

Implementation of Project-Based Learning in System Modelling and Analysis Course

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Abstract

In preparing graduates to cater demands in industry, 21st Century Skills has been embedded in curriculum. To develop the 21st Century Skills among electrical engineering students, Project-Based Learning (PjBL) has been introduced to the electrical engineering students in System Modelling and Analysis Course. Previously, students are given exercises taken from textbooks and other references only. When PjBL is implemented, it contributes to introducing students with real-world problem setting and empowering students' cognitive abilities. This paper discusses how the real-world problem is developed for the System Modelling and Analysis Course and how PjBL is implemented in the course. Jigsaw was used with the implementation of PjBL to introduce cooperative classrooms and to improve students' social skills. The real-world problem developed in this PjBL is the ship-to-shore (STS) crane system. The implementation impact was discussed based on students' reflection and the Course Learning Outcomes (CLOs) achievements. Overall CLOs achievement were above the key performance indicator. In addition, students gave positive feedback on this implementation. In conclusion, PjBL can be implemented to improve self-regulated learning among the students in order to supply them with the 21st Learning Skills.

Keywords: Jigsaw, Project-Based Learning, Self-Regulated Learning, Student-Centred Learning

Introduction

The Malaysian Higher Education has proposed an Education 4.0 framework in line with the 4th Industrial Revolution (4IR). This framework is aimed to supply graduates with the capabilities and competencies required by the demanding industry. The themes of the Education 4.0 Framework are knowledge, industry and humanity with the principles of redesigning of learning spaces, incorporation of the 21st learning pedagogies, applying fluid organic curriculum, responding to innovations and new area of knowledge and incorporation of the latest learning and teaching technologies (Rasika Lawrence, Lim Fung Ching, & Haslinda Abdullah, 2019).

In Malaysia, graduates lack of critical thinking, communication skills and language proficiency especially in English (Executive Summary: Malaysia Education Blueprint 2015-2025 (Higher Education)). The skills are crucial for success in the 21st century. Therefore, experiential learning-based which is part of Education 4.0 is essential to be incorporated in engineering courses to prepare the engineering graduates towards IR4.0.

Constructivism is a theory in pedagogy on how people learn. Constructivism scholars such as John Dewey and Jean Piaget believe that people construct their understanding and knowledge through experiencing and reflecting those experiences. One of

the experiential learning is the Project-Based Learning (PjBL) founded by John Dewey in 1897. In PjBL, Piaget focused on the intellectual or cognitive development while Vygotsky emphasized on the social environment (Ramlee Mustapha, Sadrina, Irdyanti Mat Nashir, Mohamed Nor Azhari Azman, & Khairul Anuar Hasnan, 2020). Due to that, certain educators implemented pure constructivism while certain others used both approaches (pure constructivism and social constructivism) in their classroom setting.

Five criteria of PjBL has been discussed in (John W. Thomas, 2000) as shown in Table 1.

Therefore, by implementing PjBL, it is assumed that it can support the course contents with actual industrial problems and environment. Based on the theory, it believes that PjBL is able to enhance students' understanding which consequently helps to increase the performance index of course learning outcomes (CLO) compared to the traditional lecture (Marini, 2016). Furthermore, this method has gained a lot of attention from the academic community mainly in delivering the content of engineering courses.

Cooperative learning (CL) is one of the student-centred learning (SCL) strategy. According to (Keyser, M. W., 2000), cooperative learning needs advance planning, appropriate sizes of group, assigned roles for each member and how the results will be evaluated. Based on the CL criteria, it is chosen to be integrated with PjBL in order to have systematic way to scaffold students understanding and knowledge as well as to

learn effectively (Hartikainen, Rintala, Pylvas, & Nokelainen, 2019).

Table 1. PjBL Criteria

Criteria	Explanation
Centrality	Students encounter and learn the central concept of the curriculum based on the project and that project is not limit in the curriculum.
Driving questions	The problem should be ill-defined which can be built from more than one topic.
Constructivist investigation	This investigation constructs understanding and knowledge of the students like design, decision making, discovery or model-building processes. If there is no difficulty, it is not PjBL it is an exercise.
Student driven	It is not a predetermined outcome. However, it is student autonomy, choice, unsupervised and responsibility.
Authentic	It is not a school like project. Students should be given a role in the context of real situation; they might work with collaborator or they can produce their product to be judged.

