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THE INFLUENCE OF FLIPPED CLASSROOM-BASED PROJECT ASSESSMENT ON CONCEPT UNDERSTANDING AND CRITICAL THINKING SKILLS IN PHYSICS LEARNING

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ABSTRACT

This study aims to analyze the influence of flipped classroom-based project assessment on critical thinking skills and physics learning outcomes. This quantitative research has a post-test-only non-equivalent control group design. The population is distributed into two classes. The data are collected using questionnaires and tests and analyzed using descriptive statistics and Manova. The results indicate differences between critical thinking skills and physics learning outcomes between students who learned with project assessments based on the flipped classroom approach and students who learned with conventional assessments simultaneously and partially. The significance value indicates more than 0.05. Thus, it can be concluded that flipped classroom-based project assessment influences critical thinking skills and concept understanding. Flipped classroom-based project assessment is recommended as one innovative assessment based on constructivism to improve concept understanding and critical thinking. Excellent critical thinking skills and concept understanding will help students solve contextual problems.

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Keywords: concept understanding; critical thinking skills; flipped classroom; project assessment

INTRODUCTION

Science learning has importance in human life. Science is the knowledge of human activities outcomes through steps and scientific methods from the results of general experiments so that it will be continued to be refined (Stender et al., 2018; Cornelia et al., 2019; Solé-Llussà et al., 2019). Science contains concepts, facts, principles, laws, and theories that explain a phenomenon (Asrizal et al., 2018; Suryandari et al., 2018; Tanti et al., 2020). Science education can potentially prepare the quality resources in the industry 4.0 era. The quality of resources can be realized if science learning can cultivate the ability to think creatively and logically, solve problems, master technology, and become adaptive to the development of the times. (Houseal et al., 2014; Mogari, 2014; Faize et al., 2017; Shin et al., 2017). One of the important science subjects for students is physics. Physics learning is related to the matter in the universe, from microscopic to macroscopic (Saprudin et al., 2017; Muhametjanova & Akmatbekova, 2019; Sukarni et al., 2020). One type of physical matter is wave optics. Optical wave is one of the compulsory courses in the Department of Physics. Through learning optical waves, students can understand about waves such as mechanical and electromagnetic waves (Pitriana & Hidayat, 2016; Bakri et al., 2018). Learning physics can develop curiosity through hands-on experience. The essence of studying physical sciences, especially optical wave matter, is understanding the concept and discovering the concept

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of experiment and practicum of scientific research (Day et al., 2022; Wu et al., 2022; Zhang & Häger, 2022). Good learning activities will help improve students' concept understanding of optical waves.

Concept understanding is vital in learning physics because students can develop their abilities (Haji et al., 2015; Abdullah et al., 2021). Concept understanding is a level of ability that makes students understand concepts and facts, give examples, and conclude (Harrell & Subramaniam, 2015; Sakdiah et al., 2018; Susanti et al., 2018). Indicators of understanding this concept are restating a concept, classifying, exemplifying, presenting, using, utilizing, and applying the concept (Rosdianto et al., 2017; Pujiati et al., 2018; Jeheman et al., 2019; Suparmi, 2019). Concept understanding includes the second level of Bloom's cognitive domain. This aspect concerns the ability of students to capture meaning with their sentences. Previous research stated that concept understanding is divided into three categories: translating, interpreting, and extrapolating (Pujiati et al., 2018; Putra et al., 2018; Şefik & Dost, 2020). The ability to translate is the ability of students to translate a concept (Azizah et al., 2021). The ability to interpret is knowing better and understanding concepts (Wahyuddin et al., 2021). The ability to extrapolate requires high intellectual abilities, such as making a study of concepts. The benefits of students understanding concepts are helping to remember the material, helping to understand information, and determining what students know (Putra et al., 2018; Anwar, 2018; Nasrum, 2020). Concept understanding is the basis for improving students' critical thinking skills (Yulianty, 2019).

