Teaching materials design based on project learning to improve the students’ mathematical understanding

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Abstract. Project-based learning requires students to explore and combine their knowledge and skills to solve problems in groups for a certain time. Through the development of project-based teaching materials, students learn to apply theory in an activity that produces experience, so that learning is expected to be more meaningful and improve the students’ mathematical understanding. This study aimed to determine the validity, practicality, and effectiveness of teaching materials based on project learning to improve the students' mathematical understanding, especially on the applied statistics course. The stages of this study consisted of design and development, product validation by 3 experts, limited testing of 10 students, and field testing of 97 students. The results show that the teaching material has fulfilled the valid, practical, and effective aspects used in learning because it increases the ability of students' mathematical understanding by 15.8%.

1. Introduction
Preliminary analysis of 26 students participating in applied statistics at the Muhammadiyah University of Sukabumi in 2017 resulted in several learning difficulties, including a) not being able to identify problems properly and correctly; b) do not understand the initial conditions or assumptions that must be met in the problem given; c) exchanged writing statistical symbols; d) wrong in writing the research hypothesis pairs (H₀ and H₁); e) errors in two-tailed or one-tailed testing; f) test statistics (formulas) used are not in accordance with the circumstances of the problem; g) procedural errors and calculation errors, and h) misconceptions. One example of this difficulty is presented in Figure 1.

![Sample questions and student's difficulties to solve problems](image-url)

Figure 1. Sample questions and student's difficulties to solve problems
Figure 1 explains that students have difficulty writing pairs of hypotheses from the questions given. This is certainly the impact of the inability of students to identify problems properly. Also, students also have difficulty in performing procedures for two-tailed testing. Of course, this will have an impact on the calculation of the tipping point and the conclusions that are produced. The difficulties faced by these students are part of five indicators of mathematical understanding which consists of verbally restating the concepts that have been learned, classifying objects based on the requirements to form the concept, applying the concept algorithmically, present concepts in various forms of mathematical representation, and linking various concepts [1]. This ability is one of the important abilities in mathematics that must be controlled by students. Because it will determine the mastery of other mathematical abilities.

The low ability to understand the mathematical concept will result in low student learning outcomes and of course, students will have difficulty mastering other major mathematical abilities. This means that the purpose of learning various mathematical concepts is to facilitate and even sharpen problem-solving, while through problem-solving students develop other abilities, such as mathematical understanding and representation [2].

This is evident based on a preliminary study of the learning outcomes of 26 students in applied statistics at Muhammadiyah University in Sukabumi, only 42.31% of students achieved the specified competencies, while 57.69% of students had not yet achieved that competence. Therefore, improving the quality of learning is the same as increasing the mathematical understanding ability.

Understanding the concept will be embedded well if the learning process is meaningful. Meaningful learning is a process of linking new information to relevant concepts contained in one's cognitive structure [3]. One of which meaningful learning can be done by involving student experience. One of the learning that combines understanding and experience in project-based learning.

Seven characteristics of project-based learning, including a) students make decisions and frameworks; b) there are problems that have not been determined in advance; c) students design processes to achieve results; d) students are responsible for obtaining and managing the information needed; e) there is a continuous evaluation; f) students regularly look back on their work, and g) the final results are products and their quality is evaluated [4].

The stages of project-based learning include a) Preparation phase, which includes an explanation of several projects, an explanation of important information needed regarding the completion of a project, and schedule, b) Stage of project-based learning process, including group formation and project selection, information gathering, and formulating project completion work steps, and c) The evaluation phase, which is giving assessment and feedback on student work results [5]. This stage is further clarified through 6 stages consisting of determining the project, project planning steps, schedule preparation, monitoring, reports preparation and presentation, and evaluation of the project [6].

2. Method

The research method used is Research and Development which aims to develop teaching materials based on project learning and validate this teaching material [7]. This study used the R&D stage which was applied in three stages, namely preliminary analysis and development, limited trials, and field tests. This stage is adjusted to the objectives of product quality testing which consists of the validity test, practicality test, and effectiveness test [8].

Activities carried out in preliminary analysis and development, namely needs analysis of developing teaching materials, designing teaching materials based on project learning, and validating products. This needs analysis includes the results of previous learning in applied statistics courses, adjustments to learning outcomes, material studied, and simple research projects that will be developed in teaching materials. The initial product produced at this stage is teaching materials based on project learning on descriptive statistical material and testing of simple hypotheses, namely one-sample t-test, independent samples t-test, and paired samples t-test. Furthermore, the initial product was tested for validity by a team of experts. Based on the validation assessment, the teaching material was revised according to the suggestions and comments from the validators.

