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Evaluating Project-Based Learning Success: Unveiling Insights through Supervised Machine Learning Assessment

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ABSTRACT

In physics education research, the success of implementing the project-based learning model is typically assessed based on students' learning outcomes. There are very few studies that specifically evaluate the success of implementing the project-based learning model in terms of the process. This is due to the difficulty of assessing the process itself. The aim of this research was to obtain information on the success profile of implementing the project-based Learning (PBL) model assessed using supervised machine learning. This research used a qualitative descriptive method. The subjects of the research were 60 undergraduate students at Jambi University. Data was collected based on the students' success in each stage of PBL. The stages of PBL include 1) project team introduction and planning; 2) initial research phase for information gathering; 3) creation, development, initial evaluation, and prototyping; 4) second research phase; 5) final development stage; and 6) publication of the product or artefact. Every stage of project-based learning is structured using supervised machine learning. This aims to facilitate students' direct involvement in project-based learning in supervised machine learning, enabling teachers to rapidly evaluate and give feedback. The success of project-based learning depends mostly on the precision of the students' group in project design, as indicated by studies. If the planning process is executed well, including tool and material selection, project execution procedures, and good design, students will have no challenges during the product creation stage.

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1. INTRODUCTION

The project-based learning approach (Project-Based Learning or PBL) has become a popular choice in the world of education. In recent years, innovation in learning at all levels of education has been directed towards project-based learning (Anazifa & Djukri, 2017). This is closely related to the country's goal of preparing students and learners to understand and possess the skills necessary to thrive and compete in modern life (Nugroho, Permanasari, & Firman, 2019). PBL allows students to engage in real projects that are relevant to their lives. Furthermore, project-based learning is also capable of developing high-order thinking skills (HOTs) required by students and learners in the future (Surjanti, Prakoso, Kurniawan, Sakti, & Nurlaili, 2022). PBL not only enhances students' understanding of concepts but also fosters their ability to think critically and creatively. By immersing students in hands-on projects, PBL equips them with the problem-solving skills needed to succeed in the ever-evolving workforce.

Project-based learning can be described as a form of learning that aims to enhance understanding of subject matter and develop general skills such as project management (Helle, Tynjälä, & Olkinuora, 2006). Integrating project-based learning into education provides students with authentic inquiry-based problem-solving experiences, allowing them to work independently and produce realistic products (Erdoğan & Dede, 2015; Kokotsaki, Menzies, & Wiggins, 2016). As they work on a project, students may face challenges that must be overcome before they can construct and showcase a finished product that answers the driving questions (Jaime et al., 2016; Wurdinger, Haar, Hugg, & Bezon, 2007). That's the reason many schools and educators choose to adopt this approach. Its dynamic and student-oriented nature can motivate students, develop critical thinking skills, and prepare them for success in the real world.

The success of implementing project-based learning is closely tied to the assessment process. Typically, instructors assess the success of project-based learning based on student learning outcomes, while researchers assess based on the specific abilities they aim to examine. For example, in the study by Nani & Kusumah (2015) that applied project-based learning to develop communication skills, the learning is considered successful if students' communication abilities improve. In the research conducted by Siew & Ambo (2018), which integrated project-based learning and STEM to enhance creativity, the learning was considered successful if the products produced by students met the desired criteria.

Very little research has found that directly and specifically assesses the process of implementing project-based learning within a learning process. This is due to the difficulty of conducting such assessments. Some assessments of project-based learning implementation are more general in nature. For example, in the study by Mustapha et al. (2020), the assessment of project-based learning implementation was based on student and observer perceptions using a CIPP-based questionnaire. Another study by Chen & Yang (2021) integrated IT into project-based learning for student reporting and monitoring of the learning process.

In several previous studies, the application of machine learning in the field of education has shown several advantages. Wang et al. (2017) demonstrated that machine learning can assist in adapting learning content and teaching methods to the needs of students. Siemens (2013) showed that machine learning can enhance teaching effectiveness by enabling instructors to adjust their teaching methods according to student needs. Furthermore, several other studies have indicated that machine learning can improve teaching efficiency by providing prompt feedback and suggestions for instructional improvement (Kanetaki, Stergiou, Bekas, Troussas, & Sgouropoulou, 2022; Sanusi, Oyelere, Vartiainen, Suhonen, & Tukiainen, 2022). It is a strength that machine learning can be one of the solutions that assist in the learning process.