Critical thinking is the ability to convey ideas, analyze facts, make comparisons, draw conclusions, and solve problems (Dewi et al., 2017; Polat & Aydın, 2020; Jalinus et al., 2021). Critical thinking is in the fifth level of Bloom's cognitive domain. This ability will provide an opportunity to use the information students possess to provide solutions to a problem (Sadhu & Wijayanti, 2018; Rahmawati et al., 2019; Polat & Aydın, 2020). This is why every student needs critical thinking skills to help them compare their information with information received from outside. Students with critical thinking skills can decide something with their intellectual abilities (Sadhu & Wijayanti, 2018; Taimur & Sattar, 2018; Rahmawati et al., 2019). Critical thinking skills will develop well if students already have concept understanding at the beginning. In developing concept understanding and critical thinking skills, an innovative and collaborative learning activity is needed (Changwong et al., 2018; Mulyanto et al., 2020; Pradana et al., 2020). So, based on elaboration, concept understanding and critical thinking skills are determined by the learning activities carried out.

However, the problem today is that students lack concept understanding. Based on previous research, many students still lack an excellent concept understanding (Jailani, 2017; Ikbal et al., 2018; Suparmi, 2019). Many students still have low critical thinking skills, especially in science learning (Ardaya, 2016; Nahdi et al., 2018; Putra et al., 2018). It is caused by the conventional learning model which cannot develop students' critical thinking skills (Pudjawan & Margunayasa, 2013; Nurmaliah et al., 2018). Teacher-centered learning activities will obstruct students' critical thinking skills because students only receive the delivery of material (Houseal et al., 2014; Isa et al., 2017; Aditya et al., 2019). In addition, the packaging of physics learning so far does not correspond to the nature of science. Science includes processes, products, and attitudes (Sukmasari & Rosana, 2017; Sumarti et al., 2018). Science emphasizes the process of education as a process. Science concentrates on the outcomes of knowledge as a product. It seeks to arm, prepare, and uphold for students' positive ideals as an attitude (Gunawan et al., 2019; Redhana et al., 2019). It seems that a transformation of physics learning is needed, from learning to memorize to learning to think. A new idea to overcome students' lack of maximum learning outcomes and critical thinking skills is to apply an innovative learning approach that can accommodate students to build their knowledge through assessment packaged in scientific discoveries and integrate learning technology. One of the learning approaches that can be used for learning today is the flipped classroom.

Flipped classroom learning approach can be interpreted as a change in the direct learning approach where what students usually do at school will be done at home and vice versa (Elfeky et al., 2020; Leatherman & Cleveland, 2020; Anjelina & Mawardi, 2021). Flipped classroom approach has several characteristics: providing increased interaction time between teachers and learners, providing opportunities for learners to be responsible for their learning process, switching the role of teachers into mentors, combining constructivist learning with teaching methods, giving each learner individual education, learning with repetition, and preventing learners (Ozdamli & Asiksoy, 2016; Zainuddin & Perera, 2019; Yen, 2020) Because each student has a different learning style (Margunayasa et al., 2019; Shamsuddin & Kaur, 2020), a flipped classroom approach will blend their learning styles.

Learning style is the way or tendency of a person to absorb information. Students' learning styles consist of audio, visual, and kinaesthetic learning styles (Prayekti, 2018; Morze et al., 2021). The flipped classroom will facilitate students' learning media following their learning style to help students understand the learning material. Students who have an audio learning style will be provided with learning materials in the form of audio. Students who have a visual learning style will be provided with materials in the form of digital teaching materials. Providing learning media is expected to help students in online learning, especially in optical wave material. In addition to innovative learning approaches, assessments are needed to improve concept understanding and critical thinking by conducting project assessments.

Flipped classroom-based project assessment is a collaborative learning system that combines online learning with project assessment. Project assessment develops from project-based learning (Sukmasari & Rosana, 2017). It provides an opportunity for students to discover their physics concepts by working on the project so that learning will be more meaningful. The project begins with planning, collecting data, organizing, processing, and presenting data (Marzuki & Basariah, 2015; Safaruddin et al., 2020). A project-based assessment requires students in a group to execute investigative activities within a set amount of time. Students must address numerous issues as part of project-based assessments (Sukmasari & Rosana, 2017; Amri & Tharihk, 2018). Additionally, it can direct students in inquiry-based activities to discover new information and resolve issues using the knowledge they acquire on their own (Sukmasari & Rosana, 2017). Because project assessment boosts students' confidence in performing tasks, it is appropriate for physics education (Hasibuan et al., 2020).

