

## **Effectiveness of Teaching and Learning Method in Concrete Laboratory Works**

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### **ABSTRACT**

The rising awareness of the importance of professional skills for engineering students has led to increased attention given by engineering schools to developing the critical thinking skills of students. Thus, this study discusses proposed methods implemented in the teaching and learning process in concrete laboratory experiments. A combination of problem-based and open-ended techniques of teaching and learning is used. The method is supported by creative lab demonstration using an IT tool to conduct flipped laboratory demonstration. Finally, an overall assessment, which consisted of cognitive and psychomotor domains, was conducted. Student feedback and performance in a Materials Technology course are evaluated in the context of the implementation of the proposed method. Student feedback generally indicated that the method was accepted as satisfactory and that it successfully improved the teaching and learning process where the three basic domains from Bloom's Taxonomy were applied.

*Keywords:* Critical thinking, open-ended, problem-based, flipped laboratory demonstration, student feedback

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### **INTRODUCTION**

One of the required criteria for accrediting engineering programmes is to improve engineering education (Engineering Accreditation Commission, 2012). Engineering students need to graduate with positive attributes to become competent engineers. Therefore, in engineering

education, laboratory experiments or practical work can be integrated into the curriculum to provide students with engineering experience and practice prior to graduation. Laboratory experiments can provide students with knowledge and practical skills and expose them to relevant issues in engineering (Salim et al., 2012). To improve the teaching and learning process, three basic domains from Bloom's Taxonomy must be applied. The domains of learning described in Bloom's Taxonomy are the development of cognitive, affective and psychomotor skills (Hamid & Baharom, 2013). Most of the cognitive mental skills (knowledge) are developed through classroom instruction. The affective skill component, which involves feelings or emotional areas (attitude), is developed through activities such as structured leadership of group design projects (capstone), career development activities and events (co-curricular activities), competitions and cornerstone and final-year project presentations. Psychomotor skills, which are commonly referred to as manual or physical skills (skills), are normally developed in the laboratory setting.

Among important skills that engineering students need to develop are technical skills. These skills are essential to ensure that engineering students have a successful professional career after they graduate. However, these skills can be only applied outside the classroom, in the laboratory and in assignments. Laboratory work is a very important component for engineering students. The ability to perform and conduct

experiments without supervision is among the key skills that students in engineering schools need to acquire and develop. A proper methodology and form of assessment must be planned and performed adequately to ensure that students experience a beneficial and rewarding educational experience in the laboratory. Baharom et al. (2015) proposed an assessment method to relate psychomotor and cognitive performance using quadrant analysis. Students were divided into four categories, namely, exam-based, technical-based, well balanced and poor.

However, the spoon-feeding learning pattern governed most of the traditional laboratory work conducted. Students were given laboratory manuals and they had to follow the lab demonstrator's instructions during lab sessions. Therefore, students were not required to exercise a great deal of effort before the commencement of their laboratory exercises. Problem-based learning (PBL) and open-ended learning (OEL) techniques are good options to be integrated in laboratory work. Implementing PBL and OEL in concrete technology laboratory work will reduce problems, such as free riders and lack of understanding of the relationship between individual experiments and problem to be solved. Berg et al. (2003) revealed that the open-ended experiments showed the most positive outcomes regarding learning outcome, preparation time, time spent in the laboratory as well as student perception of the experiment. However, some students with poor attitude needed more support during experiments to meet the challenge of an open-ended

experiment. The implementation of PBL in the concrete laboratory at the Department of Civil Engineering of UKM was started in the 2005-2006 session. Since then, improvement of delivery methods of class instruction and laboratory work has been carried out for continuous quality improvement (Hamid et al., 2008; Hamid & Mohammed, 2010; Hamid et al. 2011; Baharom et al. 2012).

Domin (1999) outlined four different styles in conducting laboratory, namely, traditional, open-ended, discovery and problem-based. These styles are differentiated based on outcome, approach and procedure. McComas (1997) described four levels of laboratory openness that can be differentiated by three descriptors, which are problem, ways and means and answers. A level-0 activity is traditional laboratory where all descriptors are given, while a level-3 activity is an open-ended laboratory where all descriptors are not given. Colburn (1997) suggested making small changes progressively in the laboratory activities from traditional to open-ended styles over the course of weeks or months. This method allows for the transition from traditional laboratory methods to open-ended style to avoid chaos in laboratory activities.

