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Implementation of project-based learning e-modules supported by Google Sites to improve students' conceptual understanding of global warming materials

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Abstract
The implementation of the *Kurikulum Merdeka* provides freedom in the learning process and emphasises student activity. One model that can be used is project-based learning (PjBL). With Google Sites, PjBL e-modules can become learning tools that utilise advances in educational technology. This study aims to analyse the effectiveness of the e-module PjBL, supported by Google Sites, for teaching material on global warming and student responses to it. The study employed a one-group pretest-posttest experimental design on thirty-two tenth-grade students. Data were collected through tests to measure conceptual understanding and through questionnaires to gather feedback on the e-module's practicality. The results showed that the e-module effectively enhances students' conceptual understanding, as evidenced by an N-Gain score of 0.59 and learning outcomes above the learning objective criteria. Additionally, students rated the e-module as practical 78%. These results suggest that the e-module is an effective and practical teaching tool for global warming.

Keywords: Conceptual understanding, Google Sites, PjBL

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I. Introduction

One of the models that aligns with the characteristics of the *Kurikulum Merdeka*, which allocates a significant amount of learning time to learning essential material, is the Project-Based Learning (PjBL) model. The PjBL model provides students with the opportunity to learn in groups and process knowledge through project-based learning activities, which serve as a form of character building. The advantages of the PjBL model include active student involvement, the development of 21st-century skills, and the facilitation of more meaningful interdisciplinary learning experiences [1], [2]. Research by Wahyudi [3] found that the application of PjBL provides opportunities for students to learn actively to build their own knowledge, so that students learn more meaningfully, which has an impact on student learning outcomes. The more actively students learn, the more the learning process will be able to achieve learning objectives.PjBL learning is also effective in improving conceptual understanding [4]. Based on an interview with the physics teacher of Class X SMA Negeri 1 Tayu, it is stated that students' concept understanding needs to be measured through project-based learning. Learning using the PjBL model can stimulate students' skills so that each project produced is expected to improve concept understanding and answer other important problems.

In order to understand the next concept, it is essential to understand the concept of Prerequisite Material. The cognitive process dimension encompasses the ability to process knowledge, with concept understanding representing a key aspect of this. Indicators of students' concept understanding can be measured at the levels of understanding (C2), applying (C3), analysing (C4), evaluating (C5), and creating (C6). Conceptual understanding involves mastering a variety of learning materials. Students who have conceptual understanding not only know and recognise concepts, but can also reexpress them in a more understandable way and apply them. According to [5], students are said to understand a concept if they can comprehend what they are learning and express it in their own words. Understanding the prerequisite concepts is essential for grasping subsequent ones. Additionally, these concepts can be used to explain an object.

Physics is a natural science that requires much understanding of the concepts that each student must learn. Physics must make students not only know and memorise physics concepts, but also make students understand and comprehend these concepts and connect the relationships of a concept with other concepts. Physics education is a learning process centred on understanding fundamental physics concepts, principles, and related phenomena. This process involves the exploration of these concepts through diverse instructional strategies such as experimental investigations, computer simulations, and various instructional media. The aims of physics education include fostering students' knowledge acquisition, enhancing conceptual comprehension, and developing analytical skills to interpret and engage with their environment effectively. Physics learning approaches aimed at connecting theoretical concepts with observable phenomena encourage students to actively engage with the material, resulting in improved analytical skills and environmental awareness [6], [7].

The current challenge in education is the need to keep pace with scientific developments and rapid technological advances. Information technology-based education in Indonesia is a means of preparing for the challenges of Industry 4.0, which continues to advance rapidly [8]. Implementation of technology is important for developing learning modules [9], [10]. Technology must be used in education to tailor learning to individual needs. The rapid digitisation of education is expected to produce proficient users of technology and information media, increasing competitiveness and survivability. Technology-based learning is now widely available. Google Sites is one of the educational websites that can be used to create interactive, web-based learning resources. Based on research conducted by which aimed to describe the use of Physics learning media in the form of web-based electronic modules using Google Sites on the subject of Static Electricity, the results obtained were that: 1) web-based Physics learning media using Google Sites on the subject of Static Electricity can be used to support online learning during the Covid-19 pandemic -19 pandemic to help students learn independently through Home-Based Learning (HBL), 2) this web-based Physics learning media using Google Sites is flexible because it can be accessed via smartphones, laptops, or tablets. In general, learning models through interactive learning media have been demonstrated to motivate students, thereby improving student achievement [11]. Google Sites is one of Google's products, which serves as a tool for the creation of websites. Such websites permit collaborative work at no cost. The learning materials provided can be in the form of text, images, and videos, allowing educators to vary the content.

