Experimental Design of Three Learning Methods in Economic Mathematics Course

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Abstract. This study is an experimental design study using a one-factor completely randomized design (CRD). Factors that are tested in this study are learning methods with 3 levels, namely the conventional method, the Problem based-learning (PBL), and the peer tutoring. Furthermore, these three levels can be referred to as treatment. Each treatment was repeated to 3 times, so a total of 9 experimental classes were needed. This experimental design is applied to the Mathematics Economics course. Based on the results of the analysis of variance, it is shown that at $\alpha = 5\%$ the three learning methods have different and significant effects on the score of Economic Mathematics. Furthermore, further tests were carried out using the Tukey test. Tukey's test results show that the lecture and PBL methods do not have a different effect, while the PBL method and peer tutoring, as well as conventional method and peer tutoring have a different and significant effect on the score of Mathematics Economics at $\alpha = 5\%$. The lowest average score was obtained in the class that received the peer tutoring method while the highest average value was obtained in the class that received the PBL method.

INTRODUCTION

The experimental design is a series of tests that aim to change the input variables into outputs which are the response to the test. In experimental design, there are terms called factors, levels, and treatments. Factors are independent variables that make up the treatment, where the value can be qualitative or quantitative. Then the level is the value of the factors involved in the experiment. While the treatment is a method/procedure applied to the experimental unit. The type of experimental design that will be used in this study is a one-factor Completely Randomized Design (CRD). The factor used is a learning method with three levels, namely the conventional method, peer tutoring method, and Problem Based Learning (PBL) method. The selection of these three methods is based on the ease of their application in the classroom.

In the conventional method, students only act as listeners and lecturers who explain from the beginning of the lecture to the end of the lecture. Next, the lecturer will give assignments and questions and answers. Some studies refer to the lecture learning center as a conventional or traditional learning method. [1] and [2] conducted research on the comparison of the use of conventional methods with new (modern) methods in learning Mathematics. Their research results show that the use of new methods has a positive impact on learning outcomes.

Furthermore, in the PBL method, learning is centered on the problem given by the teacher then students solve the problem with all their knowledge and skills from various sources that can be obtained. Several studies on the effect of the PBL method [3]–[8] state that the PBL method can improve student learning outcomes. PBL as a product of constructivism learning theory demands the active role of students in understanding knowledge and developing their reasoning [9]. In the PBL method students are required to be able to play an active role and think critically in solving a problem.

In the peer tutoring method, the teacher appoints students who have good academic abilities to become tutors and teach their peers. Students who act as tutors are first provided with material to be discussed in teaching and learning

activities. Then he will re-deliver the material that has been taught to his friends in his class. In other words, the provision of learning is carried out between students or students [10]. Based on several studies on peer tutoring methods [11]–[14] stated that peer tutoring methods can improve student learning outcomes.

These three learning methods will be applied to the Mathematics Economics course. Mathematics Economics is a course that applies mathematics to the field of economics. The choice of teaching methods carried out by lecturers will affect student learning outcomes. Students will get good results, if the learning used by the lecturer is relevant and supports teaching and learning activities in the classroom. In teaching and learning activities there must be three elements involved, namely educators, students, and the reality of the world [15].

The aim of this study is to determine whether the given learning method affects the learning outcomes of Mathematics Economics and which method gives the best results.

METHODS

The population in this study were FKIP and FEB UHAMKA students who took the Mathematics Economics course. Because there were 3 treatments that were tried and each treatment was repeated 3 times, in this study 9 experimental units were needed. Therefore, for this study, 9 classes were set, namely 5B, 1A, 1B, 1R, 1D, 1Aj, 1E, 1F, and 1J as experimental units.

In the experimental design using a Completely Randomized Design (CRD), the placement of treatments was carried out randomly on all experimental units because it was assumed that the experimental units were homogeneous. The results of randomization of treatment to 9 experimental units can be seen in **Table 1**.