PjBL is introduced in System Modelling and Analysis Course (SMAC), which focuses on modelling and time analysis of the ship-to-shore (STS) crane system. SMAC is a compulsory subject for the undergraduate engineering program. This fundamental course involves theoretical and mathematical knowledge of the control system in order to simulate the system performance before the designing process.

This paper investigates the achievement in the implementation of a PjBL in System Modelling and Analysis Course with the integration of cooperative learning strategy to two groups of engineering students with different backgrounds during semester 2, 2019/2020 session. The selected programs are the Bachelor of Engineering (Electrical-Mechatronics) and the Bachelor of Engineering (Biomedical) programs at the School of Electrical Engineering, Faculty of Engineering, Universiti Teknologi Malaysia (UTM). The achievement of all four CLOs of this course is observed and analysed.

This paper is structured as follows. Firstly, an overview of the course followed by the problem development. Then, the activities and assessment setup is discussed before the data analysis section. Conclusion section concludes this paper.

Course Overview

SMAC is one of the core subjects for the undergraduate program in areas of electrical, mechanical, biomedical, and chemical engineering. The contents may differ based on the basic systems involved in their programs. This course requires strong knowledge of applied mathematics, science, and circuit

analysis to derive the mathematical models of electrical, mechanical, and electromechanical systems. SMAC consists of five chapters in order to produce four CLOs. The mapping of CLOs to chapters is tabulated in Table 2.

Table 2. Course Learning Outcome (CLO) Assignment for SMAC

Items	Course Learning Outcome (CLO)	Chapter
CLO1	Apply the knowledge of basic control theory to describe the structure of control system design and control system representation.	1 and 4
CLO2	Apply the knowledge of mathematics, science and electrical engineering to derive the mathematical models of electrical, mechanical, and electromechanical systems in transfer function and state space equation.	2 and 3
CLO3	Analyse the performance and stability of system's transfer function in time domain.	5
CLO4	Use MATLAB software in analyzing control system performance and stability.	MATLAB simulation

Previously (in conventional approach) this portion of mark was dedicated for typical MATLAB problem solving assignments, where individual student was given the same set of problem to solve. Students will give same answers, but we expected different approaches in solving using MATLAB. This is a typical conventional type of assignments with same expected answers. It is still effective in using this type, but we found it hard to distinguish the original solution when there were some similar solutions. This makes us feel motivated to introduce our first PjBL approach.

In order to have a good evaluation in students' performance in PjBL, several assessments are conducted to cater both technical and generic skills as shown in Table 3.

As can be seen in Table 3, the assessment of PjBL consists of minute of meeting, peer review, progress report, presentation, and report. Some of the activities are undertaken to scaffold the comprehension of the student and contribute to the assessment indirectly. At this stage, students are required to work in a group, get linked up in order to have an overall understanding of the project, incorporate ideas, and consequently develop their knowledge of finding the best solution. All items are mapped to CLO1 with reference to the table and contribute 4 percent out of 20 percent in total to the cognitive level calculation in the fundamental knowledge of the course. In Week 7, the assessment of CLO2 is carried out from the submission of progress

report, which emphasizes on all relevant theories. From Week 8 onwards, students are supposed to begin acquainted with the MATLAB software tool before the next assessments took place which are mapped to CLO3 and CLO4. Both CLO3 and CLO4 evaluations are only applicable from Week 12 to 14 where the use of MATLAB software is critical and mandatory for the final solution.

Table 3. Mapping of Activities to CLO and Weightage of Assessment

Study Week	Activities and Assessment Items	Course Learning Outcome			
		CLO1	CLO2	CLO3	CLO4
2	Introduction	√	√	√	√
4	Jigsaw and Gallery Walk activities	√	√		
4	Minute of Meeting	1.11%			
7	Peer Review 1	0.89%			
7	Progress Report	2%	3%		
12	Presentation	√	√	√	4%
14	Report	√	√	3%	6%
	TOTAL = 20%	4%	3%	3%	10%

The other 80 percent of the marks are covered in the final examination (50%) and 2 tests (30%). Since this is the first time we implemented PjBL in this course, we agreed to replace the 20% from the conventional assignments with PjBL. With good reflection results, we might consider an increase in marks portion for PjBL.