Therefore, this study aims to analyse the effectiveness of a project-based learning e-module on global warming supported by Google Sites in improving conceptual understanding, as well as to analyse students' responses to the e-module used. This research contributes to the field of science education by providing empirical evidence of the effectiveness of digital, project-based learning tools in improving students' understanding of complex environmental issues. Additionally, integrating Google Sites as an interactive platform facilitates student engagement and accessibility, offering a practical model for incorporating technology into the learning process. These findings are expected to inform educators and curriculum developers as they design more effective and contextually relevant learning resources that promote active, meaningful learning experiences.

II. Methods

Research Design

A one-group pretest-posttest experimental design was used in this study to evaluate the effectiveness of e-modules in improving students' conceptual understanding. At the initial stage, a pre-test was administered to the students to measure their initial understanding. Subsequently, the e-module was implemented over several sessions. After the intervention, a post-test with the same level of difficulty was given to the students to determine any improvement in understanding. Data analysis was conducted by comparing the pre-test and

post-test scores, thereby determining the extent to which the e-module improved students' conceptual understanding. Additionally, data on students' responses to the use of the e-module were collected.

Participants

This study was conducted at SMA Negeri 3 Semarang in Semarang City. Cluster random sampling was used for the sample. The sample consisted of class X-11, which had 32 students. The study population was all students in the tenth grade.

Instruments

This study analysed data on the validity and reliability of the test instruments. The validity test results were evaluated using Aiken's V formula, as presented in Equation 1.

$$V = \frac{\Sigma s}{\left[n(c-1)\right]} \tag{1}$$

The validity of the test instruments is analysed in Table 1. Based on the analysis, two questions were invalid, and four had Aiken's V values equal to the table V; therefore, those questions were not used. Eighteen questions were deemed valid based on the calculation of Aiken's V values, with three representing each cognitive level according to Bloom's Taxonomy. The N-Gain test is then used to calculate the improvement in students' conceptual understanding. Here is the formula used to do that:

$$\langle g \rangle = \frac{\langle s_{\text{post}} \rangle - \langle s_{\text{pre}} \rangle}{\langle s_{\text{max}} \rangle - \langle s_{\text{pre}} \rangle} \tag{2}$$

III. Results and discussion

The e-module is a PjBL e-module supported by Google Sites. The PjBL model aims to maximise student activity and experience in the learning process. This aligns with Edgar Dale's Cone of Experience theory, which states that learners acquire knowledge more concretely through direct experience. Effective education requires a learning approach that can increase student engagement and deep understanding of concepts. In facing the challenges of 21st-century learning, the PjBL model has been proven to be one of the approaches that can actively develop students' critical thinking and collaboration skills. The use of educational technology, such as e-modules supported by the Google Sites platform, offers an innovative solution to support the flexible and interactive implementation of PjBL. This study aims to evaluate the effectiveness of implementing e-modules based on PjBL supported by Google Sites in enhancing students' conceptual understanding of global warming material.

The e-module consists of an introduction, learning content, and an evaluation. The introduction contains information related to the module. It includes the cover, foreword, table of contents, learning outcomes, learning objectives, and concept map. According to [12], learning modules must be packaged systematically and attractively; thus, the cover page design is an important part of module development. The learning section contains descriptions of the material for each subtopic, as well as project-based learning. This e-module's subtopics include facts about environmental change, the causes of global warming, and solutions to combat it. The material is presented in the first PjBL syntax: basic questions. Then, students are directed to design projects. The subsequent learning stages follow the PjBL syntax, including scheduling, monitoring project progress, assessing results, and evaluating experiences. The final section of the e-module is the evaluation section. The evaluation includes exercises and post-tests based on indicators of concept comprehension, such as interpreting, giving examples, classifying, summarising, concluding, comparing, and explaining. Since these indicators are in the C1 cognitive domain, the test instruments are developed up to C6 to improve students' understanding of concepts. The following is a detailed explanation of the e-module's structure.