Thus, the purpose of this study was to describe the current implementation of the innovative technique of combining the problem-based and open-ended method in conducting concrete laboratory works followed by student feedback on the implementation of this method for continuous quality improvement.

## METHODOLOGY

### Teaching Delivery and Lab Work Operations

Construction Materials Technology is a compulsory subject for year-two students in the Civil and Structural Departments of the Faculty of Engineering and Built Environment, National University of Malaysia. This course introduces construction materials, manufacturing processes involved and characteristics and properties. The course implements lectures, projects and laboratory work on concrete mixing and testing. Figure 1 shows the learning process flow in concrete laboratory work as part of the Material Technology class, which covers three parts, namely, delivery, operations and assessments.

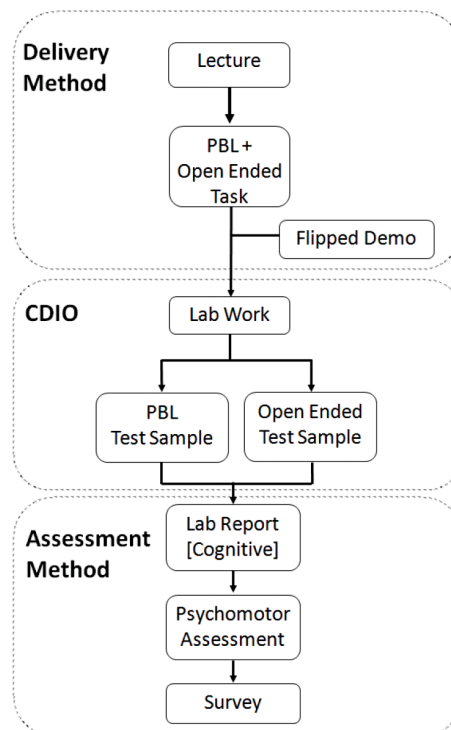


Figure 1. Learning process flow in concrete laboratory work.

At the beginning of this course, a conventional lecture was presented to the students. The purpose of this lecture was to make sure that the students had sufficient knowledge and information about the course (cognitive development). Students were given a specific task, where the first task was PBL and the second task was OEL. PBL and OEL are methods of student learning that focus on a complex problem that does not necessarily have a single correct answer (Hmelo-Silver, 2004). These methods are embedded in the process of Conceive–Design–Implement–Operate (CDIO).

In the first task, each group was assigned to design a concrete mix that would be appropriate to a specific structural element in a particular construction project. One of the examples was to design mixed concrete for the construction project in a nearby coastal area. To find solutions, students had to prepare and organise laboratory information before they carried out their lab work. They were required to decide on the suitable grade of concrete required, water-cement ratio, slump and wet density of the concrete. They had to prepare their own mix as well. In the second task, students were given an OEL problem. Students were asked to come up with a creative solution to produce floating concrete using waste material as additional material in their concrete-mix design. Then, they had to test whether the concrete grade was equal to the grade in the design and if the concrete they had made could float. Tasks 1 and 2 were run

parallel to one another, requiring that the same concrete-mix was used to complete the second task.

To fulfil this task, students worked in collaborative groups to identify what they needed to learn to solve the problems. They were divided into several groups and various different situations or problems were assigned to them. This kind of group work requires critical thinking by each individual to solve the problem. The implementation of psychomotor skills in laboratory work was executed using PBL and OEL methods. Students needed to plan, organise and sequence the series of laboratory work as well as decide the time and method to acquire information and seek feedback and help from their mentor. Monitoring strategies can be key to better learning performance, and better monitoring strategies may provide the mechanism for developing more effective knowledge construction i.e. information seeking and information structuring strategies (Biswas et al., 2013).

To help students with the laboratory work exercise, flip demonstrations (flip demos) were introduced. The flip demo was provided to students along with the laboratory manual. Students were required to study the manual and video before they started the lab work. Hence, they could read and view the steps they needed to do later in the lab work. These videos were uploaded on *YouTube* to allow the students to watch the process at any time. Sample-still shots from the uploaded video are shown in Figure 2.



(a) Lab safety.

(b) Moisture content of aggregate.

Figure 2 (a) and (b). Flipped demonstration using the YouTube platform.

### Assessments

Both direct and indirect forms of assessment can be used to evaluate students. Direct assessment uses direct evidence of student performance, either for individual students or for representative samples of students. These methods make possible the collection of evidence of student learning or achievement directly from students. Indirect assessment uses indirect evidence of student achievement including student ability, knowledge and values. In this case, assessment was conducted by means of a survey. Evaluation is important for both types of assessment to measure student performance and to obtain appropriate responses from students. The quality of student performance needs to be determined to confirm the effectiveness of this method. Students are required to be comfortable with this approach and not feel burdened by them. Assessment either indirectly or directly to check results is known as triangulation.

