

# Effect of Open-Ended Laboratory toward Learners Performance in Environmental Engineering Course: Case Study of Civil Engineering at Universiti Malaysia Sabah

N. Bolong, J. Makinda, I. Saad

**Abstract**—Laboratory activities have produced benefits in student learning. With current drives of new technology resources and evolving era of education methods, renewal status of learning and teaching in laboratory methods are in progress, for both learners and the educators. To enhance learning outcomes in laboratory works particularly in engineering practices and testing, learning via hands-on by instruction may not sufficient. This paper describes and compares techniques and implementation of traditional (expository) with open-ended laboratory (problem-based) for two consecutive cohorts studying environmental laboratory course in civil engineering program. The transition of traditional to problem-based findings and effect were investigated in terms of course assessment student feedback survey, course outcome learning measurement and student performance grades. It was proved that students have demonstrated better performance in their grades and 12% increase in the course outcome (CO) in problem-based open-ended laboratory style than traditional method; although in perception, students has responded less favorable in their feedback.

**Keywords**—Engineering education, open-ended laboratory, environmental engineering lab.

## I. INTRODUCTION

ENGINEERING practical laboratory activities commonly conducted by simply direct instruction to students which mostly asking whether the learners attain the ‘right answers’. Educators has move from conventional assessment of ‘identical’ lab reports which derive from the laboratory manual or so called cookbook of instruction-based student-teacher activities to an unconventional approaches, due to the various advantages reported [1], [2].

Four distinct styles of laboratory instruction have been established: expository, inquiry, discovery, and problem-based [3]. These are differentiated by their outcome (either predetermined or determined), the approach (could be in terms of deductive or inductive) and finally the procedure (either generated by student or given by the instructors). He also stated that the most popular style of laboratory instruction is the expository (also termed traditional or verification) style, and yet the most heavily criticized.

The successful and comfortable learning and teaching in traditional (expository) mode of laboratory is satisfactorily

enough to be achieved. The expository style approach still remains in many laboratories because it can cater for a large number of students with minimal involvement from the instructor, at a low cost, and is time efficient [4]. Furthermore, not all practical or hands-on classes can be transformed due to the nature of content and educational objectives. However, with the evolving education approaches and new technology resources, the learning activities in laboratory courses would also reform, in conjunction with the philosophy of student-centered learning, as embedded in outcome based educational approach.

The emphasized on open-ended laboratory has been set as a strength of curriculum in engineering education, due to its advantage in testing the creativity and innovativeness, challenging the students at the expected level depth and insight [5]. The concept of open ended laboratory is primarily giving students to develop their own experiments related to the topics of study. Open ended laboratory will pushes students to self-thinking and encourages them to develop their own testing instructions. Learners are expected to formulate their own strategies, with appropriate reasoning, knowledge background and logical justification. Open-ended laboratory instruction of problem based must apply their understanding of a concept to devise a solution pathway; this requires them to think about what they are doing and why they are doing it [3]. In addition, the aim of problem-based learning (PBL) is to develop self-directed, reflective, lifelong learners who can integrate knowledge, think critically and work collaboratively with others [6], thus enhancing the chances of students emerging from university with some of the skills that are highly desirable in the professionalism and career path.

To implement open-ended method in Environmental Engineering laboratory course of Civil Engineering undergraduate at Universiti Malaysia Sabah (UMS) in Kota Kinabalu, Sabah; problem-based learning is conducted. The laboratory work assists students to understand environmental issues by conducting experiments and testing on the problem cases proposed. Transition on conventional/expository laboratory to open-ended (PBL) method is discussed and the effect were quantified and investigated. Differences and challenges of the learning approach in implementing PBL in the laboratory course are highlighted.

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## II. METHOD

### A. Sample

Two consecutive cohorts of students from civil engineering programme were selected. Consecutive cohort of 2 different sample batches were investigated and named as sample Case 1 (n=41; male=18 & female=23) and Case 2 (n=52; Male=27 & female=25). Candidates were enrolled in environmental engineering laboratory course; under civil engineering program in the Faculty of Engineering, Universiti Malaysia Sabah (UMS). Within these 2 cases, students were put into small groups of 5 to 7 to allow them to communicate, work in team and discuss within peers for the whole process of laboratory investigation until completion of technical report submission.