The effectiveness of the implemented e-module was comprehensively evaluated through an analysis of the extent to which the predetermined research objectives were fulfilled, particularly focusing on the enhancement of students' conceptual understanding. This assessment employed validated test instruments designed to rigorously measure changes in students' comprehension levels before and after the intervention. By systematically comparing pre-test and post-test results, the study was able to quantify the efficacy of the e-

module in facilitating cognitive gains. Based on Anderson's theory, there are seven indicators of concept understanding, namely interpreting, giving examples, classifying, summarising, concluding, comparing and explaining [13]. The implementation of the product is carried out in three stages, namely pre-test, application, and post-test.

Table 1. Test instrument validation results

Question Item	Cognitive Level	V count	V table	Conclusion
1	C1	0.92	0.79	Valid
2		0.96	0.79	Valid
3		0.96	0.79	Valid
4		0.96	0.79	Valid
5		0.83	0.79	Valid
6		1.00	0.79	Valid
7	C2	0.88	0.79	Valid
8		1.00	0.79	Valid
9		0.88	0.79	Valid
10		1.00	0.79	Valid
11		0.75	0.79	Invalid
12		0.92	0.79	Valid
13	C3	0.96	0.79	Valid
14		0.96	0.79	Valid
15		0.96	0.79	Valid
16		0.88	0.79	Valid
17		0.83	0.79	Valid
18		0.83	0.79	Valid
19	C4	1.00	0.79	Valid
20		0.96	0.79	Valid
21		0.88	0.79	Valid
22		0.79	0.79	Valid
23		0.75	0.79	Invalid
24		0.92	0.79	Valid
25	C5	0.96	0.79	Valid
26		0.96	0.79	Valid
27		0.96	0.79	Valid
28		0.92	0.79	Valid
29		0.79	0.79	Valid
30		0.79	0.79	Valid
31	C6	0.96	0.79	Valid
32		0.92	0.79	Valid
33		0.92	0.79	Valid
34		0.92	0.79	Valid
35		0.92	0.79	Valid
36		0.79	0.79	Valid
Average		0.90	0.79	Valid

The initial stage of the research included a pre-test to evaluate students' initial understanding of the subject matter before implementing the PjBL instructional framework. Subsequently, a diagnostic assessment was conducted to ascertain individual learning styles, which informed the grouping strategy for collaborative project activities. Students then participated in the PjBL process, encompassing phases such as project planning, design, scheduling, monitoring, testing outcomes, and reflective evaluation. Upon completion of the instructional intervention, a post-test of equivalent difficulty was administered to measure the students' gains in conceptual comprehension. The efficacy of incorporating diagnostic assessments to tailor group dynamics and enhance collaborative learning outcomes in PjBL settings, particularly in physics education [14], [15]. The structured phases of PjBL are planning, monitoring, testing, and evaluation, as critical components contributing to significant improvements in students' conceptual understanding and skills development. The use of pre- and post-testing remains a validated approach to empirically assess learning gains attributable to PjBL interventions [14].

A paired-sample t-test was employed for inferential statistical analysis to compare pre-test and post-test scores and determine the significance of the observed learning improvements. Prior to analysis, a normality test was conducted to validate the assumption of normal data distribution, ensuring the appropriateness of parametric statistical methods. The outcomes of the normality assessment are detailed in Table 1, supporting the robustness and reliability of the subsequent analyses. This rigorous methodological approach strengthens the validity of the conclusions regarding the effectiveness of PjBL in improving students' conceptual understanding. The results of the normality test are presented in Table 2.