A survey of the proposed method implementation was conducted to obtain feedback from students and an evaluation of the implementation of PBL. Each student was requested to answer a closed-ended survey, which used a 5-point Likert Scale (Garvey, 2011). Three other types of student assessment were also conducted, namely, reports, examinations and a psychometric assessment test. The examinations and reports were required to evaluate their cognitive development and the psychometric assessment test was designed to evaluate their psychomotor levels. A specific rubric was used to assess the student reports and the psychometric assessment test. This approach enabled the judges (lecturers who evaluated student marks) to assess student performance in PBL constructively and reliably. The use of a rubric reflects authenticity in assessment.

A psychometric assessment test aims to evaluate student ability to conduct concrete test experiments. In this study, the assessment test was conducted as a mock test because of the characteristic

constraints of concrete. The concrete tests consisted of tests for slump, flow table and compaction. The students could select the tests randomly. The psychometric assessment test was conducted by inviting the judges for a live evaluation at the lab. The rubric was given to the judges and the evaluation ran smoothly.

Two types of assessment were developed to evaluate student performance. Psychomotor assessment rubric and a survey were developed for direct and indirect assessment. Both assessments used the Likert Scale for evaluation purposes. Direct assessment involved the creation of a rubric to evaluate student performance for a few psychometric criteria and the form of indirect assessment that was used was a survey designed to produce a response from the students on the implementation of the method. However, only indirect assessment results are reported in the next part of this paper.

## RESULTS AND DISCUSSION

Indirect assessment uses indirect evidence of student achievement that includes student ability, knowledge and values. In this case, assessment was conducted using a survey. Evaluation is important for both types of assessment to measure student performance and to obtain responses from the student. The quality of student performance needs to confirm the effectiveness of this method. Students should be comfortable with this approach and not find the approach burdensome.

The assessment of indirect and direct data is known as triangulation. However, only indirect assessment results are presented in this study.

For indirect assessment, a survey was conducted on 47 respondents. The aim of the survey was to obtain student feedback from the PBL-OEL activities conducted. The two parts of the survey were Part A, which included demographic content, such as gender and Cumulative Grade Point Average (CGPA) and Part B, which was the PBL-OEL implementation. Part B was divided into four categories, namely, (i) learning style of PBL-OEL, (ii) physical environment, (iii) demonstrator or facilitator and technician, and (iv) overall implementation. The questionnaire used a 5-point Likert Scale approach (1=strongly disagree to 5=strongly agree). The participants included 21 male and 26 female students. The results were analysed by calculating the mean score of each item from the survey. The maximum mean score was “5,” which reflects the maximum Likert Scale value (5) and indicates that students strongly agreed with those items.

Figure 3 shows feedback from students for the implementation of PBL-OEL in laboratory work. The most agreeable item in this category was “PBL-OEL encouraged the students’ participation in the discussion and interaction skills in the group.” The students agreed that PBL-OEL implementation was interesting and allowed for deep understanding of topics. Further, the students were able to express the ideas, participate in analysing the



problem as well as understand principles and the rationale for using PBL-OEL and the PBL-OEL process. Therefore, the students agreed with the implementation of the PBL-OEL in this course. The average mean value for the category PBL-OEL

implementation style was 3.8 out of 5. PBL-OEL implementation will indeed affect student performance by increasing independent learning, critical thinking, problem-solving and communication skills (Morales-Mann & Kaitell, 2001).

