Project-Based Learning in Civil Engineering: Experience from the Steel Structure Design Course at Universitas Sebelas Maret, Indonesia

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Abstract

Professional engineers in the Industrial Revolution 4.0 era are required not only to master the hard skills which involve technical knowledge but also the soft ones such as critical thinking, creativity, and teamwork. Therefore, engineering education is expected to have a curriculum designed to ensure graduates have acceptable quality in the fast-growing industrial world. Moreover, classroom learning is also expected to ensure every student develops these skills, and one of the methods to achieve this is Problem-Based Learning (PBL). This study was conducted to show the experience of the PBL implemented for the Steel Structure Design course at the Department of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret, Indonesia. The students taking the course are allowed to gain professional experience by working on a two-story steel building design project which was designed with real-life conditions. This involved having a team of 4 students acting as a consulting firm while a Term of Reference (TOR) is provided by the lecturer acting as the Project Owner. This consulting firm works on the project to produce technical calculation reports, structural drawings, and budget plans as well as weekly progress reports to the Project Owner. Furthermore, the perceptions of the students concerning the PBL implementation were further investigated through a questionnaire and the results showed they are satisfied with the PBL. This is indicated by the course performance and project/design assignments found to be at a very good level as well as the good performance recorded by the lecturers and students. It was, therefore, recommended that PBL should be applied to other relevant courses.

Keywords
Engineering Education, Civil Engineering, Project-Based Learning, Steel Structure Design Course

1. Introduction

The exponential development of digital technology is driving Industrial Revolution 4.0 and changing several activities (Das et al., 2020). This is indicated by the recent digitization, automation, and use of information and communication technology such as the industrial internet, future factories, internet of things, physical internet, internet of services, and cyber-physical systems. These are induced by the industrial revolution 4.0 to achieve a high degree of flexibility in production, higher productivity rates through real-time monitoring and diagnosis, and a lower wastage rate for materials in production (Alaloul et al., 2020). Moreover, there is also a widespread integration of technologies such as artificial intelligence (AI), robotics, advanced materials, and additive manufacturing (Lorenz et al., 2015, Schwab, 2016, and Hadgraft & Kolmos, 2020). This phenomenon is, however, not observed only at the industrial level but also in higher level of education.

Professional engineers are presently required not only to master the hard skills which include technical knowledge but also the soft ones such as critical thinking, creativity, and teamwork which are both needed by engineering graduates to compete in the job industry. Some of the employability skills required to be mastered by these graduates include (i) digital technologies for the acquisition, processing, and analysis of data which stimulates the development of sustainable construction, (ii) management of construction waste, (iii) energy efficiency, and (iv) exploitation, management and renovation of buildings, facilities, monuments, and cultural heritage (Ivanov et al., 2020). Moreover, the accreditation of institutions also requires the graduates have certain abilities such as (i)

communication, (ii) teamwork, (iii) ethics and professionalism, (iv) lifelong learning, (v) problem solving, (vi) management, (vii) decision making, (viii) critical thinking, and (ix) leadership (Kamaruzaman et al., 2019).

The fast-paced development of technology requires the transformation of the teaching-learning syllabus and pedagogy to accommodate future work needs (Zabidin et al., 2019). Therefore, engineering higher education in Indonesia is currently seeking to implement Outcome-Based Education (OBE) in its curriculum. This system is run based on the student-centered learning philosophy and focuses on the outcomes instead of the input (Rajaee et al., 2013). Moreover, the implementation of this OBE is aimed towards strengthening the character needed in the engineering profession to produce a global and professional engineer (Shaheen, 2019).

It is important to note that engineering higher education is currently making use of several learning methods such as Project-Based Learning (PBL) to achieve the desired learning outcomes. The PBL is established on the fact that engineering graduates are required to have technical and practical skills. It was initially implemented in the whole medical education curriculum in 1969 at McMaster University, Canada (Noordin, 2011) and later adopted in engineering higher education due to the close relation of problem-solving mechanisms to project works (Silva et al., 2012). This is to ensure future engineers learn and develop the skills required to perform their profession during the learning process (Coronado et al., 2021). PBL has, therefore, been globally implemented in civil engineering education as indicated in Brazil (Silva et al., 2012), Ireland (Gavin, 2011), Hong Kong (Kwan, 2016), India (Devi, 2017), United Arab Emirates (El-Maaddawy et al., 2018), Qatar (Naji et al., 2020), Tunisia (Belgasmi et al., 2020), Spain (Miranda et al., 2020), Netherland (MacLeod & van der Veen, 2020), and Norway (Lassen et al., 2018).