Research on machine learning in education and teaching has attracted significant attention (Wu & Zheng, 2021). The abundance of imperfect applications, particularly in educational evaluation and teaching, makes it important to gradually improve the effectiveness of machine learning as part of the assessment process (Horanai, Maejima, & Ding, 2022; Wu & Zheng, 2021). Additionally, leveraging machine learning offers significant advantages in educational evaluation and teaching (Lokare, Kiwelekar, & Netak, 2022). The weaknesses of imperfect applications become gaps for novel development and further research.

To get an overview of the importance of this research, the researcher conducted a preliminary study using Vosviewer to identify the novelty gap of the upcoming research. A literature analysis was carried out on 400 reputable articles published from 2010 to 2020, with the analyzed topics consisting of 200 articles on project-based learning models and 200 articles on supervised machine learning. The results of the analysis of these articles are shown in Figure 1.

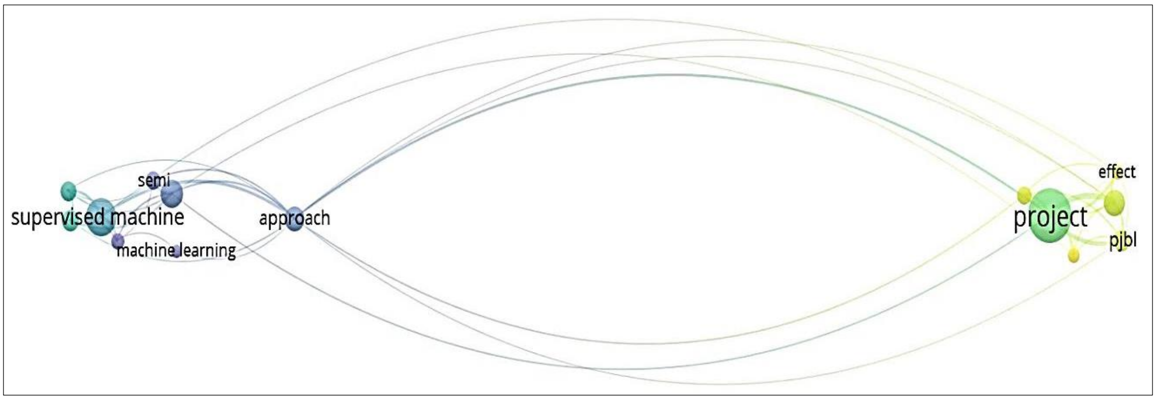

Figure 1. The relationship between supervised machine learning and PBL with several research topics

Figure 1 shows the overall structure of the relationships found in several previous studies related to project-based learning and supervised machine learning. If analyzed more specifically, no research has been found that applies supervised machine learning in assessing the success of project-based learning. Research on project-based learning mostly connects it with a specific learning approach. Based on the aforementioned issues, the objective of this research is to obtain information on the success profile of implementing the Project-based Learning model assessed using supervised machine learning.

To address the aforementioned issues and the limited direct research assessing the process of implementing the project-based learning model, an integration of project task assessment using supervised machine learning is conducted as an estimation of the success of project-based learning. The utilization of supervised machine learning has clear theoretical and practical justifications.

2. METHODS

This study employed a qualitative descriptive approach. The study involved 60 undergraduate students specializing in Physics Education at Jambi University. Students were separated into 20 groups, each comprising 3 pupils. Data was gathered according to the students' achievements at each phase of project-based learning. The stages of project-based learning are: 1) project team introduction and planning; 2) initial research phase for information gathering; 3) creation, development, initial evaluation, and prototyping; 4) second research phase; 5) final development stage; and 6) publication of the product or artefact (Anazifa & Djukri, 2017). The research included project activity material related to direct current electricity, a topic covered in the Basic Physics course.

