test and post-test mean difference test results for each group of students with different initial abilities can be seen in Table 12.

Table 12. Test results of the mean difference of pre-test and post-test in each study group

Initial Ability Category	Group	Rata-rata Skor Pretest	Rata-rata Skor Posttest	t count	t table	themselves	Is
Height	Experiment	45.50	86.88	89.85	1.89	0.00	Ho rejected
	Control	38.63	70.36	17.72	1.89	0.00	Ho rejected
Currently	Experiment	30.00	77.10	28.95	1.81	0.00	Ho rejected
	Control	24.62	65.25	55.86	1.89	0.00	Ho rejected
Low	Experiment	15.60	64.80	41.32	1.83	0.00	Ho rejected
	Control	18.56	56.67	40.78	1.86	0.00	Ho rejected

Table 12 shows that overall there is a significant difference between the pre-test and post-test scores. The data analysis technique used to test these differences is the paired sample t-test with the condition that if t count > t table in each initial ability category, then Ho is rejected.

Test of difference in the average student learning independence

The difference in the effect of the results of the implementation of PBM with the STEM approach using mobile learning and conventional learning on the learning independence experienced by students can be seen by analyzing the difference between the two means of learning independence questionnaire results in both the experimental class and the control class. The mean test of the results of independent learning was carried out using the independent sample t-test. An Independent sample t-test was used to test the comparison of the two independent sample groups.

The results of the analysis assisted by SPSS obtained data on the difference in the average student learning independence between learning in the experimental class and the control class can be seen in Table 13.

Table 13. Test of difference in average learning independence of experiment and control classes

		Levene's Test for Equality of Variances		T-test for Equality of Means		
	N	F	sig	t	Df	sig (2-tailed)
experiment	29	1.267	0.265	3.82	55.00	0.000
control	28			3.81	52.67	

The results of the analysis of the difference between the two means of learning independence in Table 13 provide an F-test value of 1.267 with a significant value of 0.265. Sig 0.265 > 0.05 gives a statement that the data variants of the experimental class and control class are the same. Because the data variances of the two classes are the same, the equal variances assumptions are taken so that the sig value for the data in the t-test for the equality of means table is 0.00. This value of 0.00 < 0.05 gives a statement that there is a difference between the independent learning of students in the experimental class and the independent learning of students in the control class.

The results of the analysis of learning independence in the control and experimental classes show that the application of PBM with the STEM approach using mobile learning can affect student learning independence. The difference in the value of student learning independence between the experimental class and the control class from the results of this t-test states that the H1 hypothesis is accepted and the H_0 hypothesis is rejected, that is, there is an effect of implementing PBM with the STEM approach using mobile learning on students' learning independence.

The average value of the student learning independence questionnaire for the experimental class was 72.62 and the average value of the student learning independence questionnaire for the control class was 65.24. The data illustrates that the implementation of PBM with the STEM approach using mobile learning further improves student learning independence when compared to the implementation of conventional learning.

Data on student learning independence is measured in five aspects including direction, learning strategies, learning activities, evaluation, and interpersonal skills. In the direction aspect, the experimental class obtained an average of 73.13 while the control class had an average of 65.55. The aspect of learning strategy in the experimental class obtained an average of 73.20 while the control class obtained an average of 65.55. The aspect of learning activities in the experimental class obtained an average of 73.85 while in the control class, an average of 65.25 was obtained. The evaluation aspect in the experimental class obtained an average of 72.41 while the control class obtained an average of 65.10. The aspect of interpersonal skills in the experimental class obtained an average of 71.12 while the control class obtained an average of 65.55. This illustrates that the overall aspects of student learning independence in the experimental class are relatively higher than the independent aspects of students in the control class.

The results of testing the first hypothesis show that the ability to solve physics problems between groups of students who learn through the PBM model with the STEM approach using mobile learning is better than the group of students who learn through conventional learning models (sig 0.20 > 0.05) Descriptively, the mean value -The average physics problem-solving ability of students who learn with the PBM model with the STEM approach using mobile learning is higher when compared to students who learn with conventional learning models. The average value of students' physics problem-solving abilities learning with the PBM model with the STEM approach using mobile learning is 75.48. The average value of the physics problem-solving ability of students learning with the conventional model is 64.50. This supports the findings in Wijaya et al. (2018) study which concluded that there is a significant effect of the application of PBM on the ability to solve physics problems. In line with that, research conducted by Yusri, (2018) concluded that there was an effect after the application of the problem-based learning (PBL) learning model on students' ability to solve math problems.