There are limited reports in Indonesia over the last decade prepared to evaluate the implementation of project-based learning in engineering education, particularly in civil engineering. Some of them only showed its use in vocational education (Syahril et al., 2019 and Indrawan et al., 2020). This means there is a need to understand the success stories, implementation methods, and evaluation of the implementation of this learning method in civil engineering education. Therefore, this study was conducted to assess the PBL experience in the Steel Structure Design course at the Department of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret, Indonesia, and also to investigate the student perceptions of PBL implementation.

2. Course Description

The Steel Structure Design is a compulsory course for students in their 6th semester or 3rd year according to the 2016 Curriculum of the Department of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia ("Curriculum book of civil engineering program Universitas Sebelas Maret," 2016). The course is related to several courses in the previous semester such as the Introduction to Civil Engineering, Engineering Drawings, Computer-Aided Design (CAD), Structural Analysis with Matrix Method, Construction System and Management, and Steel Structure.

The course is formulated to expose students to professional experience in working on a two-story steel building design project ("Semester lesson plan of Steel Structure Design Course", 2020) which is designed to resemble real-life conditions. The students are usually required to form a team consisting of 4 students to act as a consulting firm while a Term of Reference (TOR) is provided by the lecturer acting as the Project Owner ("Term of reference Steel Structure Design Courses", 2020). The project/design assignment specifically consists of 2 work packages which are the structural and creative design aspects. The structural design aspect requires each Consulting Firm to work on the project and produce technical calculation reports, structural drawings, and budget plans while the creative design aspect requires them to provide only a conceptual design in 3D drawings.

This course has 4 credits and is usually held 2 times a week with the first session focused on structural design theory while the second session is for consultation with lecturers regarding weekly project progress and discussing solutions to problems faced by the groups. The performance of the students is usually assessed by the lecturer using 30% for midterm examination, 40% for the final examination, and 30% for project/design assignment. Moreover, the 2016 Curriculum has not fully accommodated PBL (Project Based Learning) in its structure but it is partially implemented in several courses such as Irrigation and Waterworks, Foundation Engineering, Highway Pavement, Highway Geometry, Concrete Structure Design, and Steel Structure Design ("Curriculum book of civil engineering program Universitas Sebelas Maret," 2016). The project/design assignments indicate the partial implementation of this learning method in the Steel Structure Design course. This helps the students develop both hard and soft skills

and this is the reason it is important to understand their perception of the PBL in order to improve learning quality and curriculum in the future.

3. Method

The perceptions of the students concerning the PBL implementation in the course were further investigated through a questionnaire which contains 15 statements as indicated in Table 1. The content of the questionnaire was also divided into 4 categories in relation to the performance of the course, project/design assignment, lecturer, and student.

Table 1 Questionnaire Content

	Questionnaire Content	Categories
1	Course Learning Outcomes are clearly described	Course Performance
2	Courses taken by the students in the previous semester are useful in working on Project/Design Assignment in this course	
3	PBL is in accordance with learning outcomes and Project/Design Assignment	
4	Overall evaluation of course implementation showed good results	
5	Project/Design Assignment Outcomes are clearly described in the TOR (Terms of Reference)	Project/ Design Assignment Performance
6	Project/Design Assignment contributes positively to the learning process	
7	Project/Design Assignment have a sufficient level of difficulty and are in accordance with learning outcomes	
8	Project/Design Assignment duration is sufficient	
9	Consultations with lecturers and weekly progress presentations are useful for the Project/Design Assignment	
10	Project/Design Assignment is useful for students in the future	
11	Overall evaluation of Project/Design Assignment implementation showed good results	
12	The lecturer delivered the lecture effectively	Lecturer Performance
13	The lecturer held a lecture in line with the Course Learning Outcomes and Project/Design Assignment output targets	
14	Students follow the course well	Student Performance
15	Students have the ability to achieve the Course Learning Outcomes and Project/Design Assignments output targets	

The responses of the students to the questionnaire were divided into 5 categories which are (a) strongly agree (5 points), (b) agree (4 points), (c) neutral (3 points), (d) disagree (2 points), and (e) strongly disagree (1 point). Therefore, the total point of each statement in the questionnaire was calculated using Equation 1.

$$P = \sum_{i=1}^{n} \frac{(n_i . w_i) + (n_{i+1} . w_{i+1}) + \ldots + (n_n . w_n)}{n_t} \quad \ldots (1)$$

where,

P = the total point of each statement in the questionnaire
n = number of students or respondents according to the response given (Strongly agree, agree, neutral, disagree, strongly disagree)
n_t = total number of students or respondents
w = points according to the response provided by the student
5 points for strongly agree
4 points for agree
3 points for neutral
2 points for disagree
1 point for strongly disagree

Total points of each statement in the questionnaire were used to evaluate the student perceptions based on 5 categories which include excellent for total points >4-5, good for >3-4, average for >2-3, poor for >1-2, and unsatisfactory for 0-1. Moreover, the average total points were used to evaluate the student perceptions of the performance of the course, project/design assignment, lecturer, and student. This value was calculated using Equation 2.