Table 2. Normality test results

	Shapiro-Wilk		
	Statistic	**df**	**Sig.**
Pre-Test	0.97	32	0.63
Post-Test	0.96	32	0.29

Table 2presents the outcomes of the normality assessment conducted on the students' pre-test and post-test scores. The analysis demonstrates that both datasets adhere to a normal distribution pattern. This conclusion is substantiated by the Shapiro-Wilk test results, where the significance value (p-value) exceeds the 0.05 threshold, indicating a failure to reject the null hypothesis of normality. Given this confirmation of normal distribution, the paired-sample t-test was subsequently utilised to compare the mean differences between the pre-test and post-test scores. The application of this parametric test is justified by the normality of the data, thereby ensuring the validity and appropriateness of the inferential statistical procedures employed. Recent literature affirms that the Shapiro-Wilk test remains a robust and widely accepted method for assessing data normality in educational research, particularly when sample sizes are moderate [16]. Table 3 systematically reports the detailed results of the paired sample t-test, including test statistics, degrees of freedom, and significance levels. This comprehensive analytical approach strengthens the reliability of the findings regarding the effectiveness of the intervention and underscores the methodological rigour of the study.

Table 3. Results of t-test

	Mean	**Lower**	**Upper**	**t**	**df**	**Sig. 2-tailed**
Pretest-Posttest	-34.79	-38.23	-31.35	-20.63	31	0.000

The statistical analysis presented in Table 3 reveals a statistically significant difference between students' pre-test and post-test scores, as indicated by a significance level (2-tailed) below 0.05. This result provides evidence that the intervention, specifically the implementation of the PjBL integrated e-module, has positively influenced students' conceptual understanding. After confirming the normality of the data using the Shapiro-Wilk test and validating the score differences through a paired samples t-test, further quantitative evaluation employed the normalised gain (N-Gain) metric to assess the extent of improvement attributable to the instructional approach. The N-Gain values, which adjust for pre-test baseline scores, offer a standardised measure of learning gains and are comprehensively detailed and interpreted in Table 4. Additionally, the descriptive statistics of students' pre-test and post-test scores are summarised in Table 5, providing a clear overview of students' performance before and after the instructional intervention. The analysis of normalised gain (N-Gain) offers a detailed insight into the efficacy of the e-module by emphasising both the statistical and pedagogical importance of the observed enhancements in students' knowledge acquisition.

The experimental findings clearly demonstrate that incorporating e-modules into the instructional process substantially improves students' conceptual understanding. Statistical analysis using a paired-sample t-test confirmed a significant difference in students' conceptual comprehension levels before and after the e-module intervention. These results suggest that the e-modules meaningfully impacted students' learning outcomes. To quantify the degree of improvement observed across various conceptual indicators, the study employed the normalised gain (N-Gain) metric. The resulting N-gain score of 0.59 is classified as a "medium" category, indicating a notable and educationally significant increase in students' overall understanding of the subject matter. These results validate the effectiveness of e-modules as a pedagogical tool and suggest their practical relevance in fostering deeper cognitive engagement and knowledge retention. Research by Fadillah et al [17] suggests that e-modules effectively foster significant improvements in students' conceptual understanding and cognitive involvement.

Table 4. N-Gain test results

	N	Minimum	Maximum	Mean
N-Gain	32	0.42	0.83	0.59
Valid N (listwise)	32			

Table 5. Summary of pre-test and post-test scores

Student	Pre-Test	Post-Test	Student	Pre-Test	Post-Test
S-1	42	71	S-17	38	78
S-2	33	71	S-18	53	58
S-3	36	76	S-19	62	80
S-4	40	80	S-20	31	71
S-5	38	76	S-21	38	76
S-6	27	58	S-22	44	82
S-7	40	78	S-23	22	76
S-8	47	69	S-24	40	80
S-9	42	80	S-25	56	71
S-10	31	64	S-26	40	76
S-11	18	58	S-27	31	62
S-12	29	64	S-28	47	71
S-13	31	60	S-29	22	78
S-14	20	78	S-30	40	67
S-15	33	91	S-31	36	78
S-16	29	80	S-32	44	76
			Average	**36.9**	**72.9**

The results of this study align with previous studies, indicating that PjBL provides opportunities for active learning, enabling students to build their own knowledge and learn more meaningfully. This has an impact on student learning outcomes. The more actively students learn, the more likely they are to achieve the learning objectives [3]. Based on research conducted by [18] which aimed to introduce the use of Physics learning media in the form of Google Sites-based electronic modules for the topic of Static Electricity, the following results were obtained: 1) Google Sites-based Physics learning media for the topic of Static Electricity can be used to support online learning during the Covid-19 pandemic to help students learn independently through Home-Based Learning, and 2) this Google Sites-based Physics learning media is flexible because it can be accessed via smartphones, laptops, and tablets.

