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Project-Based Learning Approach in Autonomous Vehicle Course During Pandemic Outbreak: A Study Case

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ABSTRAK

Pandemi COVID-19 membawa dampak besar pada sektor pendidikan, termasuk perguruan tinggi, yang harus segera beralih dari pembelajaran klasikal ke pembelajaran daring. Pada program studi Teknik Elektro Universitas Sebelas Maret, salah satu tantangan utamanya adalah mencapai target output pembelajaran yang ditetapkan dalam mata kuliah, khususnya pada mata kuliah Kendaraan Otonom. Penelitian ini bertujuan untuk mengkaji implementasi pendekatan Pembelajaran Berbasis Proyek (PBL) dalam mata kuliah Kendaraan Otonom selama pandemi, serta memahami persepsi mahasiswa terhadap metode pembelajaran yang diterapkan, termasuk melalui pembelajaran daring dengan blended learning. *Penelitian menggunakan pendekatan studi kasus, di mana mahasiswa dibagi menjadi tiga kelompok untuk mengerjakan proyek simulasi kendaraan otonom menggunakan perangkat lunak Webots. Setiap kelompok menghadapi tantangan yang berbeda, seperti menghindari rintangan, menyalip kendaraan lain, dan parkir mandiri. Kuesioner digunakan untuk mengumpulkan data persepsi mahasiswa terhadap implementasi PBL. Hasil penelitian menunjukkan bahwa PBL berhasil diimplementasikan dengan baik pada mata kuliah Kendaraan Otonom, meskipun terdapat beberapa tantangan, terutama terkait durasi pengerjaan proyek. Secara keseluruhan, mahasiswa merasa bahwa metode ini efektif dalam meningkatkan keterampilan teknis dan soft skills mereka, seperti berpikir kritis, pemecahan masalah, dan kerja tim.*

ABSTRACT

The COVID-19 pandemic has had a major impact on the education sector, including universities, which must immediately switch from classical learning to online learning. In the Electrical Engineering study program at Sebelas Maret University, one of the main challenges is achieving the learning output targets set in the courses, especially in the Autonomous Vehicles course. This study aims to examine the implementation of the Project-Based Learning (PBL) approach in the Autonomous Vehicles course during the pandemic, as well as to understand students' perceptions of the learning methods applied, including through online learning with blended learning. The study used a case study approach, where students were divided into three groups to work on an autonomous vehicle simulation project using Webots software. Each group faced different challenges, such as avoiding obstacles, overtaking other vehicles, and self-parking. A questionnaire was used to collect data on students' perceptions of the implementation of PBL. The results showed that PBL was successfully implemented well in the Autonomous Vehicles course, although there were several challenges, especially related to the duration of the project. Overall, students felt that this method was effective in improving their technical and soft skills, such as critical thinking, problem solving, and teamwork.

1. INTRODUCTION

Since December 2019, the Covid-19 pandemic has spread all over the world. This has an impact on education, which was originally carried out classically, must change to online classes. The lecturers are required to quickly adapt to teaching methods and strategies in courses. Digital technology is being developed at an exponential rate and drove the industrial revolution 4.0 which changes many things in a plethora of things (Agustini et al., 2019; Kumar & Nanda, 2019). Industry 4.0 encompasses the digitalization of industrial production that will lead to fully intelligent, interconnected, and digitized production factories and organization activities (Anggraeni et al., 2019; Iyer et al., 2024). The industry 4.0 includes five main technologies and five emerging technologies. The leading technologies are the Internet of Things (IoT), big data analytics, cloud computing, 3D printing/additive manufacturing, and robotic systems. in contrast, the emerging technologies include machine learning, artificial intelligence, digital twin, blockchain, and 5G (Carayannis et al., 2022; Noura et al., 2019). This sort of thing happens a lot in higher education as well as at the corporate level. Industry 4.0 era, professional engineers, must be experts in terms of hard skills (technical knowledge and skills) and soft skills (critical thinking, teamwork, and creativity). An engineering graduate must possess both sides (hard and soft skills) in order to be competitive in the

