Project-Based Learning in an Element Machine II Course: A Review

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ABSTRACT
The purpose of this paper is to review project-based learning (PjBL) methods as an effective pedagogy to improve the knowledge and skills of mechanical engineering students in engineering design components. The curriculum should integrate engineering knowledge and skills in design components and processes to produce engineers needed in the industry. In this paper, We reviewed that PjBL in engineering course offers an opportunity for students to experience engineering design components that are a real-world problems and practical knowledge. Students were asked to design a power transmission system for a coffee peeler machine on an Element Machine II course. Direct and indirect assessments were conducted to measure students' performance and perception using two categories: knowledge and skill. The results show that students had demonstrated ability in both cognitive and skill; otherwise, teamwork skill was still an issue. Results from the student perception show that there was a strong correlation (Pearson methods) between knowledge and skills with $p = 0.003$ and $r = 0.607$.

Keywords: *project-based learning, engineering education, engineering design component.*

1. INTRODUCTION

Engineering education nowadays has been transformed along with the development of technology. Technology is a product of engineering and science by manipulating and modifying all resources to make an easy living. Technology can also affect humans and other living things, including engineering industries. Thus, the requirements of the industries for engineering graduates also keep changing from time to time. They seek engineering graduates who have technical and non-technical skills to solve complex problems. Both skills cannot be created by traditional teaching methods, such as listening to lectures to prepare marketable engineering graduates.

Applying traditional teaching methods in engineering education focuses more on preparing engineering knowledge on students and is not preparing students in professional skills, generic skills, and personal skills. Engineering education at Universitas Andalas has prepared graduates with intricate knowledge (cognitive), professional skills, and soft skills in problem-solving, communication, teamwork, and ethics. The learning method is carried out traditionally to achieve both hard and soft skills, where the lecturer becomes the centre of learning by transferring knowledge to passive students. So far, students have gained more knowledge (cognitive) than professional skills and soft skills, both of which are very much needed in the workplace [1]. There is a gap between what students learn at university and what they need in the workplace with traditional learning methods today. In order to change these conditions, students are provided with the opportunity to participate in solving real problems and practical knowledge following professional skills in the field. One of the learning methods that can be used to achieve this goal is the project-based learning (PjBL) method. The research results conducted by Chen and Yang's (2019) [2] show that with this PjBL method, students are more involved in the learning process with real problems in the field. So this PjBL method positively influences student academic achievement compared to traditional methods. The purpose of this paper was to review achieved of student outcomes in the form of knowledge and skills through a project-based learning method in an Element machine II course.

2. PROJECT-BASED LEARNING

Project-based learning (PjBL) is an inquiry-based instructional method that involves students constructing their knowledge by completing projects or developing actual products in the field [3,4]. According to Krajcik and Shin (2014) [4], there are six advantages of PjBL, including questioning, focus on learning objectives, participation in educational activities, the collaboration between students, use of technology, and creation of tangible artefacts. Among all these features, students' creation of artefacts can solve authentic problems. The most important is that the PjBL method differs from other active learning methods, such as problem-based learning [5,6]. Creating this artefact requires students to work together to find authentic problem solutions by integrating knowledge, skills, and affective behaviour. Lecturers are only functioned as facilitators, providing feedback and support for students to assist the learning process. Several studies on PjBL discuss PjBL practices and the impact of PjBL on student learning [6].

Regarding practice, the authors found that most of the studies discussed were limited to course descriptions in terms of course scope, lecturer requirements, and group size. As for impact, the review found that only a few studies investigated the effect of PjBL on student learning in terms of cognitive (i.e., knowledge) or affective (i.e., motivation) outcomes. In another study, Ralph (2015) [7] reviewed fourteen studies that adopted PjBL in Science, Technology, Engineering and Math (STEM) education. It turns out that PjBL can improve the development of both knowledge and skills of students. Students also feel that PjBL encourages their collaboration and negotiation in groups. However, some students reported a lack of motivation for teamwork. Reis, Barbalho, and Zanette (2017) [8] reviewed PjBL studies in engineering education by adopting bibliometrics (i.e., keyword analysis) and classifying research methods from the studies reviewed. The bibliometric results show that, for example, the top three keywords used are a project-based learning, engineering education, and problem-based learning. The classification results reveal that more than 70% of studies that focus on the undergraduate level and case studies are the most frequently adopted research approaches. In addition, several studies have shown that students' academic knowledge, skills, and motivation improve after PjBL, although students also report PjBL difficulties (i.e., time-consuming).