### B. Research Design

Environmental laboratory is one of the compulsory courses for the Civil Engineering Programme students. Case 1 used conventional instruction-based laboratory approach whereas open-ended laboratory approach was conducted for Case 2. Both case outcomes were categorized as predetermined since it is in accordance to the focus topic and instrument availability. The difference of both cases based on the predetermined course outcome was summarized in Table I.

For both cases of study, the implementation stages were categorized into i-conceptual, ii-experimental work and iii-analysis and report stage, as given in Fig. 1. The changes of approach at each stage were differentiated in the concept (lab and testing measurement) given to students, allotted time frame, instructor and demonstrator role, and the written report format and assessment feedback/monitoring techniques.

TABLE I  
SUMMARY OF THE DIFFERENCES BETWEEN TRADITIONAL AND OPEN-ENDED LAB AND ITS RELATION TO THE COURSE OUTCOME

Course outcome	Delivery and assessment method	
	Traditional lab style (case 1)	Open ended lab (case 2)
Able to carry out experiments with proper procedures and techniques in relevance to the environmental issues & problems (water quality, pollutions, waste)	<ul style="list-style-type: none"> <li>Laboratory briefing</li> <li>Laboratory work with demonstrator</li> <li>Test and final examination</li> </ul>	<ul style="list-style-type: none"> <li>Laboratory briefing</li> <li>Laboratory work with facilitator</li> <li>Student presentation lab poster</li> </ul>
Able to develop relation and practical problems and environmental issues (water/air/noise pollution) by analyzing evaluation and interpret experiment results	<ul style="list-style-type: none"> <li>Laboratory work (instruction manual)</li> <li>Procedure given</li> <li>Observation during lab work and demonstration</li> </ul>	<ul style="list-style-type: none"> <li>Laboratory work (problem based)</li> <li>Procedure generated by students</li> <li>Observation and reflection student discussion</li> </ul>
Evaluate and write technical report outcomes in the systematic format	Laboratory report	Research journal format

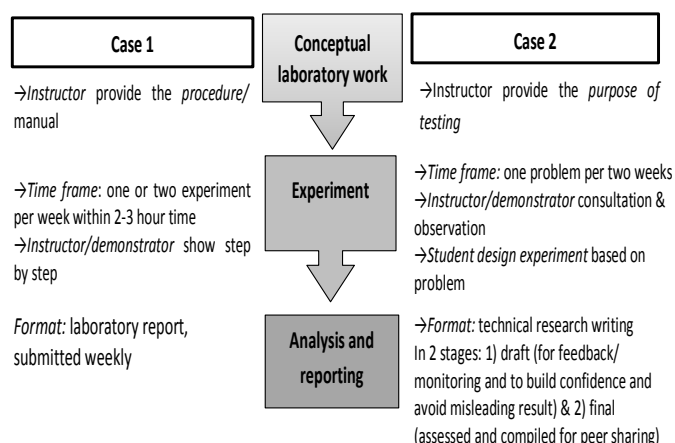


Fig. 1 Implementation difference between Case 1 and Case 2 for Environmental Engineering laboratory (civil engineering) course at UMS

The laboratory course were still utilized the same existing equipment and topics as in the course learning outcome and objectives, only the teaching and learning implementation has been modify with problem-based. In other words, adapting the learning experience for the students rather than changing the experiments. The problem cases have several routes to solve and not limited to one step solution. Examples of the titles and problems given or provided in the environmental engineering lab course were listed in Table II.

### C. Data Analysis

The measurable effect on the effectiveness of teaching and learning in open ended laboratory compared to expository (traditional) style work is simplified in Table III as follows. The Course outcome measurement method has been described elsewhere [7], whereas the course assessment student feedback evaluation is collected through questionnaire.