Project assessment can improve measuring problem-solving ability in students (Sukmasari & Rosana, 2017) and assess student contribution (Gawrycka et al., 2021; Chen et al., 2022). Previous research also stated that flipped classroom approach is worthy of use in learning because it can increase students' learning motivation (Sinaga, 2017; Widyaningrum et al., 2020). The flipped classroom approach can stimulate students to self-study (Kurtz et al., 2014; Tsai et al., 2020), facilitate students' learning, and improve their learning outcomes (Van Sickle, 2016; Van Alten et al., 2019). Based on these studies, it can be said that the assessment of projects based on the flipped classroom approach can improve the student learning atmosphere to be more positive and flexible. These advantages are why the assessment of projects based on the flipped classroom approach is a solution in physics learning.

Some aspects differentiate this research from previous ones. In this research, flipped classroom-based project assessment will be combined with the student learning style for optical wave material in physics learning. The application of flipped classroom-based project assessment is expected to improve students' concept understanding and critical thinking. This study aims to analyze the influence of the flipped classroom-based project assessment on students' concept understanding and critical thinking, especially in optical wave materials.

METHODS

This research is quantitative. It used the post-test only non-equivalent Control Group Design (Campbell & Stanley, 1963). This design was chosen because the students are divided into two classes, and their second-semester exam results are equivalent. The population of 31 students is distributed into two classes. Selection of research samples using a random sampling technique through a two-time lottery system. It divided 13 students to the experimental group and 12 to the control group. This study uses independent variables in the form of assessment types consisting of two dimensions: flipped classroom-based project assessment and conventional assessment. The experimental group was given a flipped classroom approach based on project assessment, while the control group was given a conventional assessment. There is several learning steps in the experimental group: lecturers convey learning objectives, lecturers share teaching materials and learning videos, students make papers, students present papers, students do projects, students communicate project results, and lecturers conduct project assessments. Students' projects are assessed with project instruments that include the following aspects: (1) planning (title, objectives, selection of tools/materials, data collection steps, theoretical studies, and data analysis techniques), (2) project implementation (data accuracy, data analysis, results and discussion, conclusion, reference list), and (3) project report (presentation and revision of the report). The dependent variable in this study is the concept understanding and critical thinking skills.

Questionnaires and tests are employed to collect data, with the questionnaire and test sheets as instruments. Scores of concept understanding and critical thinking skills in physics are collected as data. Students' concept understanding and critical thinking skills in physics are obtained using tests. All instruments have problem grids, answer keys, and assessment rubrics. They are also tested for validity and reliability. Five experts validated the instrument. The validity of the instrument is tested using the product moment formula. With an average coefficient of 0.81 and 0.79 for the concept understanding and critical thinking skills tests, respectively, the analysis revealed that all instrument items were deemed valid. As the Cronbach's Alpha formula employed to calculate reliability of the instrument, it showed a coefficient of 0.899 and 0.887 for the concept understanding and critical thinking skills tests, respectively. The concept understanding grid is in Table 1, and the critical thinking grid is in Table 2.

Table 1. Instrument Grid of Concept Understanding

Indicator	Cognitive of Level	Number of Questions
Deciphering the level of sound intensity	C2 Conceptual	1
Deciphering the detected frequency	C2 Conceptual	1
Projecting wave reflection	C2 Metacognitive	1
Estimating shadow distance and height	C2 Factual	2
Projecting refraction	C2 Conceptual	1
Deciphering the properties of Shadows	C2 Conceptual	1
Interpreting power	C2 Metacognitive	1
Projecting the course of interference	C2 Metacognitive	1
Deciphering the display of light waves and frequencies	C2 Conceptual	1
Total		10

The concept understanding instrument was developed based on the instrument grid, as shown in Table 1. Instruments for concept understanding consist of ten essay questions.