$$\bar{P} = \sum_{i=1}^{n} \frac{(P_i) + (P_{i+1}) + \ldots + (P_n)}{n_P} \quad \ldots (2)$$

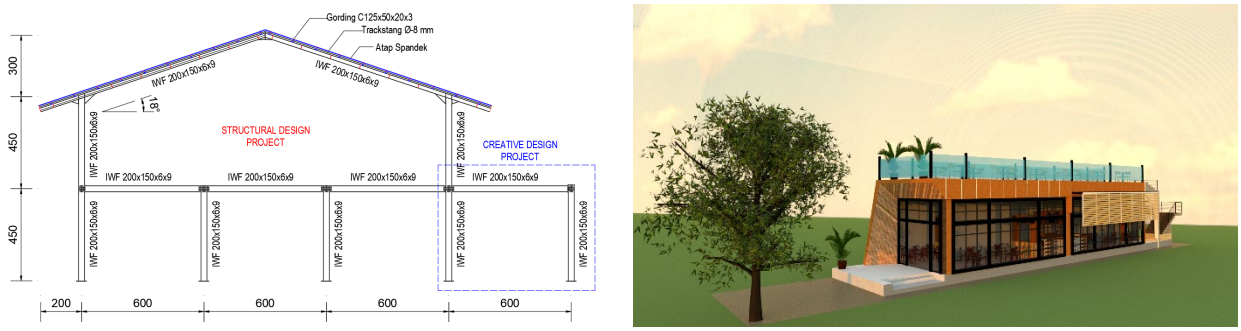
where,

$\bar{P}$ = average total point of each statement in the questionnaire
P = total point of each statement in the questionnaire
n_P = total number of P according to questionnaire categories

The students were also to provide several suggestions to improve the quality and performance of the class in the questionnaire and their responses were later used as the basis to consider in making continuous improvements to the Steel Structure Design course.

4. Results and Discussion

The Steel Structure Design course partially implements PBL through the project/design assignments where the students are required to form a team consisting of 4 individuals to act as a Consulting Firm while a Term of Reference (TOR) is provided by the lecturer acting as the Project Owner. Figures 1(a) and (b) show one of the structural and creative design projects conducted by a Consulting Firm.



(a) (b)

Figure 1 Design product for (a) structural design project and (b) creative design project by the students

The responses of the students presented in Figure 2 also showed that almost all of them represented by 15%-72% strongly agreed and 23%-62% agreed with the statements in the questionnaire. Furthermore, the data obtained were used to determine the total and average total points for each statement using Equations 1 and 2 respectively, and the results are presented in Figure 3.

The average total point presented in Figure 4.3 showed the performance of the course and project/design assignment was excellent while the lecturers and students showed a good level. Moreover, the minimum performance was discovered to be good as indicated by the total point which is less than 3. This, therefore, means the Steel Structure Design course has been implemented effectively based on the assessments of the students.