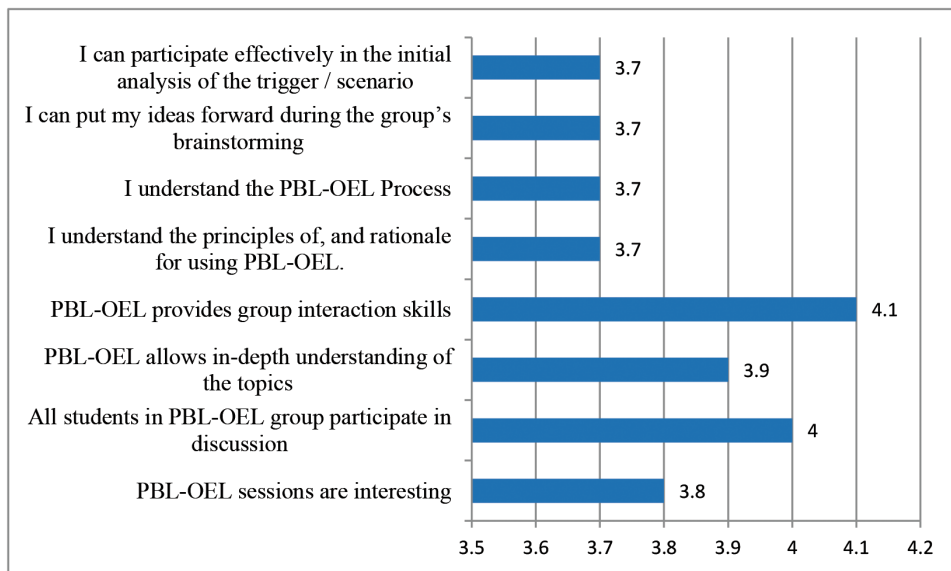


Figure 3. Students' feedback on the learning process.

Figure 4 shows the physical environment for PBL-OEL implementation responses from students. The physical environment category also played a role in PBL-OEL implementation. A good facility will help students perform better in educational activities. The result shows that the physical environment provided to the respondents was in good condition. The mean value of 3.6 indicated that the students agreed that the physical environment provided was suitable for PBL-OEL and the equipment

for the experiment was sufficient and in good condition for PBL-OEL exercises. The percentage of students who did not agree with items in this category might have resulted from the limited number of available instruments, and thus, they might have had to share tools to conduct the experiment. The sharing of instruments causes delays because of wait time, and this leads to time wasting. Thus, we recommend that the department should increase the number of laboratory equipment.

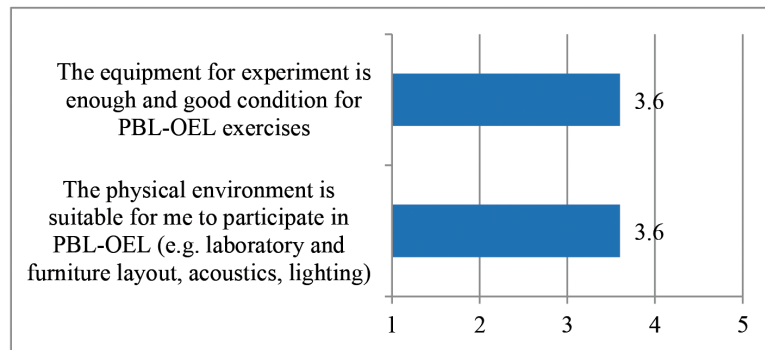


Figure 4. Students' feedback on physical environment for PBL-OEL process.

The next category of the survey was cooperation from the demonstrator and technician (Figure 5). This category measured the helpfulness of the demonstrator as instructor and technician as support personnel and the period for the

PBL-OEL implementation. Most of the students agreed that the demonstrator and technician effectively facilitated the PBL-OEL sessions and the students agreed that the time allotted for each of the PBL-OEL sessions was sufficient.

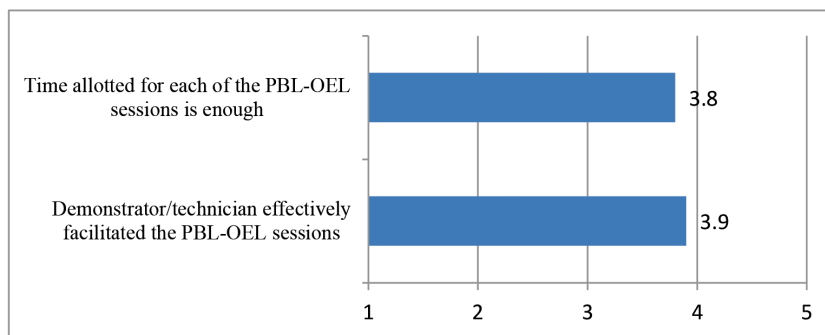


Figure 5. Students' feedback on cooperation from the demonstrator and technician.

The final category was overall implementation. Figure 6 indicates the effectiveness of PBL-OEL implementation from a student perspective. Students agreed (with a mean value of 3.9) that the PBL-OEL implementation was beneficial in helping them achieve the learning objectives. They also agreed (with a mean value of 3.9) that they were confident (with a mean value of 3.8) that PBL-OEL prepared them for

this course. Further, the students were confident that PBL would prepare them for professional life. Therefore, the students agreed with the implementation of PBL for this subject and that they could apply knowledge and psychomotor skills via the PBL-OEL method. For that reason, the comparison of student performance needs to be conducted to measure the effectiveness of PBL-OEL implementation.