Each step of project-based learning has been designed within supervised machine learning (Figure 2). This is aimed at enabling students to directly engage in the project-based learning process within supervised machine learning, allowing instructors to assess and provide feedback promptly. Assessing the success of implementing the project-based learning model is challenging. Typically, instructors and researchers rely solely on learning outcomes or assessments conducted by observers during the learning process. However, such assessments often result in multiple interpretations. The use of supervised machine learning seeks to mitigate these issues.

The data analysis in this study was directly performed within machine learning. The data analysis process follows the pattern outlined by Miles et al. (2014), which includes data condensation, data display/presentation, and drawing conclusions. Ultimately, the machine learning system will display the success percentage of each stage of the project-based learning process for each group.

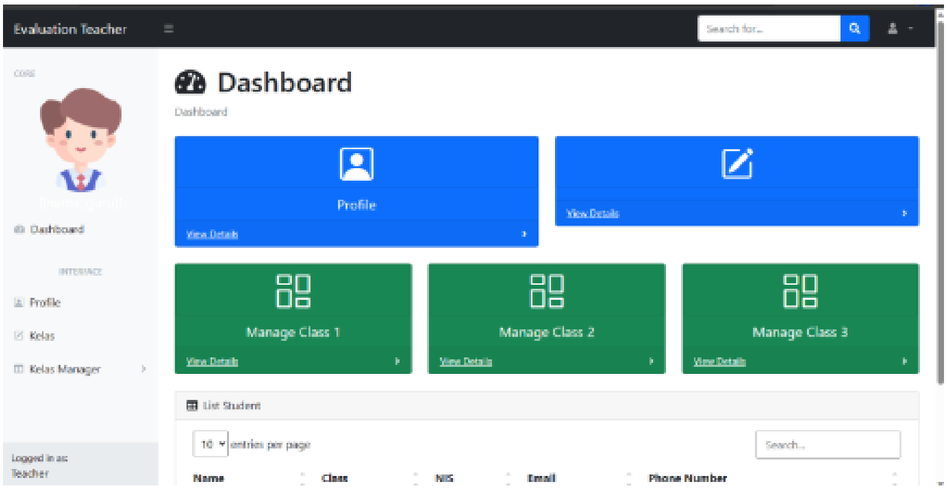

Figure 2. Display of supervised machine learning

3. FINDINGS AND DISCUSSION

3.1 Description of the Success Of Each Process in Implementing Project-Based Learning with Supervised Machine Learning Analysis

The success of learning is inseparable from the appropriateness of selecting the learning model and the success of knowledge transfer based on the chosen instructional steps. One learning model that can be considered as an alternative to traditional teaching models, where students are at the centre of the learning process, is the project-based learning model (Erdoğan & Dede, 2015). In general, project-based learning can be defined as a learning approach that allows students to gain a deeper understanding of the subject matter (Korur, Efe, Erdogan, & Tunç, 2017) and improve problem-solving skills (Johnson & Smith, 2008). Additionally, this model emerged from the societal need for preparing students for future competitiveness (Kapusuz & Can, 2014; Tekbıyık, Baran Bulut, & Sandalcı, 2022).

The results of this study in Figure 3 show the success percentage of each process in the project-based learning model applied to the concept of direct current electricity.

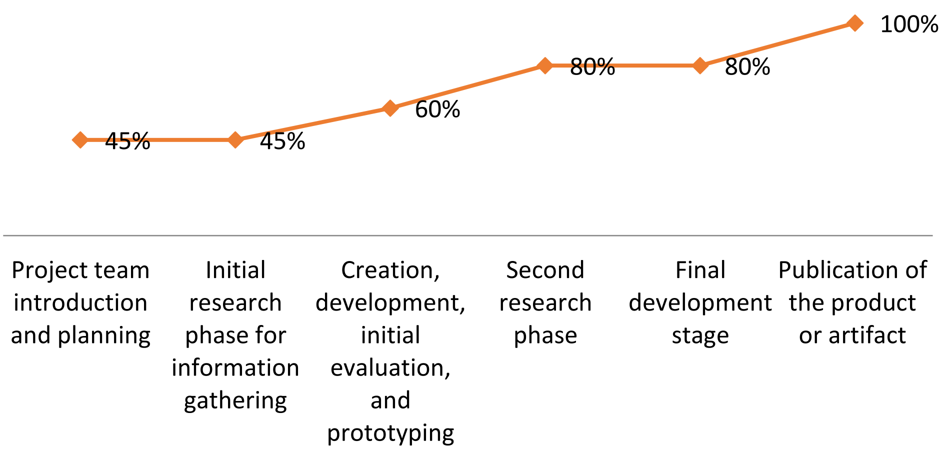

Figure 3. Percentage of success for each process in the implementation of the project-based learning model