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industry. Business skills and technical abilities in decision-making, problem-solving, and information analysis are crucial employability skills that these graduates must grasp in industry 4.0 (Fatimah & Santiana, 2017; Syaflin, 2022). The new literacy movement is intended to focus on three main literacies: 1) digital literacy, 2) technology literacy, and 3) human literacy. These three skills are predicted to be skills that are needed in the future or in the industrial era 4.0. (Shliakhovchuk, 2021; Yasdin et al., 2021). Furthermore, recognizing institutions also require graduate abilities such as (i) communication, (ii) teamwork, (iii) ethics and professionalism, (iv) lifelong learning, (v) problem solving, (vi) management, (vii) decision making, (viii) decision making, (ix) critical thinking, and (x) leadership (Suryawati et al., 2018).

The rapid-paced development of technology has to be corresponded by the transformation of the teaching-learning syllabus and pedagogy to accommodate future work needs (Liu et al., 2020; Mursyidin et al., 2022). At the present, higher education in engineering in Indonesia is seeking to implement Outcome-Based Education (OBE) in its curriculum. OBE is operated based on the student-center philosophy and focuses on the outcomes instead of the input (Aminuddin et al., 2021; Custodio et al., 2019). The implementation of OBE in engineering education is designed to reinforce the graduate's character needed in the engineering profession as a global and professional engineer. Currently, engineering higher education implements several learning methods to achieve the learning outcomes. The Universitas Sebelas Maret's Electrical Engineering Department has set up a program based on Project-Based Learning (PBL) and case method. The PBL approach provides the skills to pursue with life-long learning, to carry out teamwork, problems solving to real life problems (Boye & Agyei, 2023; Pecore, 2012). PBL's implementation is grounded in the requirement that engineering graduates possess technical and practical abilities. PBL adjusts the material that future engineers have to learn and develop the skills required for doing their job during the course (Harisantoso et al., 2020; Karnoto, 2022). One goals of PBL is to shape students to develop positive attitudes, critical thinking, independent learning skills, collaboration, and ability to solve real problems which contextually will be useful for the future. PBL is student-centered learning and student activity encourages the formation of small learning communities within the scope of the course (Harisantoso et al., 2020; Mohamadi, 2018). PBL allows for intense interaction outside of the classroom to collaborate and solve problems and complete projects.

In the last decade, there have been limited reports in Indonesia evaluating the application of project-based learning in engineering education. The Autonomous Vehicle course is a compulsory subject for the 6th semester (3rd year), especially for students in the Mechatronics Control (KM) concentration. This course is in the 2019 Curriculum of the Department of Electrical Engineering, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia (Pisarov & Mester, 2019). Robot engineering courses must have been taken to be able to take this course. This course is linked to a number of courses from the previous semester such as: robotics, programming, image processing and control systems. Three credits are available for this course, which meets once each week (Bosman & Fernhaber, 2019; Dopo & Ismaniati, 2016). The theory around the introduction of autonomous vehicles, ADAS, sensors, localization, navigation, and control architecture was covered in the lecture's first session. The second session is then utilized to discuss solutions to issues groups are having and speak with lectures about the status of weekly projects. In the end, student performance is assessed by the lecturer based on the following provisions: 30% midterm test, 30% final test, and 40% project/design assignment.

The Autonomous Vehicle course partially implements PBL through working on simulation design project assignments. Through this course, students can develop knolwedge and soft skills (critical thinking, problem solving, creativity, and teamwork) (Avando Bastari et al., 2021; Mun et al., 2022). Therefore, student's perceptions of the partial implementation of PBL in this course need to be known. This will be beneficial for improving the learning quality and curriculum in the future. The aim of this study is to examine the implementation of the Project-Based Learning (PBL) approach in the Autonomous Vehicles course during the pandemic. Furthermore, through a questionnaire, the study also looked into how the Project-Based Learning implementation in this class was perceived by the students. The novelty of this study is presents a unique approach by combining PBL with blended learning, particularly during the pandemic when traditional classroom learning was not feasible. The adaptation to online platforms and the structured teamwork with regular progress reporting set it apart from other studies that focused on singular learning methods during the pandemic.