TABLE II  
SEVERAL OF EXPERIMENT WORK AND PROJECT CASE TITLES FOR BOTH LABS

Traditional lab style (case 1)	Open ended lab (case 2)
Experiment A: Demonstration of Aerobic Digestion	Case A: study on feasibility of food waste for biogas as renewable energy
Experiment B: suspended solid determination in polluted water sample	Case B: lake water quality in School of Science: is it suitable for consumption?
Experiment C : Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) determination using Azide Modification method	Case C: Reliability of Student hostel water filter
Experiment D: Noise monitoring test using noise level meter	Case D: Noise level in lecture hall

TABLE III  
ANALYSIS PERFORMANCE FACTOR STUDIED IN THIS WORK

Analysis factor	Parameter of measurement	Unit
Course assessment (student feedback) before end of course	Course assessment on: 1) delivery and assessment, including resources and equipment 2) facility of learning including resources and equipment 3) soft skills including communication, critical thinking teamwork and ethics.	Student survey rating (likert scale) of 1 to 5; with value of 1 disagree up to 5 as agree  i.e. Disagree → Agree 1→2→3→4→5
Student course grades	Total course marks of assessment and evaluation	Percentage of grade achieved(A, A-, B+, B, B-, C+, C, C-)
Course outcome (CO) learning indicator	Student continuous assessment and evaluation	CO1-Very poor, completely not achieved CO2-Poor, CO is not achieved CO3-satisfactory of CO achieved CO4-Good, CO of the course achieved CO5-Very good, course outcome has excellently achieved

### III. RESULT AND DISCUSSIONS

The student distribution characteristics for both case is considered similar since are final year civil engineering undergraduate students of consequent year of cohorts and have consistent sample background in terms of gender distribution with 56% and 48% female and 44% and 52 % of male student respectively in sample case 1 and case 2.

The comparison of student survey which conducted before the final exam of course is illustrated in Fig. 2. The survey was given to student before end of the course (at week 12 out of 14) as to avoid biasness with their final examination result and grades. As shown in Fig. 2, student satisfaction and perception towards the implementation of the course were given lower rating for PBL-lab style compared to traditional lab. The course student feedback has lower rating of 3.8 - 3.9 in case 2 compared from previous cohort of case 2 (traditional lab) which are 4.2 - 4.3.

The responds and perception could be attributed to their experience and difficulties in understanding concept, interpreting laboratory cases while refine hypothesis and correlate results, that has pushes them to give more work and effort than traditional lab. This was also observed by Azer et al. [8] at their early investigation and then they introduced further training in knowledge application, select task-based and student-centered approach through short and long term learning environment via four integrated laboratory classes. Proven as well by Kelly and Finlayson [4] using PBL lab approach, students often do not like changes or new challenges yet would be effective when conducted progressively at longer duration (i.e. Year to year of study). Therefore, in spite of implementing open-ended lab at later stage which is for this cohort at their end of their study (final year), it would be more effective when employed from early year of study.

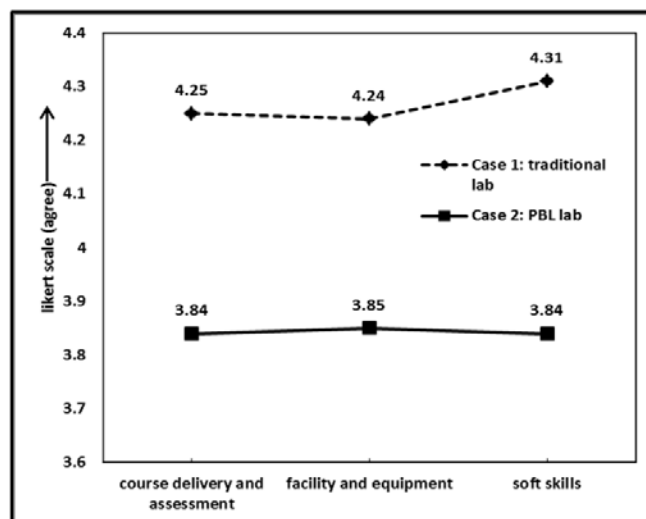


Fig. 2 Course assessment (student feedback) before end of course (week 12 out of 14)

Interestingly, in spite of their perception and feedback on the course, the achievement for both cases of sample in terms of course grade were shown a positive increment when transition from traditional to problem-based lab as illustrated in Fig. 3. Most student feedback toward the course is given less likert scale when PBL implemented, however the grade has been increasing. The assessment include final test, quiz or poster presentation and continuous assessment of lab report for traditional or journal research write-up in PBL lab. Student was able to perform better grades in PBL lab implementation and skewed positively higher than traditional lab.