Problem Development

To cater both engineering students’ background, a common crane control system is designed. The ship-to-shore (STS) crane system is commonly used for loading and unloading containers from ship to shore or vice versa. The crucial part in the STS crane control system is the STS process cycle where it can be defined as the time taken for the crane to lift and lower the container. If the cycle time between lifts can be reduced, then more STS operation can be performed within a cycle. The schematic of a linear STS crane hoisting trajectory for one cycle of lift is illustrated in Figure 1.

The operation of STS crane starts from the position P to Q and then travel to R before lowering to the waiting lorry at S. In this case, the time taken for lifting (t_{lift}) and lowering (t_{lower}) to be calculated properly, which depends on the total mass of container, hook, and spreader. For modelling and simulation, detail

specifications of the STS system for lifting and hoisting applications are given as follows:

- a) Four types of DC-motor specifications and prices
- b) Five different ships with five mass of containers
- c) Travelling specifications for the STS crane trolley

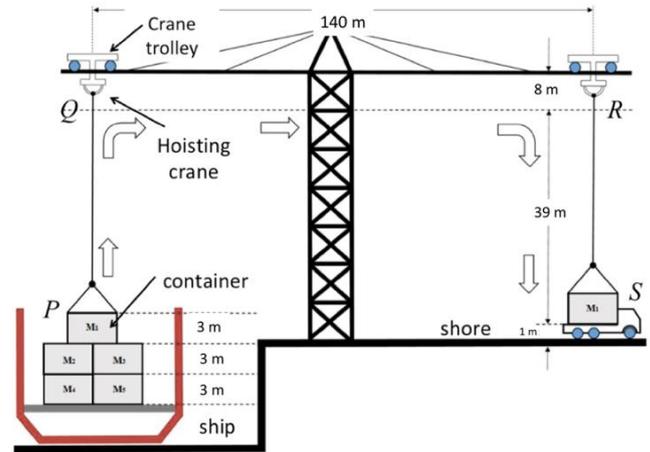


Figure 1. Simple schematic of STS system

Aligned with the CLOs in Table 1, the objective of the project is to provide instructional approach to the students in developing their knowledge and skills by solving all the given questions. The questions are designed to engage students with the STS crane control problems that they may face in the real-world and as a guided instruction steps to help student complete the project. The questions are designed as follows:

- i. Draw the functional block diagram to represent the hoist crane system (including the disturbance and friction). You have to consider the actual type of disturbance and friction that exists within the system.
- ii. Determine the suitable motor type for the load type. Derive the transfer function of all components, if possible.
- iii. Choose and justify the best motor type if the maximum desired time for the unloading or discharge process is 20 minutes (redesign if not suitable) for each lift cycle.
- iv. Design the hoist motor trajectory based on the (iii) and label the lifting, travelling and lowering times. Also, calculate the total energy consumed, E by the motor.
- v. Simulate the hoist crane system using MATLAB Simulink with all parameters obtained from steps 1 to iv and parameters are tabulated in Table 1, Table 2 and Table 3. Observe, discuss and evaluate the simulation results.
- vi. To improve the crane hoisting performance, design the best possible hoist motor trajectory for the selected load to unload or discharge all five containers in the shortest period of time. Please include relevant consideration

regarding price, speed, and Return of Investment (ROI) of the proposed hoist motor.

Activities and Assessment Setup

From the designed questions, set of tasks are created and mapped to all CLOs as depicted in Figure 2. The number of created tasks represents the number of students' group for the AL activities conducted in this PjBL.

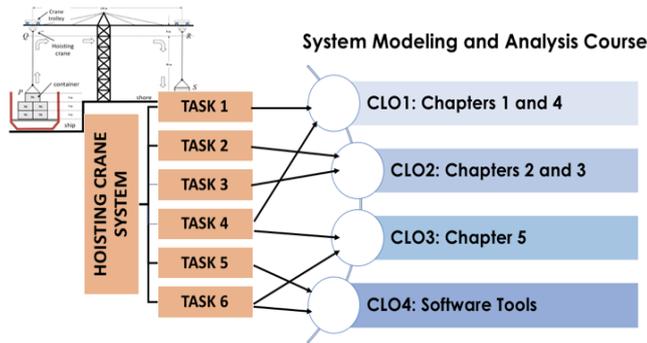


Figure 2: Project to CLOs mapping

In Week 2, overview of the project is introduced. A list of tasks to be performed is given in Table 4 to allow the students to see the details, the big picture and the complex relationship between these two.