2. METHOD

This study employs a case study research design, with a focus on the implementation of Project-Based Learning (PBL) in the Autonomous Vehicle course during the COVID-19 pandemic. The methodology integrates both qualitative and quantitative approaches to gather comprehensive data regarding the teaching methods and student experiences. The participants of this study consist of students enrolled in the Autonomous Vehicle course at the Department of Electrical Engineering, Universitas Sebelas Maret, during the 2019 curriculum. A total of three groups, each consisting of 3-4 students, participated in the study.

Data collection was carried out by a questionnaire to further explore the students' awareness of the PBL implementation in the course. The questionnaire has 16 statements that students must respond is show in Table 1. Four types of content from the questionnaire; course performance, PBL assignment, lecturer performance, and student performance that can be separated out.

Table 1. Questionnaire of Content

No	Questionnaire	Evaluation
1	The course learning outcomes are well-defined	Courses
2	PBL helps student achieve learning objective courses	
3	Acording from PBL gets new experience in learning process	
4	Evaluation of the implementation of the course provided beneficial results overall	
5	The Problems offered have variouss challenge to be solve	The PBL Assignment
6	The team give discretion to planning the project	
7	Meetings and weekly project reports with lecturers are beneficial for working on Project	
8	Project Assignments are sufficiently challenging and aligned with learning objectives	
9	Project Assignment have positive contribution in process learning in the course	
10	Project Assignment duration is sufficient	
11	The team are final the project on time	
12	The lecturer has carried out the lecture well	Lecturer
13	the lecturer gives pay attention at the PBL process to achieve the goal	
14	the lecturer provides constructive feedback according to group needs	
15	The output targets for project assignments and course learning outcomes can be met by students	Student Impact
16	Student will continuous improvement about soft and hard skill that achieves from the project	

Five categories of student replies to the survey were created: strongly agree (5 points), agree (4 points), neutral (3 points), disagree (2 points), and strongly disagree (1 points). Henceforth, Equation 1 is used to determine the overall score of each statement in the questionnaire. The sum of the points for each of the statements on the questionnaire was used to evaluate student comprehension. For this purpose, student's awareness is divided into 5 categories: (a) excellent (total points >4-5); (b) good (total points>3-4); (c) average (total points >2-3); (d) poor (total points >1-2); and (e) unsatisfactory (total points 0-1). Additionally, the average total points can be used to assess how well students understand the course performance, the PBL assignment, the lecturer, and themselves. Students can give any suggestions for improving the quality and performance of the class in the questionnaire. In the end, the assessment results, and recommendations from students through questionnaires were used as the basis for consideration to make continuous improvements in the implementation of the Autonomous Vehicle course.

3. RESULT AND DISCUSSION

Result

Project-based learning is mostly implemented in Autonomous Vehicle course through project/design assignments. The lecture begins with the formation of 3 teams consisting of 3-4 students, each team choosing one of the topics/problems offered by the lecturer. Each team determines the roles of its members based on the TOR (Term of Reference) provided. The role of the lecturer as the owner of the project who doubles as an education facilitator. For 3 weeks, each team worked independently divided into the stages of planning, preparation, and product presentation. Each of these stages is monitored by the project owner through weekly progress. The work generated on the Autonomous Vehicle project is shown in Figures 1.

Figure 1. Simulation Design of Product

Student responses were divided into five categories; strongly agree (5 points), agree (4 points), neutral (3 points), disagree (2 points), and strongly disagree (1 point). These responses of the students were presented in Figure 2.