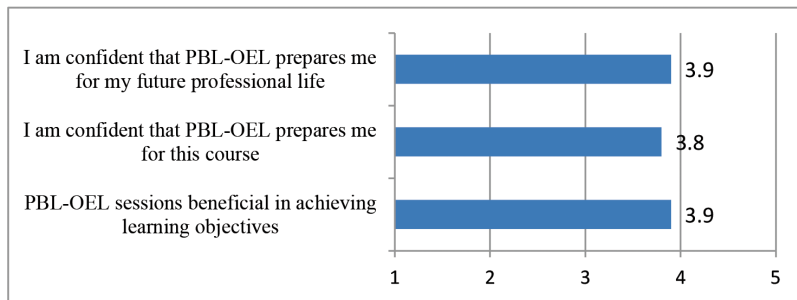
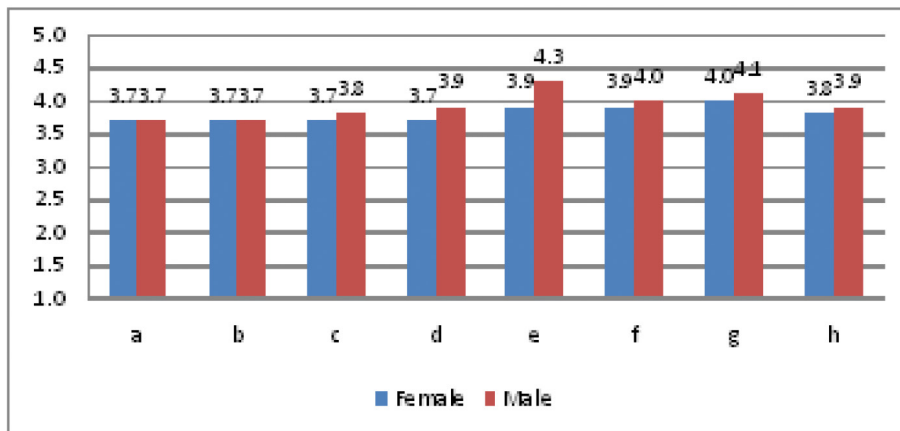


Figure 6. Students' feedback on the overall process of PBL-OEL.

The survey results were also analysed based on gender differences. Only survey questions from Part B, category (i), learning style of PBL-OEL were analysed. Figure 7 shows that, overall, not much difference was seen in giving feedback between genders. However, the male average scores agree to most of the statements, and are

higher than the female responses. The clear difference in response was seen for question (e), where the male and female mean values are 4.3 and 3.9, respectively. Thus, more males than females agreed that PBL-OEL provided group interaction skills.



Notes:

- a - I can participate effectively in the initial analysis of the trigger / scenario
- b - I can put my ideas forward during the group's brainstorming
- c - I understand the PBL-OEL Process
- d - I understand the principles of and rationale for using PBL-OEL
- e - PBL-OEL provides group interaction skills
- f - PBL-OEL allows in-depth understanding of topics
- g - All students in PBL-OEL group participate in discussion
- h - PBL-OEL sessions are interesting

Figure 7. Gender difference in answering Part B: Category (i) learning style of PBL-OEL survey.

Finally, the analysis of the survey was conducted based on student academic performance, where respondents were grouped based on their CGPA. Students were grouped in four CGPA classes where first class includes a CGPA of 3.60 and above, second class was between 3.00 and 3.59, third class was between 2.50 and 2.99 and fourth class was below 2.50. Only the results of three questions from the first category (learning style of PBL-OEL) are presented in this study, as they show clear differences. As shown in Figure 8, most of the fourth-class students (67%) strongly agreed that the PBL-OEL sessions were interesting compared to first-class students (25%). The results showed that students who belonged to the lower class liked the way PBL-OEL sessions were conducted. The sessions involved several hands-on laboratory activities, which made the work

more interesting. In PBL-OEL laboratory sessions, students need to develop technical skills, which are essential for all engineering students to ensure they have a successful professional career.