In the limited trial phase, the teaching material products that had been validated by experts were limited tested to 10 mathematics education students at the Muhammadiyah University of Sukabumi.
using a single one-shot case study method [9]. In this phase, the students are given treatment in the form of learning by using the teaching materials based on project learning during one meeting (1 x 150 minutes). At the second meeting, students were given a mathematical understanding ability test. This stage is ended by revising some parts of the teaching material adapted to the implementation in the class.

In the field test phase, product testing was conducted on 97 students participating in applied statistics in the Mathematics Education, Elementary School Education, and Agribusiness Study Program at Muhammadiyah University of Sukabumi for the 2017/2018 academic year, each for 4 meetings (4 x 150 minutes). This field test uses before-after experimental design [9], namely comparing the effectiveness of before and after using statistical teaching materials based on project learning to the students mathematical understanding. Data analysis was performed using the Wilcoxon test at a significance level of 5%.

3. Result and Discussion

Teaching materials based on project learning are developed through four stages, namely determining teaching materials and learning indicators, designing project assignments in the form of simple research tailored to the previously selected material, designing learning outcome evaluation instruments, and evaluating the final results (products). These four stages are adjusted to improve students' mathematical understanding skills. This stage can be seen in Figure 2.

![Figure 2. Design the Teaching Materials Based on Project Learning](image)

Based on Figure 2, the material selected in this teaching materials based on project learning is descriptive statistics and inductive statistics which are collaborated with project tasks in the form of simple research. The material discussed in descriptive statistics is the presentation of data in the form of diagrams and tables, the size of the central tendency (mean, median, and mode), and dispersion size (variance and standard deviation), while the material discussed in inductive statistics is a hypothesis testing that is limited to two samples, namely one-sample t-test, paired-samples t-test, and independent samples t-test. The feasibility of the material used of this teaching material was assessed using 9 statements. The results of expert evaluations regarding material feasibility have an average of 4.44 on a scale of 5 or classified as very good criteria. This result shows that the material used is following the specified learning indicators.

Project tasks are developed in the form of simple research assignments because there is a match with the characteristics of the project which includes questions that can assign assignments to students, the process can be planned, monitored the implementation, and results can be evaluated. Also, through simple research, students are required to create a framework, determine decisions, and be responsible for getting information. The feasibility of project assignments was assessed using 12 statements. The
results of the assessment indicate that the project assignments presented are very suitable for the material selected, with an assessment of 4.33 or classified as very good.

After assessing the feasibility of the material and the accuracy of the project components with the material, the teaching material was also measured based on the assessment of the feasibility of language usage (5 statements), the feasibility assessment of the presentation (5 statements), and the effectiveness on the teaching and learning process (3 statements). Even this aspect of assessment has an assessment with a very good category. Thus, the overall assessment of the teaching materials based on project learning is categorized as very good, with an assessment of 4.48. The results of the assessment in detail can be seen in the Table 1.

| No | Assessment criteria                                      | Average Rating | Information                          | Conclusion       |
|----|----------------------------------------------------------|----------------|--------------------------------------|------------------|
| 1  | Feasibility and depth of material                        | 4.44           | 88.80% criteria have been met        | Very good        |
| 2  | Suitability and feasibility of project assignments with selected material | 4.33           | 86.60% of criteria have been met     | Very good        |
| 3  | Feasibility of language use                              | 4.30           | 86% of criteria have been met        | Very good        |
| 4  | Feasibility of presentation                              | 4.50           | 90% of criteria have been met        | Very good        |
| 5  | Teaching materials effectiveness on the teaching and learning process | 4.83           | 96.60% of criteria have been met     | Very good        |
|    | Average                                                  | 4.48           | 89.60% of criteria have been met     | Very good        |

Evaluating products resulting from project assignments is done by compiling evaluation instruments consisting of three types, namely peer-assessment of preparation and implementation the project (10 statements), assessment of research report (13 statements) and assessment of presentation in class (7 statements). The results of the evaluation of the preparation of this evaluation instrument have an average of 4.50 or are categorized as very good. This shows that the teaching materials developed have met valid criteria.

