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Implementing STEM Project-based Learning and Scaffolding Strategy for Electrical Engineering Students in a Feedback Control Laboratory Course

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Abstract: The control system is the significant unit of study for the third-year Electrical Engineering. Mathematics, physical, digital signal, and programing are involved in the course. The challenging of teaching this course is the concept quite difficult to relate between the mathematical concept and the real applications. Therefore, in this research the control system laboratory course is provided the teaching approach using scaffolding and project-based learning (PjBL) to help guidance students step by step as a scaffold to enhance the students' learning experience than using the traditional teaching model. The learning approach of this model is to providing supports students' successful deep learning in feedback control system concepts and complete PjBL. Moreover, the students were encouraged with systemic thinking and engagement in class.

Keywords: feedback control laboratory, project-based learning, scaffold, engineering education

1. Introduction

The context of control systems based on science, technology, engineering, and mathematics (STEM). In recent, STEM frameworks are increasing involved in the engineering curriculum. The traditional teaching models do not provide a good solution of teaching in the engineering education because the students are only passive learning. Moreover, the students cannot engage concept of knowledge and the physical world applications. This is the challenge of teacher to solve the problem.

The PjBL is one of the types in problem-centered instructional approaches which student can be active learning. This approach is very useful in STEM education. PjBL help to increate inquiry learning, engagement, creativity, skill and critical thinking skill. In addition, it can help to improve a soft skill such as working as a team or collaboration.

Scaffold is a technical to help students to achieve learning or task when students cannot be able to complete it by themselves or struggle. The scaffolding guide base on individual students' skill. Students can get more support if students' have low level ability. On the other hand, the support could be decrease when students gain more ability to finish the task (Belland, 2017).

This aims of this research is to use the scaffolding techniques in Feedback Control Laboratory course in purpose to supports student able to do the PjBL, which helps students to deal with real life problem. For the scaffolding act like a guide tool to ensure that the students can cope with the complex solution. To use of scaffold for STEM PjBL is one of the keys to help students to be able to solve the problem and created the project with students' knowledge.

2. Literature Review

PjBL approach is normally use in teaching for engineering. Many researchers have investigated the benefit of PjBL approach. Andrade (2012) proposed the opinion of leaning in PjBL that the method can help student to understand mathematics, conceptual and more realistic way to cope with the problem as an engineering. In addition, PjBL was integrated to vocational teachers to persuade teacher to use information and communication technology to support their teaching (Chookaew, 2017). Moreover, the critical thinking, creativity, and transfer of learning skills are other three important parameters that need to improve in the student engineering. PjBL and Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse (SCAMPER) strategies was implemented in the computer science and the engineering project courses in purpose to improve critical thinking, creativity, and transfer of learning skills (Wu, 2020). PjBL have a big advantage not only for student engineering but also have a big challenge on some students because they cannot complete by themself. Vygotsky's proposed the idea zone of proximal development (ZPD) of children learning. The model consist of the child can do independently and the child cannot do without supporting. Therefore, to complete the project, each student needs the different supporting. Many researchers try to find the way to help student to success on learning using PjBL. One of the strategies that use to cope this problem is scaffold. Such as, a case study of students which difference backgrounds in Applied Mathematics, Civil Engineering, and Industrial & Engineering Management are doing PjBL together. The scaffolding techniques help them to achieve their project (MacLeod, 2020).

However, learning context of feedback control systems using PjBL is important for electrical engineering students. Students need to find the relevance between concept and real applications. Moreover, students need to practice in critical thinking skill and collaborator skill. Not all students can hand on the project by themselves, sometimes they need the supporting from the expert person. Teaching approach by PjBL with scaffold can help increase student to success on learning because the scaffold technic help to find the suitable way for each student problem.

3. Methodology

The implementation on scaffolding in PjBL is used during feedback control laboratory course. The experiment was set up for third year of Electrical engineering program in Sirindhorn International Institute of Technology, Thammasat University (SIIT). Firstly, the students who pass the Feedback Control Theory course, conducts the laboratory for eight topics: Modeling and Simulation in MATLAB/Simulink, SIMULINK: Proportional plus Integral plus Derivative Controller, Compensator Design, Electronic PID controller, Introduction to Sensors and Actuators, Introduction to PLC, Advanced PLC programming, and PID Controller for Servo Systems. These topics contain the computer-based simulation for computer-aid design purpose, and the hand-on experiment for relevant with the real applications. After they finished all topic, they are encouraged to choose one out of three PjBL topics and worked in small team. Scaffolding was set as an instructional strategy for guideline students in these activities. During they did the experiment on PjBL, teacher assistants (TA) guided the students for helping them to reach the goal. At the end of the course, students had to present and demonstrate the students' competition PjBL and discussed with other groups and TA.

3.1 Learning activities framework

In this research, we focused on implementing scaffolding strategy to supported student learning in Feedback Control laboratory course. In each students' group, the instructions of supporting are difference between students' group. It depended on current students' ability. The expected goal of using scaffold is to support students to generate students' motivation, creativity, and skill to complete PjBL activities.