3. METHODS

A project task was given to the students who took the course of Element Machine II in even semester academic year 2020/2021. The detail of the project task was to design a power transmission system of a coffee peeler machine. It consists of three main elements: hopper, hammer mill, and a blower. An engine powers it, and the engine's power will be distributed to the hopper, hammer and blower. Each team was asked to design a power transmission system consisting of the pulley, chains, and gears to transmit the power from the engine to the hopper, hammer mill and blower. All of the power transmission systems must be used. Each team has the main task of working and delivering an output that meets requirements. The requirements for each team were to sketch possible transmission systems that were used based on shaft-driven characteristics, select a power transmission system appropriately, choose the dimension of pulley and chains based on the data book, and design a spur gear system. Students must complete the project task in seven weeks.

The results of the design project of each team were measured by an analytic rubric that was designed based on the task's requirement criteria. The criteria consisted of knowledge and skills. The criteria for knowledge were to choose a transmission system, to choose belts and chains, sketch spur gear, design gear, and draw a design result of the power transmission system of a coffee peeler machine. The criteria for skills were teamwork, writing a report, and drawing mechanical drawings.

A cross-sectional study measured students' perception of achieving competencies (cognitive and skills) through the PjBL method. Data were collected from students who there were 49 students consisted of 9 females and 40 males. The students were eight groups, and each group consisted of 6 to 7 students. Due to the Covid 19 outbreak, each group discussed through the zoom platform.

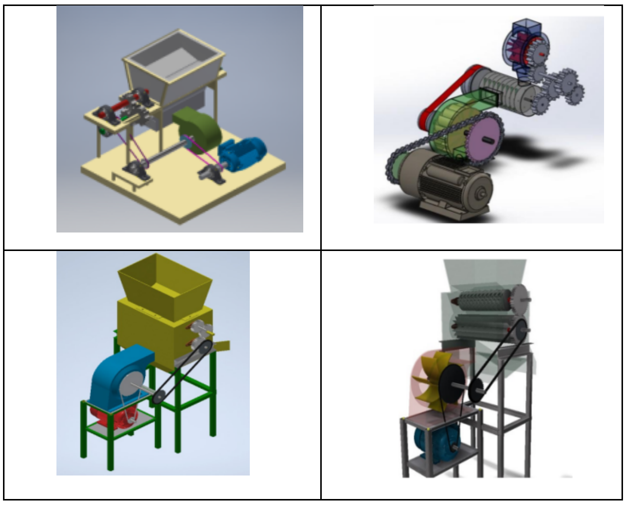

Figure 1 Some designs of the power transmission system of coffee peeler machine made by students

4. RESULTS AND DISCUSSION

4.1 Results

The target of the project task was each group asked to design a power transmission system of a coffee peeler machine. Some results of the project task conducted by students using the PjBL method can be seen in Figure 1. The figure shows that students had accomplished their project tasks very well. From the teaching method by using PjBL, students have demonstrated their ability to identify, formulate, and solve the problem to systematically design a power transmission system of a coffee peeler machine and deliver a good quality of output. The project task was to design a power transmission system consisting of the belt, chain, and gears.

The project task was assessed based on an analytic rubric developed by the lecturer with criteria consisting of both cognitive and skills. The results of the direct assessment are shown in Figures 2 and 3. Figure 2 shows the knowledge assessment results in applying theory to the problem. Most of the group showed their ability to choose power transmission system, belt design, and chain design in level excellent. Otherwise, most of the group had shown outstanding levels in sketching gear systems and designing gear.

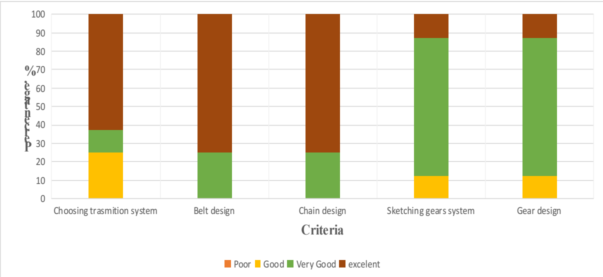

Figure 2 Direct assessment results of knowledge

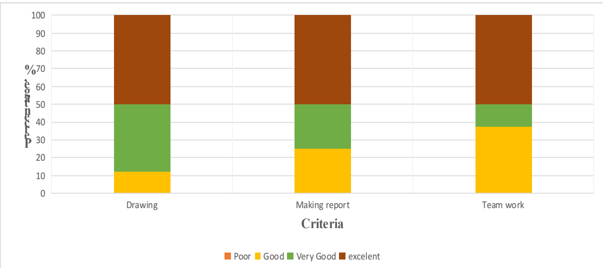

Figure 3 Direct assessment results of skills

Figure 3 shows the results of the assessment of skills which are consisted of mechanical drawing, making a report, and teamwork. Teamwork skill was the lowest achievement among the skills.