Table 2. Instrument Grid of Critical Thinking Skills

Dimensions of Critical Thinking Skills	Indicators of Critical Thinking Skills
The Formulation of the Study	Formulate questions that guide the investigation
To give arguments	Arguments as Needed
	The Whole Argument
Make Deduction	Deduce logically
	Interpret correctly
Do Induction	Analyze data
	Make a conclusion
Do Evaluation	Evaluate based on the facts
Decide and execute	Determine the way out
	Choose the possibility that is implemented

The critical thinking skills instrument was developed based on the instrument grid, as shown in Table 2. The instrument of critical thinking skills have 10 essay questions. Descriptive analysis and inferential statistics were used to analyze the data in this study (Agung, 2014). Descriptive analysis in this study measures the Mean and Standard deviation. In comparison, inferential analysis is done with MANOVA analysis. The normality test, variance homogeneity test, multivariate homogeneity test, and multicollinearity test are prerequisite analyses. The IBM SPSS Statistics 26.0 was used as data analysis application.

RESULTS AND DISCUSSION

The results of descriptive analysis showed differences in concept understanding and critical thinking skills of students who studied with the flipped classroom-based project assessment and students who studied without it. This condition is seen from the difference in the average score of students' concept understanding, who scored 8.50, indicating that the concept understanding of the experimental group is greater than the control group. Likewise, the critical thinking skills score showed a difference of 9.10, in which the experimental group had better critical thinking skills than the control group. Therefore, there is an influence of learning with flipped classroom-based project assessment on concept understanding and critical thinking skills. The descriptive analysis also showed that critical thinking skills are more influenced by learning with flipped classroom-based project assessment compared with concept understanding variables. The complete descriptive analysis are presented in Table 3.

Table 3. General Description of Concept Understanding (CU) and Critical Thinking Skills (CTS)

Statistics	Experimental Group		Control Group	
	CU	CTS	CU	CTS
M	81.40	76.10	72.90	67.00
SD	8.40	8.20	4.60	11.70
Qualification	High	High	High	Average

The Kolmogorov-Smirnov normality test was the first pre-requisite test performed. All data are found to be normally distributed by the analysis, indicated from GIS.> 0,05. The variance homogeneity test using Levene's Test of Equality and the multivariate homogeneity test using Box's Test of the covariance matrix equation are the next pre-requisite tests. The homogeneity analysis produced same findings. According to the GIS value, the research data originated from a homogeneous group. Every test yields a value that is higher than 0.05. Sig value of Levene equivalence test is 0.13 for concept understanding of physics, while Sig. from critical thinking skills is 0.10. On the other hand, Box's Test of Equality of Covariance Matrices yielded a F value of 1.53 and Sig. 0,21. The multicollinearity test that comes next is intended to ascertain whether each studied dependent variable exhibits multicollinearity symptoms or not. Multicollinearity makes use of VIP values and tolerance. According to the analysis, there are no signs of multicollinearity between the data of concept understanding and critical thinking skills in physics, which is indicated by the tolerance value of 1.00 and VIP of 1.00. According to the test analysis, all conditions for carrying out the MANOVA test were achieved, enabling hypothesis testing using Manova. Table 4 displays the results of the Manova calculations.

Table 4. Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.
Intercept	Pillai's Trace	0.99	1788.25	2.00	22.00	0.00
	Wilks'Lambda	0.01	1788.25	2.00	22.00	0.00
	Hotelling's Trace	162.57	1788.25	2.00	22.00	0.00
	Roy's Largest Root	162.57	1788.25	2.00	22.00	0.00
X	Pillai's Trace	0.48	10.14	2.00	22.00	0.00
	Wilks' Lambda	0.52	10.14	2.00	22.00	0.00
	Hotelling's Trace	0.92	10.14	2.00	22.00	0.00
	Roy's Largest Root	0.92	10.14	2.00	22.00	0.00

Based on the data analysis of concept understanding and critical thinking skills in physics, students given a flipped classroom-based project assessment and students given a conventional assessment resulted in significances = 0.001 on the value of F Pillai's Trace, Wilks, Lambda, Hotelling's Trace, Roy's Largest Root = 10.14 B. The significance number 0.00 is smaller than that of 0.05. Based on the analysis results, the null hypothesis rejected and accepted the research hypothesis that states a difference in concept understanding and critical thinking skills in physics between students given a flipped classroom-based project assessment and students given a conventional assessment. To test hypotheses 2 and 3, it used Manova inter-subject influence test. The analysis results are presented in Table 5.