Table 1. Results of randomization of treatment into experimental units

Conventional	PBL	Peer Tutoring
5E, 1A, 1B	1R, 1D, 1Aj	1E, 1F, 1J

The linear model in a completely randomized design is:

$$Y_{ij} = \mu + \tau_i + \mathcal{E}_{ij}\,;\; i = 1,\ 2,\ and\ 3;\ j = 1,\ 2,\ 3 \qquad 1)$$

Information:
Y_{ij} : economy math scores as a result of the treatment methods of learning to- i repeat to- j
μ : mean general
τ_i : Influence of teaching methods to- i
$\mathcal{E}_{ij}$: Effect of treatment randomized to- i replay to- j .

Hypothesis:
H_0: $\tau_1 = \tau_2 = \tau_3 = 0$ (the three learning methods did not affect the response observed).
H_1: at least one i, so that $\tau i \neq 0$ (at least one learning methods affect the observed response).
To decide which is accept or reject the null hypothesis, we use Anova formulation showed at Table 2.

Table 2. Analysis of Variance

Source of Variation	Degree of freedom (df)	Sum of Square (SS)	Mean of Square (MS)	F_{count}
Between Treatment	$t-1$	$SSB = \sum_{i=1}^{t} \frac{Y_i^2}{r} - FC$	$MSB = \frac{SSB}{t-1}$	MST/MSE
Error	$t(r-1)$	SSE = SST - SSB	$MSE = \frac{SSE}{t(r-1)}$	
Total	$tr-1$	$SST = \sum_{i=1}^{t}\sum_{j=1}^{r} Y_{ij}^2 - FC$		

Description :
t = number of treatments, in this case t = 3
r = number of repetitions, in this case r = 3

$$FC = \frac{Y_{..}}{tr}$$

Rejection criteria $H_0 : F_{test} > F_{0.05\,(t-1,\,t(r-1))}$

In addition , if the decision is to reject the null hypothesis, it will be continued with Tukey's further test. Tukey's further test was used to see which method was significantly different and which one had the greatest effect. The Tukey's – HSD test formula is:

$$HSD = q\sqrt{\frac{KTG}{r}} \qquad 2)$$

with r = number of replications and q = value in Table Tukey's - HSD (Table q) with $\alpha = 0.05$ when db error and the number of treatments k certain.

This hypothesis testing is done by using analysis of variance. However, before using analysis of variance, it is necessary to test the following assumptions:

1. There is Additive Effect
   The influence of treatment and environmental factors is additive, meaning that the level of experimental results is only influenced by the addition of treatment. In the linear model of CRD (Eq. 1), the treatment (τ_i) and error (ε_{ij}) are additive, in other words the effect of addition from the treatment is constant for each replication and the effect of replication is constant for each treatment. Response value (Y_{ij}) is the general average value plus the addition of treatment and error. To test the effect of additives, the Tukey test is used with the following hypothesis and formula:
   H_0: additive model vs H_1: non-additive model

$$SS_{non\text{-}additive} = \frac{Q^2}{r\sum(\bar{Y}_{i.}-\bar{Y}_{..})^2\sum(\bar{Y}_{.j}-\bar{Y}_{..})^2} \qquad 3)$$

   with
   r = number of repetitions
   $Q = \sum(\bar{Y}_{i.}-\bar{Y}_{..})(\bar{Y}_{.j}-\bar{Y}_{..})Y_{ij}$

$$F_{test} = \frac{SS_{non\text{-}additive}}{SSE/dfE} \qquad 4)$$

   If $F_{test} > F_{\alpha(1,dbg)}$, then the additive model is met.

2. Normal distribution error
   Testing the assumption of a normality distributed error using the Saphiro-Wilk test. If the significance value is greater than 0.05, then at a significance level of 5% it can be stated that the error for CRD on the score of Mathematics and Economics is normally distributed.
3. Homogeneity of Error Variety
   To check the homogeneity of variance from the error data, the Levene test was used. If the significance value is greater than 0.05, then at the 5% significance level it can be stated that the error for CRD on the score of Mathematics and Economics has a homogeneous variance.
4. Independent Error
   To be able to find out whether the experimental error is independent of each other, a plot between the error value and the estimated value of y_{ij} can be used. If the scatter plots between the estimated value y_{ij} with the value of the error is not patterned (random), it can be said that the assumption of independent error is fulfilled.