The reasons that underlie the excellence of learning with the PBM model with the STEM approach using mobile learning in achieving student problem-solving abilities can be viewed in terms of PBM syntax. The role of students in the PBM stage with the STEM approach using mobile learning clearly shows that students play a more active role during the learning process. During the third and fourth stages, students will begin to use their thinking skills and abilities to solve the problems at hand. PBM model with

The STEM approach uses mobile learning that adheres to constructivism, student creativity is highly emphasized. The findings in this study indicate that in the problem-solving process in the given questions, students with high initial abilities on average solve questions in detail and well according to the actual solution. They use all the information and basic thought processes related to the problem in question and apply it to finding solutions to existing problems. The entire problem given can be solved in clear stages and in accordance with the physics concept related to dynamic electricity. Meanwhile, the group of students with moderate ability, in the process of knowing it, tends to be incomplete in writing and is constrained by simple technology design as in question number 5 which uses students' abilities to design a learning lamp technology. Students with low abilities tend to solve problems using makeshift procedures. For example in instrument number 2, students with low abilities tend to make mistakes with a lack of writing in the process of knowing and direct at the final completion only and are constrained by simple technology design as in question number 5 which uses students' abilities to design a learning lamp technology.

This study shows the effect of PBM with the STEM approach using mobile learning on students' ability to overcome physics problems because PBM in the process will be able to increase student learning motivation in solving a problem, the material is relevant and contextual. Besides, PBM also develops thinking at a higher level, meaning that it is not only limited to increasing knowledge but also developing students' abilities in overcoming problems. This finding is in line with the opinion of Dwi et al. (2013) which states that the level of problem-solving ability lies at the end of learning activities in PBM, in the form of individual tests, the teacher trains students to be adept at solving problems.

Based on the explanation above, it is clear that the PBM model with the STEM approach using mobile learning is able to accommodate students' problem-solving abilities. When compared with students who learn with conventional learning models at SMA Negeri 3 Balaesang, of course, students who learn using the PBM model with the STEM approach using mobile learning will be superior. This could be due to the conventional model, teachers convey information directly to students by arranging lesson times to achieve several clearly defined goals as efficiently as possible (Slavin, 2008). Teacher-centered learning will certainly reduce students' opportunities to hone their thinking skills and problem-solving abilities.

Learning independence in problem-based learning implementation with stem approach.

Student learning independence in the experimental class on average is higher than students who use conventional methods. The application of PBM with the STEM approach using mobile learning greatly affects students' learning independence. In this study, indicators of student independence are measured in five aspects, namely: direction, learning strategies, learning activities, evaluation, and interpersonal skills. The comparison of the average student learning independence can be seen in Figure 2. The findings in this study indicate that in all aspects measured, students in the experimental class have higher learning independence than in the control class. This supports the findings in the research of Suastra et al. (2019) who concluded that the learning independence of students through problem-based learning models is better than those who learn through conventional learning models.

The fulfillment of the independence indicators in PBM with the STEM approach using mobile learning because this learning uses problems as a first step in collecting and integrating new knowledge also focuses on student activeness in learning activities. Independence in groups, makes them try to find solutions to these problems so that students are responsible for solving problems from the assignment that has been given. This supports the findings in Sharon & Petra (2014) show that introducing students to the PBM approach can promote a more meaningful learning pattern characterized by critical processing of subject matter and independent learning processes. This is in accordance with the opinion of Abdullah (2014) that learning with the PBM model allows students to be involved in learning things, including independent learning and learning to work together. Thus, based on the results of this study, it can be interpreted that PBM with the STEM approach using mobile learning is able to encourage students to complete student assignments and responsibilities by emphasizing the concept through student worksheets.

The results of this study can be interpreted, that by having an independent attitude students can choose and evaluate their own learning outcomes. One of the steps in PBM is to develop and present the work. Where at this stage students present the results of their group work which is represented by their group friends and group members pay attention to the explanation or presentation of their group friends who are appointed to read out the results of their group work. It is at this stage where the indicators of student learning independence and belief in their learning ability are observed. Students who are appointed by their group members to present the results of their discussions are motivated by a sense of confidence in their abilities. Students who believe in their abilities are not afraid of the moment presenting the results of the group's work if there was an error. Being confident to appear in front of his group is a plus for him because he has met the indicators of independent learning with one of the PBM steps. If there is an error in the student's answer, the teacher will provide reinforcement through questions and answers to the group to discuss problem-solving. One other indicator of independent learning is that students are able to manage their learning methods. The fulfillment of these indicators with PBM is because in the steps the teacher assigns individual assignments in the form of homework.