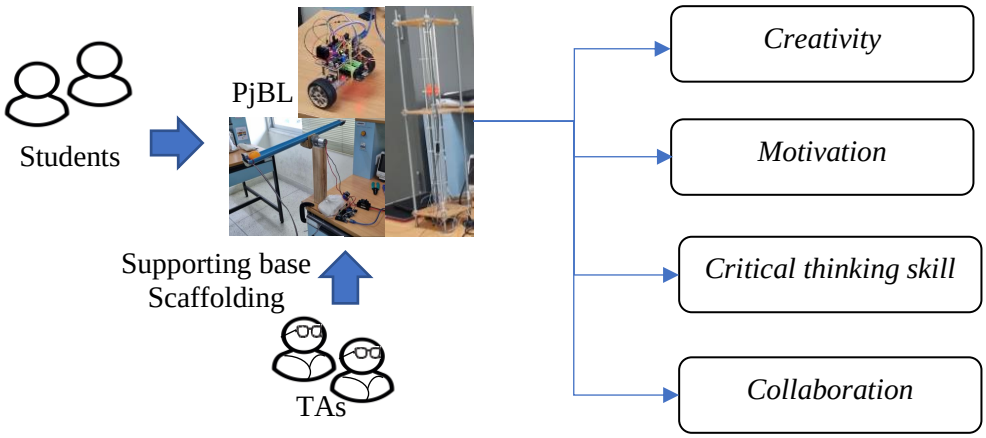
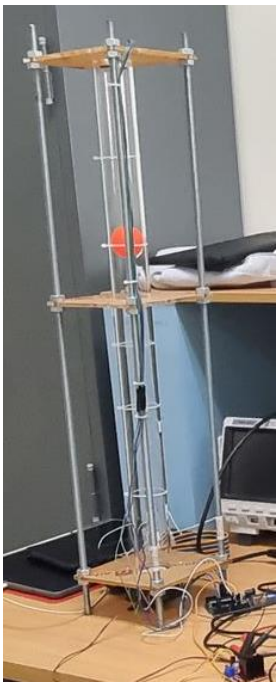


Figure 1. PjBL with scaffolding activities framework

3.2 Learning tools design

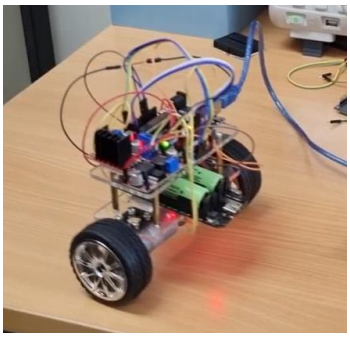
In this work, the PjBL was created in three topics: ball levitation, ball and beam, and two-wheels balancing robot as shown in Figure 2 for addressing the different control problems. Technically, the objective of ball levitation is to stabilize the height of ball in the transparent tube by adjusting the speed of fan duct. The challenge of control action is to deal with nonlinear term in gravity force acting to the ball and air turbulence inside the tube. The objective of ball and beam is to maintain the ball position by adjusting the slope of beam. Two-wheels balancing robot, well-known unstable system is to stabilize the body of robot the in upright position. Arduino Uno board which is low-cost and easy for self-learning is utilized as the main controller for receiving all sensors information, calculated the control action and sending the pulse width modulation (PWM) command to the DC motors.

The students are assigned as 2-3 members per group for working as a team. Each group selected their own topics as they prefer. After topic selection, the parts such as acrylic bodies, DC motor and necessary electronic components were distributed to each team.



(a) Ball levitation system

(b) Ball and beam system



(c) Two-wheels balancing robot

Figure 2. PjBL topics

3.3 Learning activities design

Before starting the project based, the students require to achieve feedback control theory course in the period semester. Then conduct the traditional feedback control laboratory for 8 weeks. Three topics are computer simulation to model, design and simulation and evaluation the time-domain response. The rest topics are experimental laboratories which is relevant between the control theory and actual hardware, as shown Figure 3. The instructor provides the material and shortly briefs the context of each module to review students' basic knowledge. After the students conducted the experiment following the instruction, they need to summarize what they had learnt. The expected outcomes of this process are to review the basic knowledge of feedback control, be familiar with the software and hardware equipment, and the getting the idea of coding.

Activity 2 had been served after students' complete activity 1. In this period, students are assigned as group of 2-3 persons. Each group selects only one topic from three hand-on PjBL topics as mentioned in previous section. The process is involved in learning, planning, constructing, discussion, testing, evaluation, presentation, and demonstration. In addition, students can learn a teamwork skill.

In this process, based on the scaffold strategy, the supported learning can be obtained both from TAs and team members. For TAs, they are encouraged to support students in each team to gain more complex skill which students cannot learn by themselves to complete the PjBL. Team members can advise friends among groups immediately when someone in the team have problem until the skill level of all members are the same. The following is the activities that we are mentioned above.