Table 4. List of Tasks

Tasks	Description
1	Draw functional block diagram, do assumptions, identify limitations of the system.
2	Derive DC motor operation principle of electrical and rotational output modeling and find the transfer function of overall system.
3	Determine the rotational and translational mechanical equations with Task 2.
4	Modeling the lowering process, from hoisting crane to the lorry.
5	Part planning design; find fast time duration for completing task from listing and lowering processes.
6	Hoist motor trajectory performance analysis, the transient and steady state responses.

At the Onset stage, each student is assigned with a specific task in a group. Basically, the task is to allow each student to independently research the related information, assimilate information, create their own conceptual understanding within specific period before sharing their ideas with the other students in the same group. Indirectly, activity at this stage

expands students' ability to think critically and boosting their efforts. Then, in Week 4, their first in-class group activity is conducted through the implementation of one of the famous CL activities, the Jigsaw.

The Jigsaw is embedded into this PjBL for in-class activity to provide an early integration of the students' understanding with the guidance from the lecturer. In the class, each student is gathered in their respective Expert Group (EG) where they have to discuss the task given and find a consensus on the task-related information by building a contribution from each other. The EG is a group formed by students with the same task.

Once they have fully understanding their own task, they go back to their respective Home Group (HG) to explain and clarify their task in detail and finally relate with other members' tasks for establishing a potential solution. The HG is designed such that all members will have different tasks and the integration of the tasks is crucial to complete the PjBL process.

At the end of the activity, all students are expected to have a general understanding of what they will do next to achieve the goal of PjBL. Starting from the Execution Stage, all students are dependent on each of their members for the complete solutions. Thus, more assessment related to the students' participation are conducted progressively including the minute of meetings and peer evaluation. Referring to the students' reflection, majority of the students agreed that this activity has greatly enabled peer interactions and allow them to teach and learn among themselves. Students can explore more possible solutions for different type of load in order to find better performance and system stability during required time.

The summary of the overall PjBL process is depicted in Figure 3.

Data Analysis

Data is taken from students' reflection and evaluation marks from the assessments in Table 2.

A. Students' Reflection

Students' reflection is taken from e-Learning with anonymous setting. Reflection from the students is important which can help us to understand their experience of learning during the activities. In this project, two reflections are conducted using the e-Learning platform provided by our university. First, reflection for the Jigsaw activity and second, reflection on the overall project as follows:

- Students' satisfaction on the Jigsaw
- Best and bad parts and suggestions for improvement.

Some samples obtained from the students' response for (a) and (b) are shown in Figure 4.