As shown in Figure 9 and Figure 10, about 25% of the first-class student showed full understanding of the principles of and rationale for using PBL-OEL and they understood the PBL-OEL process. The percentage of neutral feeling increased from second-class to fourth-class students, with none of the first-class students opting for neutral for the statements. Even though most of the fourth-class students liked the PBL-OEL session, they seemed not to understand fully the principles, rationale and the process of PBL-OEL itself. The limitation of their cognitive achievements could be one of the reasons for this result.

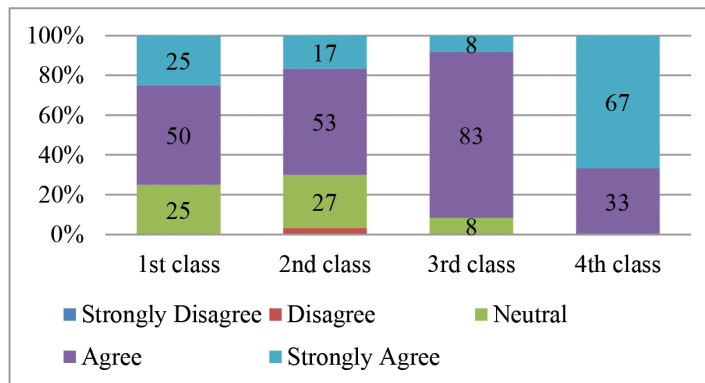


Figure 8. Feedback on “PBL-OEL sessions are interesting” based on level of students’ academic performance.

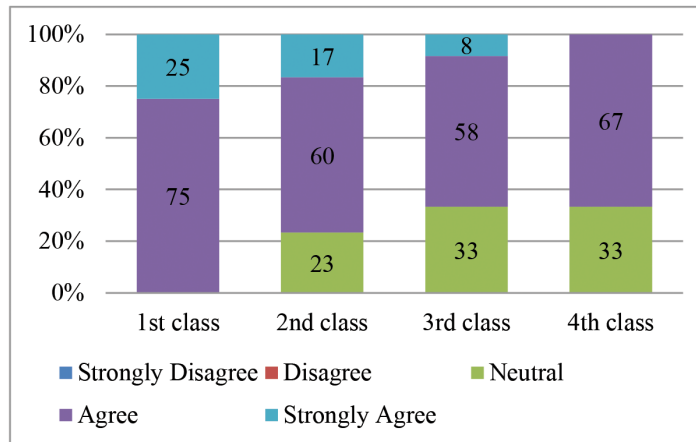


Figure 9. Feedback on “I understand the principles of, and rationale for using PBL-OEL” based on level of students’ academic performance.

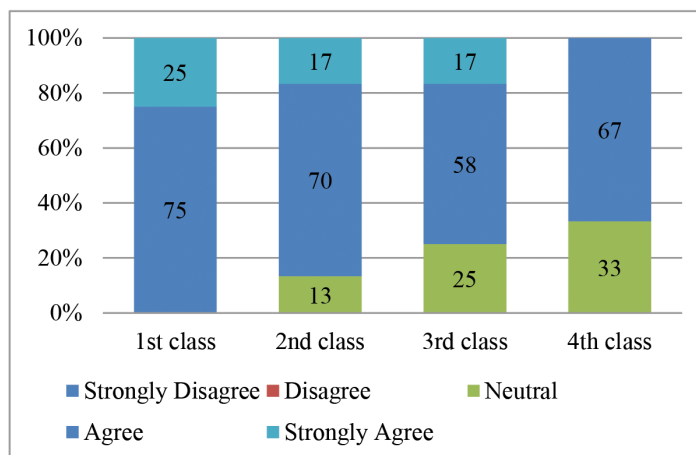


Figure 10. Feedback on “I understand the PBL-OEL Process” based on level of students’ academic performance.

## CONCLUSION

Overall, the results revealed positive outcome and responses towards the implementation of the proposed method. Student feedback generally indicated that the method was accepted as satisfactory and had successfully improved the teaching and learning process as all of them agreed with the statement given in

the survey. In addition, based on gender, more male respondents agreed with the learning style of PBL-OEL compared to the female respondents. The results also showed that more third-class and fourth-class students (CGPA, 2.00-2.99) seemed not to be attracted to the PBL-OEL learning style compared to first-class and second-class students (CGPA, 3.00-4.00).

Finally, the results also revealed that a few key areas need to be improved, such as facilities provided and understanding of the importance of PBL-OEL process. Therefore, additional effort by the student, lecturer and technicians must be made to ensure effectiveness of the implementation of this teaching-learning method.

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