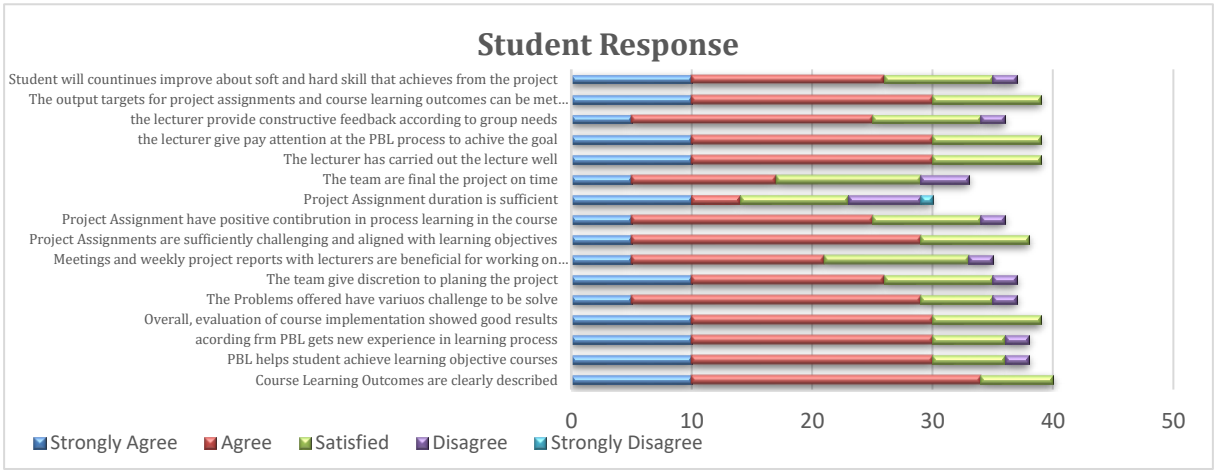

Figure 2. Student Responses

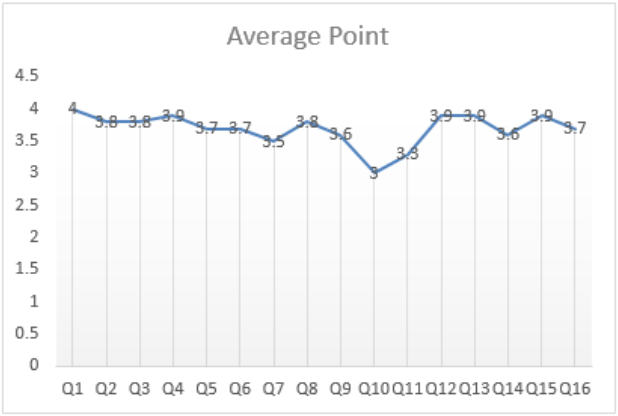

Figure 3. Total Points of Each Statement in the Questionnaire

Based on Figure 2 and Figure 3, the average total point, it was concluded performance of : course (Q1 - Q4) = 3,875; PBL (Q5 - Q11) = 3,5; Lecturer (Q12 – Q14) = 3,8; and Student (Q15 & Q16) = 3,8. All statement was at a good level, the minimum performance was good get point 3 on the statement about project duration. However, a closer examination reveals that there are still several areas in which it may be improved.

Discussion

Based on the research findings on the implementation of Project-Based Learning (PBL) in the Autonomous Vehicle course at Universitas Sebelas Maret during the pandemic, it was concluded that this approach was quite successful, although there are several areas for improvement. The study emphasized that PBL posed unique challenges for students, particularly in online learning with a blended learning method that combined online classes and partial teamwork (Dewanti, 2022; Sefriani & Sepriana, 2022). During the course implementation, students were divided into small groups to work on autonomous vehicle simulation projects using Webots software. Each team was assigned different problems and tasked with completing the project within the allotted time. These projects included features such as autonomous driving, obstacle avoidance, and automatic parking. Although there were limitations in terms of time and the need to deepen programming skills, the results of the projects were assessed to be at a good performance level, with some notes regarding the project duration and understanding of the software used (Ahdhianto et al., 2020; Frydenberg & Andone, 2011).