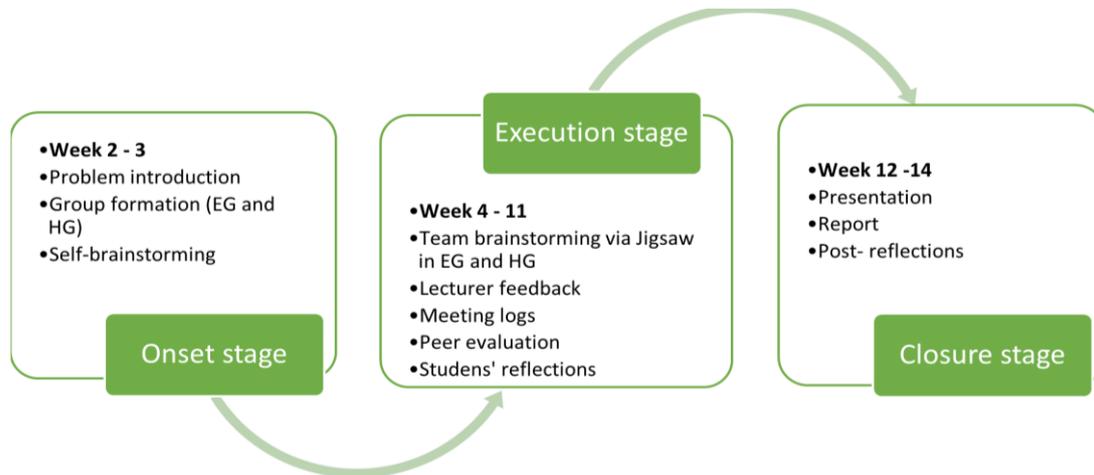


Figure 3. Overall PjBL process

Response number	Is Jigsaw activity helps you clarify your understanding about the case study? What is 'BAD' and 'BEST' things about this activity?	Do you work effectively with your EXPERT group members?	Does your member in your HOME group able to give you a comprehensive understanding on the case study?	Do you feel your EXPERT group members promotes better learning, improves your motivation, and increases enjoyment of the learning case study.
Response number: 1	Yes, it helps. I can get information that I don't know from other people	I think so!	Yes	Yes, they do.
Response number: 2	Yes it did help, it was good to share the ideas and to know different point of views to understand the case	Yes	Yes	Yes
Response number: 3	The best thing is that it help us understand more about the subject	Yes	Yes, kind of	I guess yes
Response number: 4	the best thing is that we could understand our task easily. The bad thing is the lack of time	yes, definitely	Yeah, they clarified everything to us	yes, these kind of activities make us cooperate with each other
Response number: 6	Actually the most interesting part of this case study is that it helps us to work as a team. We tried to cooperate each other which develops our communication skills. Most importantly real life problems like this really help us to gain lots of experience about life.	I think this case study deals with lots of interesting things and the benefits of the case study is way more than compare to that of the drawbacks. In my opinion there is nothing bad about this case study.		I think it would be better if the use of simulink in MATLAB is made compulsory. Like all the group should have to use simulink to design transfer function. It would help the students to gain knowledge regarding an added feature in MATLAB
Response number: 7	Team working, exposing us into real life problems and help us solving it	Not giving the chance to choose our group mate, hard for communication and making work more complicated		Giving the chance to work with partners from our choosing
Response number: 8	To know how to solve a real life problem. Also there are plenty of resources in the web to take as reference. The participation from the members was quit good as in the task it was said to assign someone to do a specific job. So this time no one did a free riding in the group project.	According to me there was not bad. I love to have this type of topic.		For me there is always a room for improvement. It would be better if school can arrange a field visit related to the topic. It actually gives a power visualize more and encourage to do the job. Also students can learn about the work environment.

Figure 4. Students' Reflections

Overall, for item (a), satisfaction of students is categorized into two; satisfy with the way Jigsaw activity is conducted and satisfy with the Jigsaw activity outcomes. Referring to Figure 5, it is observed that only one response out of 30 responses received from students of Biomedical Engineering is not happy with the way of Jigsaw activity is conducted. The student commented that one of his members was not participating in the activity. Case study can be improved with accurate data from manufacturers for motor specifications, testing with multiple loads weight and involve analysis on accuracy and hoisting

and traveling cranes capabilities in achieving suitable complexity so that everybody must contribute to solve the problem. In addition, peer evaluation will be provided to make sure everyone contributes to the groups. For item (b), all students agree that the Jigsaw activity can thoroughly develop their comprehension of the project as all HG members are able to perform their role effectively by correctly explaining their task. Each of them is able to explain and summarize the content of their task to their group members. At the end of the activity, students able to get the overview of the core problem in the project.

B. CLOs Performance

The analysis of students' performance has been done based on the CLO of the course. The performance of the students from two different programs is compared. By referring to Figure 6, the overall CLOs performance of Electrical Engineering students is higher than that of Biomedical Engineering students

except for CLO4. Electrical Engineering students have advantage in achieving CLO1 to CLO3 since they have a good fundamental knowledge of Mathematics and Physics from the previous courses that can assist them in quickly and accurately getting the ideas. CLO4, on the other hand, assesses the proficiency of using the MATLAB tools, in which both groups of students are a beginners and new to this programming software.