The next phase of the study involved a thorough analysis of student responses regarding the development and implementation of the e-module in the instructional context. Data were systematically collected using a rigorously designed questionnaire consisting of fifteen statement items that encompassed three evaluative indicators: (1) student interest and engagement with the e-module, (2) the coherence and clarity of the material, and (3) the appropriateness and precision of the language used in the e-module content. The questionnaire was administered to a sample of thirty students at the conclusion of the learning sessions to ensure that the feedback was based on direct experience with the practical application of the e-module. The timing of data collection enabled a well-informed assessment of the module's practicality, encompassing factors such as usability and accessibility, alongside its overall effectiveness in facilitating the learning process. A summary of learner evaluation responses is presented in Table 4. These findings provide essential empirical evidence regarding the perceived value and operational feasibility of the e-module, forming a robust foundation for ongoing refinement and optimisation to improve educational outcomes. Recent research underscores the importance of evaluating e-modules on dimensions of practicality and effectiveness to ensure they meet learner needs and support independent learning [16], [19]. Studies employing rigorous evaluation frameworks, including learner feedback, report that such evaluations deliver critical insights into usability, accessibility, and learning impact, which are vital for iterative module enhancement [6]. This evidence-based approach to evaluation ensures that e-modules not only function well technically but also effectively support cognitive engagement and knowledge retention in physics education.

Table 6. Recapitulation of student questionnaires

Assessment Aspect	Total Scores	Maximum Score	Percentage (%)	Criteria
Interest	556	720	77	Practical
Presentation of Materials	558	720	78	Practical
Language Presentation	284	360	79	Practical
Average			78	Practical

Based on the data summarised in Table 6, the average percentage score obtained from the practicality assessment of the PjBL-based e-module was 78%, categorising the module as meeting practical criteria. This finding indicates that the PjBL-oriented e-module is not only feasible but also highly suitable for facilitating the enhancement of students' conceptual understanding within the learning process. The development of the e-module deliberately employs clear, accessible, and student-friendly language to ensure it is comprehensible to learners with diverse profiles. Furthermore, the content of the e-module strategically integrates physics concepts with everyday phenomena, fostering meaningful contextualisation that helps students connect theoretical knowledge with real-world applications. This pedagogical approach promotes cognitive engagement by enabling learners to relate abstract physics principles to familiar daily experiences, thereby enhancing deeper understanding and retention of the subject matter.

Recent studies support this approach. Research shows that e-modules designed with clear and straightforward language contribute significantly to ease of use and effective self-directed learning among students [20], [21]. Additionally, integrating physics concepts with real-life contexts has been found to increase students' interest and conceptual understanding by making the material more relevant and relatable [22]. This alignment with active learning principles also fosters higher-order thinking skills such as critical and creative thinking in physics education [23]. Therefore, an e-module designed with such clarity and contextual relevance not only facilitates conceptual comprehension but also strengthens critical thinking abilities and the capacity to apply knowledge to everyday life situations in physics learning. Collectively, these attributes underpin the practicality and educational value of the PjBL-based e-module as a practical instructional resource that aligns with contemporary constructivist learning paradigms and supports student-centred learning objectives.

IV. Conclusions

The results obtained from this study clearly demonstrate that the implementation of the e-module had a significant positive effect on students' conceptual understanding. Specifically, the gain value of 59% indicates a substantial improvement in students' comprehension of the subject matter after utilising the e-module. In addition to its effectiveness in enhancing understanding, the e-module based on the PjBL approach also received a favourable evaluation in terms of practicality. With a practicality score reaching 78%, the e-module meets the criteria required to be considered user-friendly, accessible, and suitable for integration into the learning process. These findings collectively suggest that the PjBL-based e-module is not only effective in supporting knowledge acquisition but also practical for implementation within educational settings. Therefore, this e-module serves as a valuable instructional tool that facilitates improved conceptual understanding among students while being feasible to apply in various teaching and learning contexts.

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