In terms of performance evaluation, the majority of students stated that PBL helped them achieve learning objectives and provided valuable new experiences. However, students offered several suggestions, including extending the project duration, introducing the software before the project begins, and implementing the project

directly using small hardware for a more hands-on experience (Aziz et al., 2016; Wajdi et al., 2022). Overall, the PBL approach in this course proved effective in helping students develop technical skills and soft skills such as critical thinking, problem-solving, and teamwork. Additionally, the results of student questionnaires indicated that this method can continue to be used and further developed in the future, including combining blended learning with classical classroom learning using hardware (Benli & Sarikaya, 2012; Suparno et al., 2019).

Several students mentioned that the time allocated for project work was insufficient. This aligns with findings from previous study who noted that students working on complex, real-world simulations often require additional time to fully explore problem-solving approaches and refine their work (Heo et al., 2015). The time constraint can hinder deep engagement with the material, limiting the development of both hard and soft skills that PBL aims to cultivate, such as critical thinking and creativity. Students suggested that using a small car in the project might provide more hands-on experience. Similar to the findings by other study hands-on projects using physical hardware can enhance students' understanding of complex concepts by allowing them to directly engage with the subject matter (Song, 2021). Physical models help bridge the gap between theoretical knowledge and practical application, which is a core benefit of PBL. Students requested more guidance on software usage before starting the project to avoid delays. Research by previous study also emphasizes the importance of equipping students with necessary technical skills before commencing projects, particularly in courses that integrate advanced software like Webots for autonomous vehicle simulations (Onori et al., 2018). A lack of proficiency in these tools can lead to time being wasted on learning basic functionalities instead of focusing on the project itself. The need for more focus on coding implementation was another suggestion. This is consistent with the findings of other study who highlighted that integrating coding skills into engineering education is essential in preparing students for the demands of Industry 4.0 (Kilis & Yildirim, 2019). Practical coding assignments not only reinforce technical skills but also help students understand the real-world applications of their projects.

This study demonstrates that the implementation of Project-Based Learning (PBL) in the Autonomous Vehicle course has been successfully conducted, especially under pandemic conditions where online learning was the only option. PBL has proven effective in enhancing students' technical skills in designing autonomous vehicle simulations using Webots software. Additionally, the PBL approach helps students develop soft skills such as critical thinking, problem-solving, creativity, and teamwork, which are crucial in the industry 4.0 era that demands a combination of technical expertise and soft skills. More broadly, this study supports the continued implementation of PBL in the post-pandemic era, where a blend of online and face-to-face learning could provide a richer learning experience, especially if supported by relevant hardware. This study has several limitations. First, the implementation of PBL was limited to software-based simulations, which may not fully replicate real-world conditions. The use of actual hardware (such as small cars) as a project medium could provide more practical and in-depth results. Second, the limited duration of the project was reported by some students as a constraint, potentially preventing the maximization of learning outcomes. Lastly, the use of Webots software requires advanced programming skills, but not all students have equal abilities in this regard, highlighting the need for additional guidance in programming to enhance the effectiveness of the project

4. CONCLUSION

Project-Based Learning has been implemented in part in the Electrical Engineering Courses at the Faculty of Engineering at Universitas Sebelas Maret for the 2019 Curriculum. Several courses are held with full or partial implementation of Project Based Learning, example for full PBL courses is Creative Project Courses 1 to 4. The Autonomous Vehicle course partially implements PBL through working on simulation design project assignments in pandemic outbreak. Through by online course, student can develop soft skill experience. Based on student perceptions questionnaire, it can be concluded that the course and simulation design project assignment is at a good level of performance with several notes to be an improvement. Otherwise, For the reason, it is concluded that the Autonomous Vehicle Course has been implemented well, when the pandemic was over, the method can continue be implemented blended with the classical room using the real hardware and the problems. This way hopefully can make the students get more experience.

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