Table 5. Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected	CU	451.86	1	451.86	10.15	0.00
	CTS	518.48	1	518.48	5.17	0.03
Intercept	CU	148642.76	1	148642.76	3338.92	0.00
	CTS	127807.76	1	127807.76	1274.77	0.00
X	CU	451.86	1	451.86	10.15	0.00
	CTS	518.48	1	518.48	5.17	0.03
Error	CU	1023.92	23	44.52		
	CTS	2305.98	23	100.26		
Total	CU	149700.78	25			
	CTS	131490.15	25			
Corrected Total	CU	1475.78	24			
	CTS	2824.46	24			

Note:
CU: Concept Understanding
CTS: Critical Thinking Skills

Based on the data analysis results of concept understanding in physics, statistical value F = 10.15 with a significance of 0.00. The number of such significance is smaller than that of MPEG = 0.05. In connection with that, the null hypothesis rejected and accepted the research hypothesis that states, "There are differences in understanding of physics concepts between students given flipped classroom-based project assessment and students given conventional assessments." The group of students given a flipped classroom-based project assessment achieved a concept understanding with a higher average score than those students given a conventional assessment. The results of data analysis of critical thinking skills obtained a statistical value of F = 5.17 with a significance of 0.03, smaller than 0.05. In connection can be taken conclusions, null hypothesis rejected and accepted the research hypothesis that states, "There are differences in critical thinking skills between students given flipped classroom-based project assessment and students who are given conventional assessments."

The findings indicate a significant influence of students given flipped classroom-based project assessment with students given a conventional assessment. Students given the flipped classroom-based project assessment achieved critical thinking skills with a higher-grade point average than those given a conventional assessment. A flipped classroom-based project assessment provides opportunities for students to think critically and be active in learning. The flipped classroom approach makes learning activities more enjoyable compared to conventional learning approaches. Learning that can make learners comfortable in learning will help increase motivation and the spirit of learning (Schwinger & Otterpohl, 2017; Kryshko et al., 2022). This learning motivation will be seen when students seriously and seriously study well (Tsai et al., 2020; Van Alten et al., 2020; Zheng & Zhang, 2020). Of course, increased student motivation makes learning activities run smoothly, and learning goals can be achieved to the maximum. Based on the elaboration, the flipped classroom-based project assessment positively influences learning activities.

There are differences between flipped classroom-based project assessment with a conventional assessment because it allows students to be active, independent, and responsible in the learning process. This learning aspect of critical thinking skills and students' physics learning outcomes can be developed simultaneously. It is essential for students to feel that they can evaluate what they have learned, which will further give them confidence and motivation in their learning process (Carpenter et al., 2020; Tsai et al., 2020;

Van Alten et al., 2020). This is because excellent project assessment has a positive influence on the classroom environment, which becomes more dynamic and gives students opportunity to be more independent and responsible in executing the projects that are assigned (Marzuki & Basariah, 2015; Safaruddin et al., 2020). In addition, the project assessment offers students the opportunity to investigate and discover interesting topics that are authentic. Using this flipped classroom-based project assessment, student involvement in the learning process can be enhanced and impact students' understanding and critical thinking. Flipped classroom facilitated students learning so that it has an impact on learning motivation (Tsai et al., 2020; Van Alten et al., 2020) and learning (Andujar & Nadif, 2020; Zheng & Zhang, 2020; El Sadik & Al Abdulmonem, 2021). Learning should consider aspects of assessment and review the process to make students gain a complete understanding (Dahalan & Hussain, 2010; Gotwals et al., 2015; Wu et al., 2021). Flipped classroom approach is an effective learning solution (Qingqing, 2016; Anugrah et al., 2020; Anjelina & Mawardi, 2021). In addition, the findings of this study align with previous studies that found that project assessment improves student competence (Hairida & Junanto, 2018; Rahayu et al., 2020).