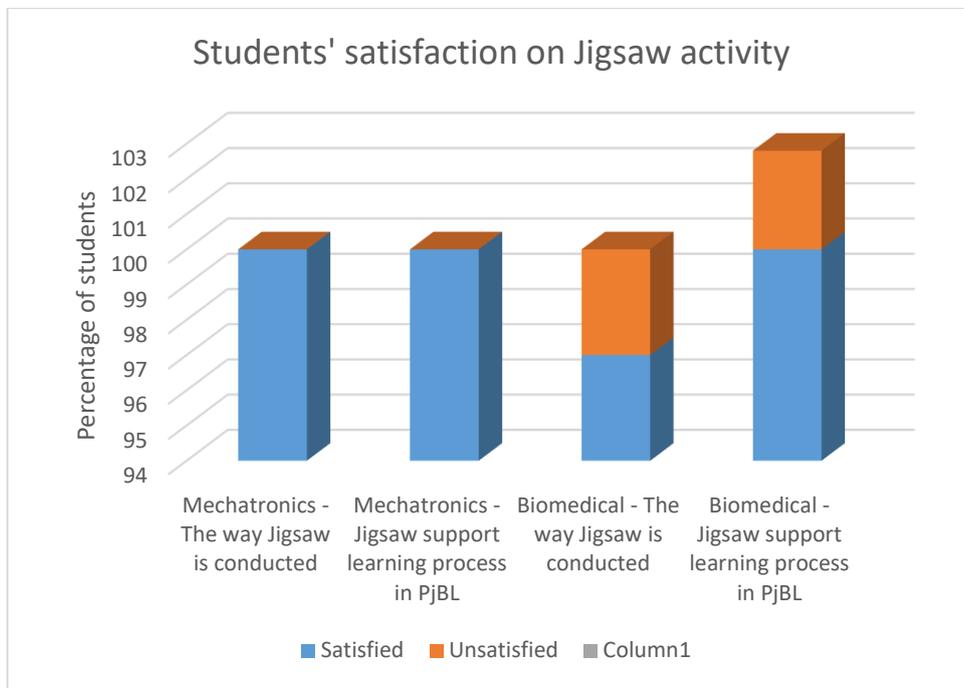


Figure 5. Students' satisfaction on Jigsaw activity

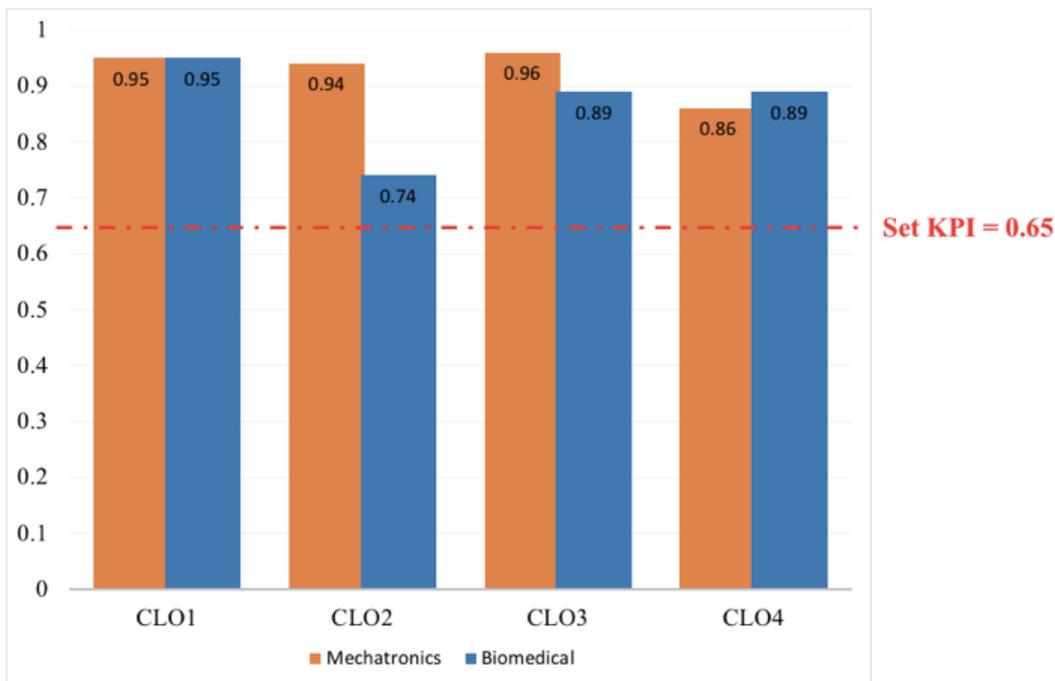


Figure 6: KPI achievement for CLO1 to CLO4

Conclusion

PjBL was implemented in the System and Modelling course. The course is a core course for the third year Electrical Engineering and Biomedical Engineering students in UTM. In order to scaffold students' understanding and knowledge, the Jigsaw was integrated with the PjBL. Based on the students' reflections, regardless of their background, majority of the students appreciate the learning process and satisfy with the outcome from the activity. Since the activity relies on peer teaching with guided instruction, having the associated prior basic knowledge helps the Electrical Engineering students to perform better in achieving the CLO 1, 2, and 3. In future, guided instruction will be replaced with an unguided instruction to fully meet the characteristics of PjBL.

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