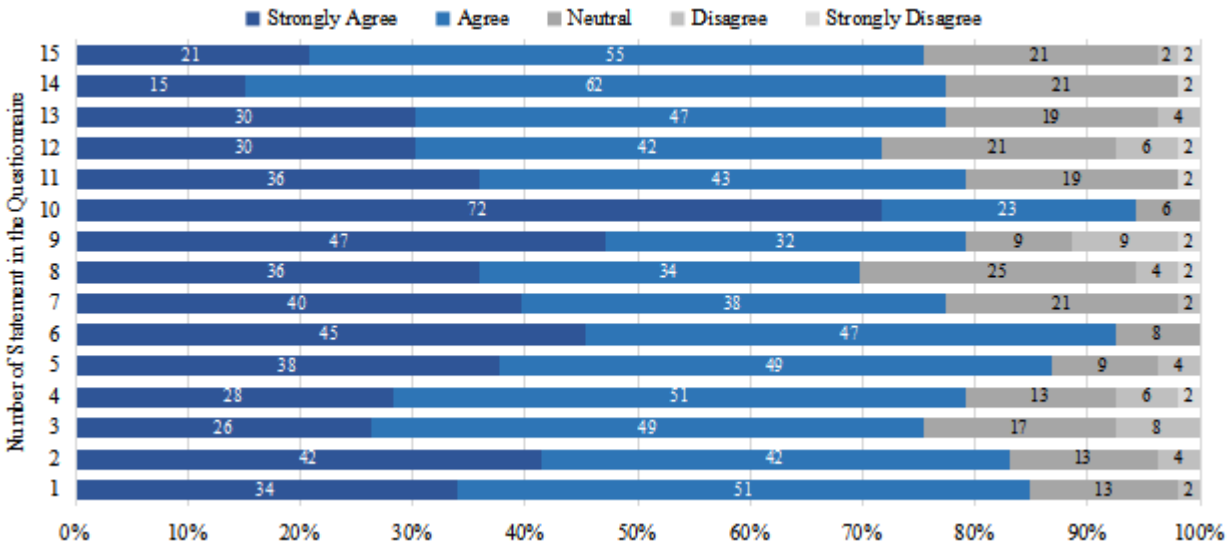


Figure 2 Student Responses' Percentage

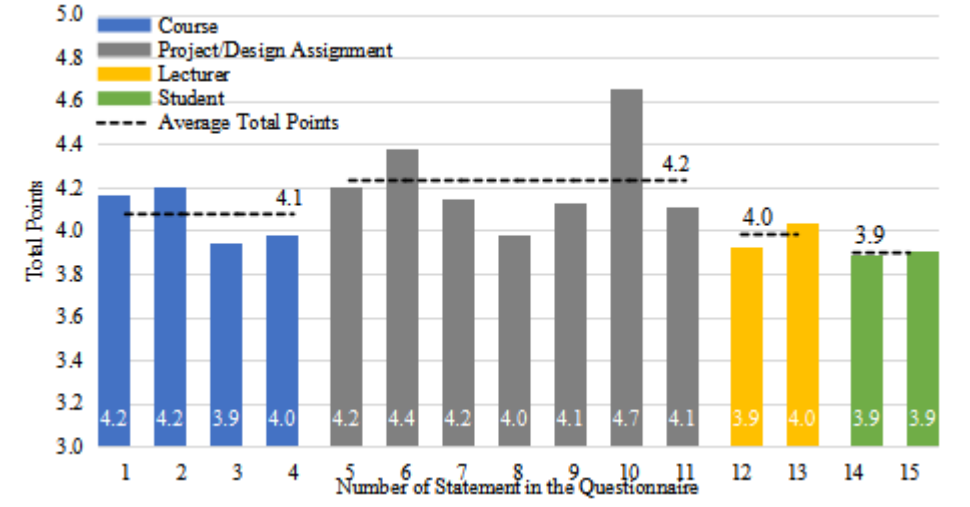


Figure 3 Total and Average Total Points of Each Statement in the Questionnaire

Further review based on the suggestions provided by the students showed there are other things to be improved to ensure quality and some of them include the following:

a. The use of design examples in lectures to make students understand the design theory easily
b. Explanation of workflow to make the students do the project/design assignment well
c. Provision of technical calculation reports, structural drawings, and budget plans documents examples to make the students have an idea of the outputs required from the assignment
d. BIM software utilization in projects/design assignments to keep up with the development of the construction industry
e. Industrial exposure improvement through field trips, case study projects, and collaboration with practitioners
f. Student participation improvement
g. Improving the course material quality through the utilization of structural modeling software tutorial, 3D drawing, and lecture video
h. Improving the learning methods quality through interactive lecture, increased consultation time with lecturers, and competent assistant involvement

i. The lecturer should give feedback to project/design assignment
j. Increment in the work duration for projects/design assignments

5. Conclusion

The Department of Civil Engineering, Faculty of Engineering, Universitas Sebelas Maret has not fully accommodated the PBL (Project Based Learning) in its curriculum structure but partially implements the learning method in some of its courses such as the project/design assignments in Steel Structure Design. This was directed to assist the students in developing both hard skills such as technical knowledge and skills as well as soft skills such as critical thinking, creativity, and teamwork.

The student perceptions assessed through questionnaires showed the performance of the course and project/design assignment is at an excellent level while those associated with the lecturers and students showed a good level. Therefore, the Steel Structure Design course was found to have been effectively implemented from the student's perspective. It is, however, important to note that it is not easy to implement PBL in the curriculum but its partial implementation in the Steel Structure Design has shown positive results. The learning method is, therefore, recommended to be applied to other relevant courses.

Acknowledgments

This research was financially supported by the Faculty of Engineering, Universitas Sebelas Maret, Surakarta, Indonesia. The authors also appreciate all the respondents and the administrator of the Civil Engineering Department for their support.

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Biographies

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Siti Nurlita Fitri completed her undergraduate degree in the Civil Engineering Department, Sepuluh Nopember Institute of Technology (ITS) in 2016 and continued with the Magister of Geotechnical Engineering, Civil Engineering Department, Sepuluh Nopember Institute of Technology (ITS) in the same year and graduated in 2018. This author worked on several projects related to geotechnical engineering and foundation analysis in ITS between 2016-2018 and also as a lecturer at Sebelas Maret University in 2019. Her interests are in geotechnical engineering, soil improvement, landslide, and engineering education.