After the teaching materials have been developed and validated, the teaching materials are tested for practicality through limited trials and field trials. At the limited trial stage, learning activities are carried out for 2 x 150 minutes. The first meeting began with a pre-test of students mathematical understanding ability. The last 50 minutes are used for the formation of groups of 5 people each, dissecting the contents of the project with descriptive statistical material, determining the target time for project completion, determining the project instrument, analyzing the data, division of task groups, and reporting the results. This activity went well. Student responses showed a high enthusiasm for learning. The completing the project task to take data into the field, analyze the data, and make the final report given for one week. In the second meeting, students collected the project work report and presented the results in front of the class for 1 x 50 minutes. Then the last 2x50 minutes, students were given a post-test of mathematical understanding ability. The data from the limited test results were analyzed using the Wilcoxon test at a significance level of 5% (see Table 2).
Table 2. Results of the Wilcoxon Hypothesis Test

| Treatment | N  | Average | Statistics | Asymp. Sig. (2-tailed) | Conclusion |
|-----------|----|---------|------------|------------------------|------------|
| After     | 10 | 78.60   | -2.803     | 0.005                  | H<sub>0</sub> Rejected |
| Before    | 10 | 60.60   |            |                        |            |

Table 2 shows that the results of the students’ mathematical understanding ability increased by 18%. Also, based on the Wilcoxon test results at a significance level of α = 5%, it can be seen that the students’ mathematical understanding ability after using the teaching materials based on project learning is significantly better than before. This shows that teaching materials based on project learning developed to meet the practical criteria used in applied statistical learning in the classroom.

Field trials are carried out for 8 meetings with each duration is 3x50 minutes. In the first 3 meetings, the learning treatment was given without teaching materials. The material presented in the form of descriptive statistical material, presentation of data, measures of central tendency and data dispersion using direct learning which is given by using power points, given examples, class discussions, and given the individual assignments in the last step. At the 4<sup>th</sup> meeting, students are given a test of mathematical understanding ability that is calculated as learning outcomes before teaching materials based on project learning are implemented. At the 5<sup>th</sup> to 7<sup>th</sup> meetings, treatment was given using teaching materials based on project learning. In completing project assignments, students are required to be able to collaborate with group friends, share tasks effectively, take data to the field, analyze data, report results in the form of reports, and present the results in front of the class. The material given in this assignment is hypothesis testing which is limited to a maximum of two sample groups, such as one-sample t-test, paired-samples t-test, and independent samples t-test. At the last meeting, students were given a final test of mathematical understanding ability that was calculated as learning outcomes after the implementation of teaching materials. The description of the research data can be seen in the following Table 3.

Table 3. Students’ Mathematical Understanding Result

| Treatment | N  | Average | Std. Deviation | Normality test | Conclusion |
|-----------|----|---------|----------------|----------------|------------|
| Before    | 97 | 57.72   | 15.84          | 0.001          | Not Normal |
| After     | 97 | 66.84   | 9.98           | 0.200          | Normal     |

Table 3 shows it can be seen that there is an increase in the students mathematical understanding ability after using teaching materials of 15.80%. This shows that teaching materials based on project learning play a role in improving students' mathematical understanding ability. However, to test whether the increase originated from teaching materials based on project learning that were significant or not statistically, the Wilcoxon test was carried out at a 5% significance level. This is because the normality of data is not fulfilled. The results of the analysis can be seen in the Table 4.

Table 4. Hypothesis Testing Results with the Wilcoxon Test

| Test Statistics | After - Before |
|-----------------|----------------|
| Z               | -4.820<sup>a</sup> |
| Asymp. Sig. (2-tailed) | 0.000 |
| Conclusion      | H<sub>0</sub> Rejected |

a. Based on negative ranks.

Table 4 shows that the students mathematical understanding ability after using teaching materials based on project learning is better than before. These results indicate that the teaching materials based on project learning developed have effective criteria to improve students' mathematical understanding ability in applied statistics. This result is in line with several previous studies that revealed that the
development of learning devices based on Project Based Learning in high school statistical material using the ADD (Analysis, Design, Development) development model is in very valid and practical criteria [11]. Other studies also suggest that teaching materials based on the project effectively improve the academic achievement of mechanical engineering students at UNM significantly [5], effectively develop the affective, cognitive, psychological aspects that achieve completeness above 75% in the electrical engineering department of Surabaya State University [4], effectively foster student achievement on trigonometry subjects at SMAN 1 Godean [10].