3.2 Description of Findings at Each Stage of Project-Based Learning.

Students in the study were tasked with grasping the concept of direct current electricity through project-based learning. The learning process commenced with the instructor's demonstration and presentation of movies on the principles of current, voltage, resistance, and brightness of lighting in series and parallel circuits in real-life scenarios. During the demonstration, the instructor posed questions to the students as a component of the project team's introduction and planning phase. This interactive approach helped students actively engage with the material and apply their knowledge to practical situations. By encouraging critical thinking and problem-solving skills, the project-based learning method proved to be effective in enhancing understanding of direct current electricity.

There were four main questions posed, namely: 1) What kind of circuit is applied in home electrical installations?; 2) How does the brightness of a lamp differ when connected in series and parallel?; 3) What are the characteristics of current and voltage in series and parallel circuits?; and 4) How does the total resistance differ when connected in series and parallel?. The students were encouraged to conduct experiments to explore the answers to these questions and present their findings in a group discussion. This hands-on approach allowed for a deeper understanding of the concepts and practical applications of circuit theory. Through these experiments, students were able to observe firsthand the differences in circuit behavior between series and parallel connections. By actively engaging in the experimentation process, they were able to solidify their understanding of current, voltage, and resistance in circuits. This interactive learning experience helped them grasp the practical implications of circuit theory in real-world applications.

Based on the machine learning analysis results (Figure 3), it was found that the success rate in this stage is 45%. The findings indicate that students presented different hypotheses regarding the opening questions given by the instructor. For the first question, some students believed that the circuit applied at home is a parallel circuit because if one branch is open, it does not affect the other branches. Additionally, there were students who believed that the circuit applied at home is a combination of series and parallel circuits. For the second question, students answered that "lamps connected in series will shine brighter." This diversity in responses suggests a range of understanding among students when it comes to circuit configurations. Further investigation into the reasoning behind these hypotheses could provide valuable insights for improving teaching methods in this subject area. It is important for educators to address these misconceptions and provide clear explanations to ensure that students have a solid understanding of circuit configurations. By encouraging students to engage in hands-on activities and experiments, teachers can help reinforce concepts and clarify any misunderstandings.

Regarding the third and fourth questions, several students thought that: 1) the current is lower in a series circuit compared to a parallel circuit, 2) the current is lower and the resistance is higher in a series circuit. In a series circuit, the voltage is equal to the battery's voltage. However, in a parallel circuit, the voltage is distributed. Additionally, the overall resistance in a parallel circuit is lower. The results suggest that pupils have some remaining misunderstandings about direct current electricity concepts. It may be beneficial to provide further clarification on the differences between series and parallel circuits to help students grasp these concepts more effectively. Incorporating hands-on activities or demonstrations could also enhance their understanding of electrical circuits.

These findings are consistent with the results of several previous studies. Based on the findings of several studies, it has been shown that students experience difficulties in understanding the dynamic electricity material. The majority of students face challenges in sketching and interpreting circuit diagrams (Engelhardt & Beichner, 2004; Stetzer, van Kampen, Shaffer, & McDermott, 2013) and confusion in understanding the concepts of current, potential difference, and resistance (Kock, Taconis, Bolhuis, & Gravemeijer, 2014; Smith & van Kampen, 2011). Students believe that current and resistance are the main concepts, while voltage is considered a consequence of current and not its cause (Pfister, 2004). Furthermore, students also employ incorrect models regarding the concept of electric current, such as believing that the current decreases when passing through a resistor (Sangam & Jesiek, 2012).