The aspects of independent learning can be found in PBM. The findings obtained in this study were that students with high independence were more motivated in directing their abilities, managing time, and learning methods to solve the problems they wanted to solve. This is in line with the opinion of Schunk (2012) that motivation can affect what we learn, when we learn, and how we learn. Students who are motivated to learn a topic tend to involve themselves in various activities that they believe will help them learn, such as activities in PBM syntax, mentally organize and memorize material that must be studied, take notes to facilitate subsequent learning activities, check their level of understanding and ask for help when he does not understand the material. Independent character starts with the ability to understand yourself positively and is then nurtured through the ability to motivate yourself, and is strengthened through the principle of never giving up. A person who has strong independence will be able to overcome all problems and navigate life well.

From the analysis of the results of the research carried out, it was found that there was a relationship between the ability to solve physics problems and students' learning independence in learning. The multivariate test results showed the value of the F significance test for Wilks' Lambda of 0.00 and Hoteling's Trace of 0.00. This means that there is a relationship between the ability to solve physics problems and students' learning independence. The results of the multivariate test analysis also showed that the F-calculated significance value of the ability to solve physics problems was 0.00, which means that there were differences in problem-solving abilities based on the applied learning model. The contribution of the learning model in explaining problem-solving ability was 31.1%. The significance value of the F count of the independent learning of students is 0.00 which means that there are differences in student learning independence based on the learning model applied. The contribution of the learning model to students' learning independence is 21%. This supports the findings in Wijaya et al. (2018) study which concluded that there is a significant interaction between the ability to solve physics problems and learning independence in terms of the learning model. In line with that, research conducted by Sulistyani et al. (2020)

concluded that there is a significant positive relationship between learning independence and mathematical problem-solving abilities.

The findings in this study indicate that students who take PBM with the STEM approach using mobile learning tend to actively use their abilities and skills to solve the problems at hand. This can be observed when students actively take action in collecting data through investigations and processing data in an organized, systematic and independent manner. PBM enables the development of independent learning skills that require students to be individually responsible for learning, especially in problem-solving skills. This is in line with the opinion of Ates & Erylmaz (2011) that PBM allows students to seek information from the subject matter and this allows them to deeply understand the concepts of physics. Lycke et al. (2006) show that students who are taught through PBM show better learning independence and they are more active in contributing to the group learning process and using a wider range of learning resources than students in traditional learning. As a result, situations in PBM can provide opportunities for students to develop their own independent study skills that will help them to solve physics problems.

In the problem-solving process, various attitudes and skills are required that support students' ability to solve problems, one of which is student learning independence. The findings in this study also show that students who have an independent attitude tend to take more initiative in deciding what is needed in the problem-solving process. They use all the basic information they know and relate it to one another to solve physics problems. This is in accordance with the opinion of Knowles in Fidiana et al. (2012) stated that students' initiative in learning independence is a very good indicator fundamental. Thus there is a significant interaction between the ability to solve physics problems and learning independence.

Conclusions

Based on the discussion and analysis, the following conclusions can be drawn: there is a significant effect of implementing PBM with the STEM approach using mobile learning on the ability to solve physics problems. This influence is evidenced by the difference in the test scores of the ability to solve physics problems between students who take PBM with the STEM approach using mobile learning and students who take conventional learning. The mean pre-test in the experimental and control classes were 29.31 and 26.75, respectively. After doing the post-test in the experimental and control classes, it was obtained 75.48 and 64.50. The increase in scores in the experimental class was 46.17 while the control class experienced an increase in scores by 37.75. This influence is caused by the situation in PBL which requires students to be active in carrying out activities that challenge students' thought processes in solving physics problems. There is a significant effect of implementing PBM with the STEM approach using mobile learning on students' learning independence. This influence is evidenced by differences in the learning independence of students who take PBM with the STEM approach using mobile learning with students who take conventional learning. Students who take PBM with the STEM approach using mobile learning get an average independence score of 72.62 while students who take conventional learning get an average independence score of 65.24. The fulfillment of the independence indicators in PBM with the STEM approach using mobile learning because this learning uses problems as a first step in collecting and integrating new knowledge also focuses on student activeness in learning activities. PBM with the STEM approach using mobile learning also requires students to familiarize themselves with independent learning individually or in groups. There is a significant interaction between the ability to solve physics problems and learning independence in terms of the learning model. Student activity in the PBM stage requires students to take responsibility for their own learning, including in terms of aspects of self-direction, learning strategies, learning activities, evaluation, and interpersonal skills. Some of these aspects are directly needed by students in finding solutions to the physics problems they face.

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