- *Activity 1:* learning 8 modules and conducting the experiment in a usual class
- *Activity 2:* PjBL (hand-on)
    - Learning / brainstorming ideas/ research on their topic
    - Planning/ designing the schedule of project
    - Constructing the hardware tool
    - Discussion with TA
    - Testing/ analyzing
    - Evaluation
    - Presentation and demonstration

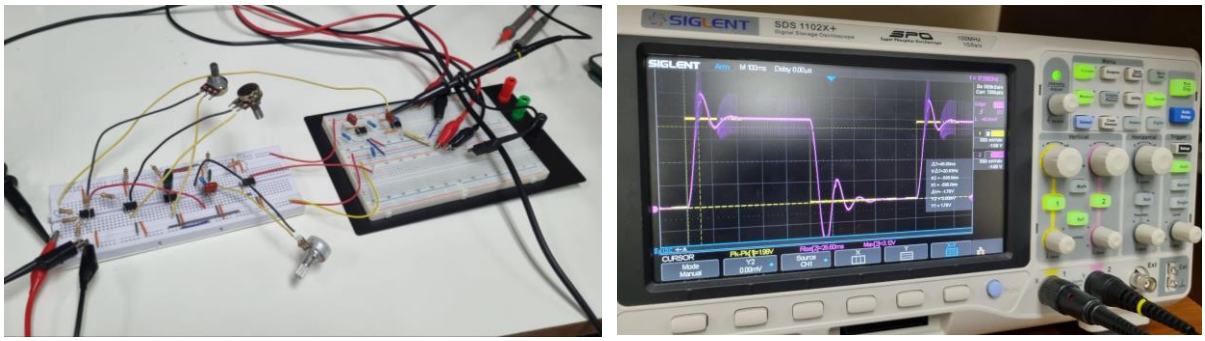


Figure 3. Example of experiment in activity 1 on the topic of electronic PID controller

4. Results

To evaluate students' learning using PjBL, we asked students for survey the questionnaires based on outcome of students learning. In addition, to evaluate students' performance, TAs give the score for each group which are depended on the performance.

The survey has been collected data in both qualitative and quantitative. The survey has seven questions which the result shows in Table 1. The result shows that PjBL are strongly help support students in creativity, motivation, critical thinking skill, and teamwork. The collaboration is the best impact on doing PjBL followed by motivation and critical thinking respectively. As students' viewpoint, the Pros and Cons of online feedbacks are represented in Table 2. Some students are the satisfying with our implement approach. They feel they gained more knowledge, and motivation from PjBL. Moreover, TAs and senior student can support to students to do the project based on the

scaffolding strategy. On the other hand, some dissatisfaction feedback is also shown for example, they cannot crop with the hardware problem and time limit. This kind of feedback helps the instructor and TAs for improving the PjBL in the feedback control course in the next year.

Table 1. *Analytical results of student survey.*

questionnaires	***Score***						
Experiment	***5***	***4***	***3***	***2***	***1***	***mean***	***SD***
PjBL supports students to gain their skills in using handyman tools.	23	6	5	1	0	4.22	0.85
PjBL supports students to gain more encouraged and motivated.	26	6	2	1	0	4.38	0.73
PjBL supports students to gain experiment on analysis and evaluate problem.	22	7	5	1	0	4.19	0.85
PjBL supports students to gain relevance between theory and real-world applications.	20	10	4	1	0	4.16	0.81
PjBL supports students to gain positive attitude in learning	23	6	4	2	0	4.19	0.92
PjBL supports students to gain applying creatively with other relate applications	24	8	2	1	0	4.32	0.74
PjBL supports students to gain skill in teamwork.	26	7	2	0	0	4.43	0.58

Where 5, 4, 3, 2, 1 mean strongly agree, agree, fair, degree, and strongly disagree respectively.

Table 2. *Student' point of view*

Students' point of view
Thank you teacher I have gained a lot of knowledge. It's like being an engineer. It's really fun to do, write the code, assemble the machine, connect the wires, and most importantly solve the problem. It appreciates to know how well we can do it. Thank you very much. Love it.
The course is well organized and TA's are so supporting too.
This is what I am waiting for in Electrical engineer studies. Hand-on project is the best way to implement my knowledge, it is very fun. Thank you so much!
I take much time for this project, and I have learned overalls about technical skill from project. Thank you teacher, TA and brother Phatam.
The electronics which teacher gave are sometime not efficiency to the project itself.
From our group viewpoint: First, the 12VDC motor might be too heavy for typical battery supply on that size. Second, the ADXL345 measurable sensor might be suitable in theory (alignment of sensor), but the spike (noise) was hard to be compensated in higher acceleration.
Need more time for doing the final project.
Because the score criteria is the same for every project, the difficulty of every project should be roughly the same.

5. Conclusion

In this work, we implemented the PjBL with scaffolding strategy to help students achieve for leaning in Feedback Control Laboratory Course. Student survey shows that students agree on using PjBL can gain in their outcome on motivation, creativity, critical thinking skill, and collaboration. And with the scaffolding strategy that TAs use for guideline the need of help of student in PjBL can help support students to complete their project.

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