There is an influence of flipped classroom-based project assessment on concept understanding. Project assessment encourages students to have higher cognitive thinking (Agustina, 2016; Cifrian et al., 2020; Gomez-del Rio & Rodriguez, 2022). Flipped classroom-based learning that uses several online learning media and virtual labs will make learning more interesting (Elfeky et al., 2020; Van Alten et al., 2020; Anjelina & Mawardi, 2021). Learning activities with project assessment facilitate students to learn as thinkers, not just passive recipients. Lecturers are no longer dominant as the main source of students acquiring knowledge (Choi et al., 2014; Nyatanga & Mukorera, 2019). This learning involves students' active role in constructing their knowledge through scientific discovery activities (Palazón-Herrera & Soria-Vílchez, 2021; Purba, 2021). Project assessment syntax, such as planning projects, implementing projects, and communicating project results, practice the students to think logically, critically, and analytically under the guidance of lecturers. This learning creates an active learning environment for students to get knowledge, apply knowledge, and improve critical thinking skills. Other research findings also corroborate that students are required to think to recognize the problem, investigate to find answers to the problems encountered, or prove the hypothesis formulated in the preparation of conclusions (Can et al., 2017; Hairida & Junanto, 2018; MacLeod & van der Veen, 2020).

There is an influence of flipped classroom-based project assessment because it provides learning media according to students' learning styles to improve their critical thinking skills. Project assessment will be optimal if accompanied by media use in the form of technology in learning. Appropriate learning Media will help students learn to improve their critical thinking skills (Syawaludin et al., 2019; Pramestika et al., 2020; Seruni et al., 2020). The use of flipped classroom approach in learning has advantages in terms of time effectiveness (Susanti & Pitra, 2019; Clarisa et al., 2020). Providing learning materials and videos on the flipped classroom approach can improve student learning readiness. Students have more time to do practicum activities (projects), analyze practicum results, practice questions, or have a discussion related to the material. This approach gives students more opportunities to optimize critical thinking skills through discovery, making learning through virtual labs more meaningful. This is in line with previous research states that inquiry-based virtual laboratory learning provides opportunities for students to learn together through discussion activities, express ideas, foster self-confidence, and develop creative thinking and critical thinking skills (Aşiksoy & Islek, 2017; Abdjul et al., 2019; Gunawan et al., 2019).

There is an influence of flipped classroom-based project assessment because the flipped classroom approach makes it easier for students to learn. Learning with a flipped classroom approach is done through the Learning Management System, Google Classroom. Students can access Classroom accounts through a Google account or the Google Classroom application (Setiawan & Oka, 2020; Purba, 2021). This application's convenience is connecting the classroom account to the students' G-mail account so that any updates to the material and tasks given by the lecturer will appear on their mobile phones. Students follow online learning through Google Classroom to obtain learning materials, learning videos, practical simulations, assignments, and quizzes given by lecturers. The material is presented in PowerPoint and learning videos to increase students' learning motivation. Using media in the form of learning videos provides a learning experience, not only seeing and reading but also listening to the material (Brame, 2016; Andel et al., 2020). Learning can be adjusted to the learning speed of each student by repeating learning videos continuously. The practicum simulation video contains practical demonstrations conducted by students in online learning activities in the virtual lab. In the virtual practicum, students can do several activities as in real practicum, and only students do it with computer software (Mirdayanti, 2017; Iskandar, 2018; Abdjul et al., 2019). This indicates that the essence of virtual practicum activities is not much different from real practicum and can still train students' critical thinking skills. Students still acquire knowledge through scientific discoveries and can develop critical thinking skills without face-to-face learning. This is in line with previous studies' findings that virtual laboratories can significantly improve students' critical thinking skills (Herga, 2016; Aşiksoy & Islek, 2017; Yusuf & Widyaningsih, 2020). The provision of practical simulation aims to make it easier for students to learn and understand the steps of the project to be carried out. Flipped classroom-based project assessment involves students actively in the learning process. Students have a better chance of optimizing their critical thinking skills and learning outcomes. Flipped classroom-based project assessment is recommended as one innovative assessment based on constructivism to improve concept understanding and critical thinking.

CONCLUSION

Flipped classroom-based project assessment influences concept understanding, critical thinking skills, and physics learning outcomes simultaneously and partially. This learning provides opportunities for students to cooperate cooperatively with peers to exchange ideas. This learning also provides opportunities for students to learn actively and independently to be more responsible for the learning process and results. Flipped classroom-based project assessment is recommended as one innovative assessment based on constructivism to improve concept understanding and critical thinking. The study results are beneficial for teachers as an alternative to innovative learning. They are also helpful for other researchers regarding project assessment, concept understanding, and critical thinking skills

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