RESULTS AND DISCUSSION

The descriptive statistics of score for each experimental class is shown in Fig.1. The figure shows that the class with the highest mean score is the class with the Lecture teaching method with a score of 78.667. While the class that received the PBL method obtained a mean of 69.667 and the class with the TS method obtained the smallest mean value of 54.677.

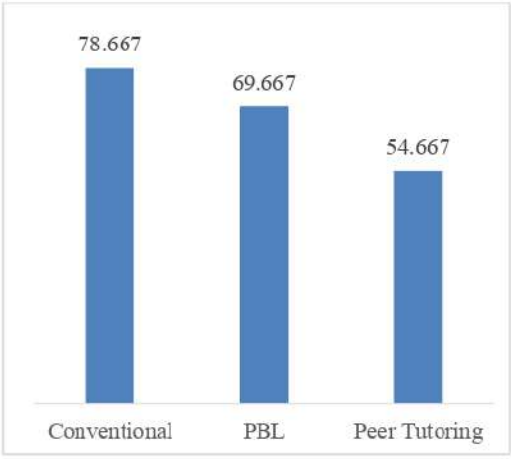

FIGURE 1. Bar Chart Mean score of Mathematics Economics

The result of the calculation of the analysis of variance are shown in Table 3, the value of $F_{count} = 15.75 > F_{table} = 5.143$ with a p-value of 0.004. So, it can be concluded that H_0 is rejected at level of significance 5%. So it means that there are at least a pair of learning methods that have a different effect on the score of Economic Mathematics.

Table 3. Analysis of Variance

Source of Variation	Degree of freedom (df)	Sum of Square (SS)	Mean of Square (MS)	F_{test}
Between Treatment	2	882	441	15.75
Error	6	168	28	
Total	8	1050		

The results of testing assumptions for the data on the error value of Mathematics in Economics are:

1. There is Additive Effect

   The statistical results of the additive effect test obtained the value of F hit= 0.23 with an F value of 0.05 (1.6) = 5.987. Because the value of Fhit > Ftable, then H0 failed rejected. This means that at the 5% level of significance, it can be concluded that the model's additive assumptions are met.
2. Normal distribution error

   The results of the normality test on the error data, in the Saphoro-Wilks test value of 0.953 with a significance value of 0.72. Value Significance is more substantial than 0.05 so that the level of real 5% can be stated that the error for the RAL on the value of Mathematical Economics distribution Normal.
3. Homogeneity of Error Variety

   To check the homogeneity of variance from the error data, the Levene test was used. Levene test results obtained a value of 1.672 with a significance value of 0.265. Because the significance value is greater than 0.05, at the 5% significance level, it can be stated that the error for the CRD on the score of Mathematics and Economics has a homogeneous variance.

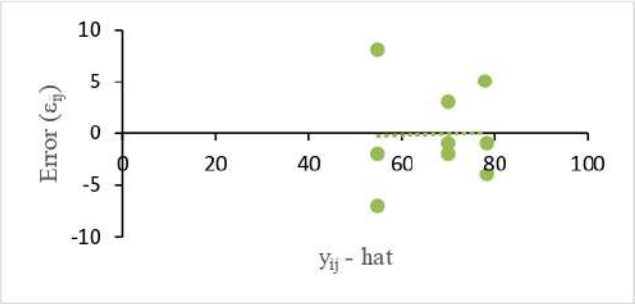

Figure 2. Scatterplot of experimental error

4. Independent Error

To be able to find out whether the experimental error is independent, a plot between the error value and the estimated value of yij is used. Fig. 2 shows that the plot between the estimated yij value and the error value is not patterned (random). This indicates that the assumption of freedom of error is met.