The indirect assessment was also conducted to measure students' perceptions outcomes. The survey was conducted using a structured questionnaire with nine questions to measure competencies with two dimensions: knowledge and skills to see the correlation between cognitive and skill among students. The students were asked to choose a number on a scale from 1-7: 1 as least agreement and seven as most agreement. The question asked, and the survey results are shown in Table 1.

The Pearson correlations method was performed to demonstrate the correlation between knowledge and skills. The results of the Pearson correlation method on knowledge and skills are shown in Table 2. Table 2 shows a strong correlation between students' knowledge and skills (p = 0.003) and a positive pattern (r = 0.607). It means that the higher students' level of knowledge, the better their skills.

Table 1 Questions and results of respondent's survey

Criteria for assessment	Competences	
	Knowledge	**Skills**
Does the PjBL method make students understand the topic of power transmission systems?	5.7	
Does the PjBL method able to select correct power transmission systems?	5.8	
Does the PjBL method able to choose pulley transmission appropriately?	5.9	
Does the PjBL method able to choose chains transmission appropriately?	5.8	
Does the PjBL method able to design and choose gears transmission appropriately?	5.8	
Does the PjBL method able to increase team works skills?		6.4
Does the PjBL method able teamwork in a team?		5.8
Does the PjBL method able to increase communication skills in a team quickly?		5.4
Does the PjBL method increase self-confidence in giving ideas and suggestions to the team?		6.1

4.2. Discussion

Application of the PjBL method on an Element Machine II course reinforces the theoretical concepts of the course with practical experience of students through the real problem. Students enjoy the course in implementing the theoretical aspect in the project, and easy to link the experiential practice to the theory in the course. The students get experience reading data books of belts and chains and applying them for their task.

Table 2 Correlations between knowledge and skills

		Knowledge	Skills
Knowledge	Pearson Correlation	1	.607(**)
	Sig. (2-tailed)		.003
	N	49	49
Skills	Pearson Correlation	.607(**)	1
	Sig. (2-tailed)	.003	
	N	49	49

** Correlation is significant at the 0.01 level (2-tailed).

The skills of students develop and link to outcomes of ABET, namely: to function on teamwork, to identify, formulate, and solve engineering problems, and to communicate effectively. The design component machines skills of students increase through this teaching method. Students work in a team in order to enforce their working skills. They are also to submit one joint report for the project and to do a group presentation. Then, each group must make a mechanical drawing for their design in the report. They used mechanical drawing software to increase their engineering tools in drawing. These activities could also increase communication skills in oral and writing. According to Kuppuswamy and Makhure [9], the PjBL approach through experience engineering design is beneficial for students. When they work in the industry, they will practice and simulate their skills.

Teamwork skills had become an issue. Some group members ran well, but some struggled to form a good team. 85 % of respondents agreed that they could deliver the project task very well from the survey. Only 15 % of them were not sure they delivered the task very well. The problems faced by the group not delivering the task very well were not the only limitation of their knowledge but also technical problems they found as long as group discussion. Some group members had difficulty understanding the theory, and some of them said that they were difficult to discuss in zoom flat form due to lost signal, etc. As long as Covid 19 outbreak, the problems faced students who live in a rural or remote area and outreach of signal telecommunication of provider. This situation was a challenge in the implementation PjBL approach in the engineering design course. Time management is crucial for a successful project task where the team must stick to a time slot and concentrate on the project's main point [10].

5. CONCLUSION

The PjBL method on an Element Machine II course is driven by the end product that each group wants to produce, and the main focus is given to the whole production process. PjBL begins with an assignment to carry out one task that emphasizes the development of engineering skills by providing real-life engineering practice that produces a final product. The PjBL approach motivates students to learn based on actual problems in the workforce, and it will have a clear picture of what an engineer does.

PjBL approach provides students with problem-solving where students work in groups, solve the real problem, and implement the theory in practical work. So, students' knowledge and skills would increase as long as the project is done in groups. Knowledge in sketching gear systems and designing gear was lower than others. Besides, writing reports and using engineering tools when using mechanical engineering drawing software could also increase. Otherwise, teamwork skill was the lowest achievement among the skills.

From the student perspective, there was a strong correlation between knowledge and skills (Pearson method) with $p = 0.003$ and $r = 0.607$.

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