Based on the learning process, the acceptance of research hypotheses is inseparable from the use of projects presented in teaching materials. This project-based applied statistical teaching material was developed with reference to the project criteria used, namely a) students making decisions and frameworks; b) there are problems that have not been determined in advance; c) students design processes to achieve results; d) students are responsible for obtaining and managing the information needed; e) there is a continuous evaluation; f) students regularly look back on their work, and g) the final results are products and their quality is evaluated [4]. Examples of projects presented in teaching materials can be seen in the following figure.

![Figure 3. Examples of Simple Research Projects](image)

Finalizing the project in figure 3 can be done through 6 stages consisting of a) determining the project; b) project planning steps; c) schedule preparation; d) monitoring; e) reports preparation and presentation, and f) evaluation of the project [6]. These stages train students to understand the problem, develop a problem-solving plan, cooperate, share tasks effectively, be responsible for the data produced, and manage time as well as possible. This is in accordance with Indrawan's research, et al., who argued that through project-based learning, students would work in teams, find skills in planning, organizing, negotiating, and making agreements about the tasks to be performed, who was responsible for each task, and how information will be collected and presented scientifically [12]. The core ideas in project-based learning provide opportunities for students to investigate real-world problems to gain new knowledge. Thus, the benefits of project-based learning can improve students' mathematical understanding ability. This fact is in line with the results of Serin's research which identified students' involvement in learning so that more opportunities for improving mathematical abilities such as critical thinking, problem-solving and self-employment [13].

4. Conclusion
The results of data analysis show that the teaching materials based on project learning developed have met valid, practical, and effective criteria used in statistical learning, specifically to improve students' ability to understand mathematical concepts. This teaching material can then be used as a learning alternative that encourages students to explore their knowledge and experience at the same time. Nevertheless, this teaching material was developed limited to applied statistical subjects and was limited to the material for two-sample testing. So that for further research, teaching materials should be developed by extending the scope of material regarding testing hypotheses with more samples in statistical subjects, also need to be developed in other subjects or other mathematical abilities, so that the project's effectiveness is more visible on another students' mathematical abilities.
References

[1] Killpatrick, Swafford and Findell 2001 *Adding it up: Helping children learn mathematics* (United State of America: National Academy of Sciences).

[2] Minarni A, Napitupulu E and Husein R 2016 Mathematical understanding and representation ability of public junior high school in north Sumatra *J. Math. Educ.* 7 43-56.

[3] Dahar R W 1996 *Teori-teori Belajar* (Jakarta: Erlangga).

[4] Sani M 2015 Pengembangan Modul Pembelajaran Berbasis Proyek Pada Mata Kuliah Pemeliharaan dan Perbaikan Mesin Listrik di Jurusan Teknik Elektro Universitas Negeri Surabaya *J. Pendidikan Teknik Elektro* 4 259-267.

[5] Rais M 2010 Model Project Based-Learning Sebagai Upaya Meningkatkan Prestasi Akademik Mahasiswa *J. Pendidikan dan Pengajaran* 43 246-252.

[6] Hosnan, M 2016 *Pendekatan Scientifik dan Kontekstual dalam Pembelajaran Abad 21* (Bogor: Ghalia Indonesia).

[7] Borg W R and Gall M D 1983 *Educational Research: An Introduction* (New York: Longman).

[8] Nieveen N 1999 Prototyping to Reach Product Quality in Plomp T, Nieveen N, Gustafson K, Branch R M and van den Akker J (eds) *Design Approaches and Tools in Education and Training* (London: Kluwer Academic Publisher).

[9] Sugiyono 2011 *Metode Penelitian Pendidikan: Pendekatan Kuantitatif, Kualitatif, dan R&D* (Bandung: Alfabeta).

[10] Gerhana M T C, Mardiyana M and Pramudya 2017 The Effectiveness of Project Based Learning in Trigonometry *J. Phys. Conf. Ser.* 895 012027.

[11] Durohman, Noto, and Hartono 2018 Pengembangan Perangkat Project Based Learning (PJBL) Pada Materi Statistika SMA *J. Pendidikan Matematika* 2 1-18.

[12] Indrawan E, Jalinus N and Syahril 2019 Review Project Based Learning *International Journal of Science and Research* 8 1014-1018.

[13] Serin H 2019 Project-Based Learning in Mathematics Context *International Journal of Social Sciences & Educational Studies* 5 232-236.