This conclusion leads us to carry out further tests so that it can be seen which treatment pairs have different effects and which pairs have no different effects. Further test that is used in the research is that Tukey, so as to obtain a value statistic Tukey test required value q table At the level of real 5%, k = 3, and df error = 6, obtained by the value of q at 4.34 . With such value of statistical test Tukey- it is:

$$\text{HSD} = 4.34\sqrt{\frac{28}{3}} = 13.259.$$

Furthermore, the HSD value is compared with the average difference between treatments contained in Table 4. If the value of the average difference between treatments is greater than the statistical value of the HSD test, it can be said that the two treatments have different effects on the value of Economic Mathematics. Based on these criteria, it is concluded that the lecture method and peer tutoring, as well as the PBL method and peer tutoring have different effects on the value of Economic Mathematics, while the lecture method with peer tutors does not have a different effect on the value of Economic Mathematics.

Tabel 1. Difference in Mean Between Treatments

Treatment Mean	$\bar{Y}_{1.} = 78.667$	$\bar{Y}_{2.} = 69.667$	$\bar{Y}_{3.} = 54.667$
$\bar{Y}_{1.} = 78.667$	-	…	…
$\bar{Y}_{2.} = 69.667$	9.00	-	…
$\bar{Y}_{3.} = 54.667$	24.00*	15.00*	-

Notes: *) significant at alpha= 5%

Based on the results of the Tukey test, it was concluded that the learning outcomes of Mathematics Economics using the conventional and PBL methods were not significantly different. This is supported by the results of research by [16] which states that there is no significant difference in the groups who receive learning using the PBL method with the traditional method (conventional) for learning Mathematics. This is because in both the conventional and PBL methods, teacher are still the center information in the learning process.

The advantages of the PBL learning model are increasing students' interest, motivation and learning activities, helping students transfer students' knowledge to understand real-world problems, and providing opportunities for students to apply the knowledge they have in the real world [17]. These advantages are difficult to manifest in the Mathematics Economics course which discusses a lot about demand, supply, Equilibrium points, etc. Its because students find it difficult to apply these cases in their daily lives.

When students study with their peers, students can develop better abilities to listen, concentrate and explain peer tutors to their friends, enabling them to be more successful than teachers [18]. A meta-analysis of 50 independent

studies on peer tutoring methods in Mathematics at various levels of Education shows that 88% of the use of this method has a positive effect on academic performance [19]. However, in this study the peer tutor method actually had the smallest average value. This could be due to the lack of knowledge of the tutor or his group mates, so that the process of transfer of knowledge and discussion within the group did not run ideally for the Mathematics Economics course. Further research on this matter is still very much needed.

CONCLUSIONS AND SUGGESTIONS

Experiments using a completely randomized design (CRD) with the treatment of giving lecture methods, PBL, and peer tutors in the Mathematics Economics course, in an average score of 78.667; 69.667 and 54.677. The lecture method has the highest average score while the peer tutor method has the lowest average score . Based on the variance analysis test that has been done, it can be concluded that the lecture method, PBL, and peer tutoring have an effect on the value of Economic Mathematics with a p-value of 0.004.

The results of further tests using Tukey – HSD showed that learning using the Conventional method and PBL did not have a different effect on the score of Economic Mathematics. The average value of these two methods is not significantly different, only 9 points drift. This can be caused because in the lecture or PBL method, learning activities are still centered on the lecturer as a provider of information (lesson materials).

The treatment of peer tutoring methods with the Conventional method and PBL have a different effect on the score of Economic Mathematics. This is because the difference between the average value of the peer tutoring method with lectures and the peer tutoring method with PBL is quite large. Class with Peer tutoring method had a smallest average value. Based on these findings, the researcher does not recommend the use of peer tutoring methods in the Mathematics Economics course. However, further research to analyze these findings is still very much needed to be able to find out more deeply the factors that cause the peer tutoring method to be ineffective in the Mathematics Economics course.

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