After the demonstration and Q&A session, students proceed to the initial research phase for information gathering. In this process, guided by machine learning, students are asked to create project design drawings, determine the tools and materials to be used, and develop project activity steps. Each stage is filled out and uploaded into the machine learning system. An example of a student's design drawing is shown in Figure 4. Based on that design, students engage in creation, development, initial evaluation, and prototyping.

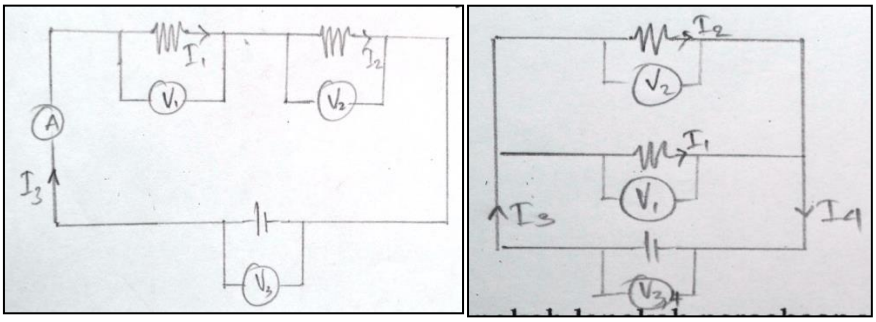

Figure 4. Student's project design

The findings from the initial research phase for information gathering indicate that the success rate in this stage is 45%. The main issue faced by students in this phase is difficulty in understanding the purpose and scope of the project to be carried out. This aligns with the results of several previous studies that explain how students may struggle to clearly comprehend the objectives of the project they are about to undertake (Afriana, Permanasari, & Fitriani, 2016). Additionally, determining a suitable and realistic project scope presents another challenge in the planning phase (Sormunen, Juuti, & Lavonen, 2020). Other research findings also explain that when projects are conducted in groups, students may face difficulties in collaborating and coordinating their work (Erdoğan & Dede, 2015; Mutakinati, Anwari, & Yoshisuke, 2018). This is what causes the success rate of students at this stage to be quite low.

Students make fewer errors in the creation, development, initial evaluation, and prototyping stages. Based on the results displayed in the machine learning system during the final stage, it is found that students have achieved a suitable understanding of the concept of direct current electricity (80%). Although 20% of students still obtained results that are not accurate or do not align with their initial planning, these errors did not significantly affect the discovery of the concept of direct current electricity. The success in this stage is essentially determined by several factors, such as understanding the requirements, planning and design, as well as group collaboration among students.

The use of machine learning as part of the implementation of project-based learning is highly appropriate. Machine learning is a data processing technique that enables computers to learn from data and experiences to improve performance in specific tasks (Lampos, Mintz, & Qu, 2021; Wu & Zheng, 2021). In education and teaching, machine learning is employed to create models and algorithms that can enhance the learning experience and improve student performance (Horanai et al., 2022; Sanusi et al., 2022). The important thing about Machine Learning is that it can help in the early detection of possible learning difficulties or developmental delays. By analyzing patterns of behavior and student achievements, the system can notify educators about the need for additional assistance or required interventions.

Several previous studies have applied machine learning to assist teachers and instructors in education. For example, machine learning can be used to gather information about individual learning needs and styles, enabling teachers to adjust their teaching methods more effectively for each student (Sanusi et al., 2022). Machine learning can also be employed to create models that predict students' future performance, allowing teachers and instructors to provide timely interventions and support to students in need (Horanai et al., 2022). Furthermore, machine learning can be utilized to organize student tasks and schedules, helping them manage their time and workload more efficiently (Chassignol, Khoroshavin, Klimova, & Bilyatdinova, 2018). This is the advantage of machine learning.

4. CONCLUSION

Based on the results of this research, the use of machine learning can detect early learning difficulties, perform automated assessments, conduct in-depth data analysis, and provide decision support. This research has limitations, where machine learning is specifically used to assess the success of implementing each step of project-based learning. Further development is needed to assess the students' and learners' proficiency in using machine learning, such as understanding concepts, critical thinking, and others. Additionally, future research could explore the effectiveness of machine learning in identifying specific learning disabilities and tailoring interventions accordingly. It is also important to consider ethical implications and potential biases that may arise from relying solely on machine learning for educational assessments.

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