Furthermore, the continuous assessment and evaluation include poster presentation for case 2. The idea is to expose and make students aware the concept of the laboratory work and the purpose of doing testing, with the available equipment in the environmental lab.

In the first day of lab, students were given safety briefing and given their first task to prepare and present poster on the existing equipment. Many of the students initially were anxious because they were usually provided with laboratory manuals and given lab demonstration, however the key is to ensure student cooperation and learning with opportunity to demonstrate their expertise to others. Also, poster sessions were suitable for classes of all sizes, promote collaborative learning, encourage creativity and independent thought, develop research and communication skill, and ease the grading burden on instructors [9]. Poster was selected as learning techniques for students to understand and apply the concept of equipment testing available in the lab, yet encouraged to utilize equipment outside the environmental lab in solving their problems/task. Hence, it allows students to demonstrate their expertise in a dialogue manner, allows students to get immediate feedback from peers and evaluators and also it gives students the opportunity to learn to present information in a format common to many professionalism [10].

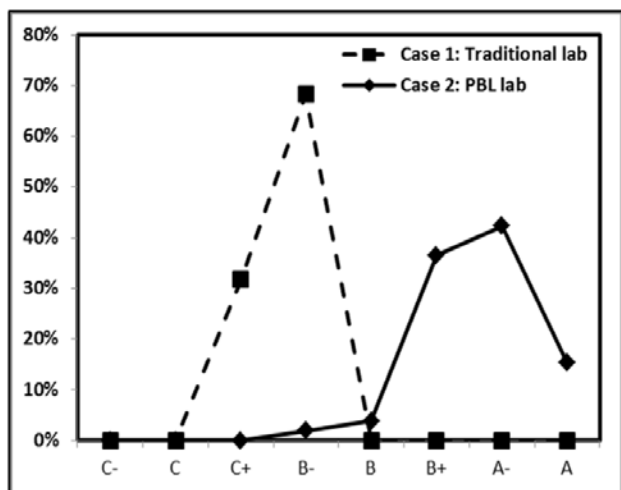


Fig. 3 Student grade achievement for both lab style in the environmental lab course

For case 1 which were conducted expository (traditional lab), step or procedure are given and student are expected to follow step by step. Whereas in case 2, students were self-directed due to the given task are open-ended, imposing them to innovate and conduct investigation on the real issues. Moreover, the laboratory activities and task mode of question/task was indirect and thought as 'mini research' approach. The difference was explained previously (Table II).

The analysis of course outcome (illustrated in Fig. 4) found that the course outcome has increased in the implementation of PBL in lab work. Both courses has achieved more than the indicator level which is 2.00 out of 5.00 [7], however the implementation of PBL lab has successfully increased the achievement of course outcome from 3.4 to 3.8. This is approximately 12% increment and could be the indicative on the influence of facilitation and discussion throughout the course improvement. Furthermore, learning capability during PBL approach has increased student understanding and at the same time incorporating student ownership, relating experiments to previous experiences, and getting students to use higher order cognitive skills that would provide authentic investigative processes [10].

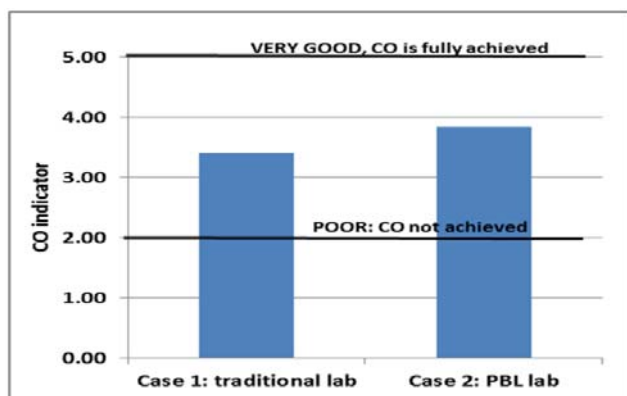


Fig. 4 Influence of traditional and PBL lab to the average course outcome

#### IV. CONCLUSION

In conclusion, transition of laboratory course taught for civil engineering student of Universiti Malaysia Sabah has demonstrated an increase in their learning performance. Both traditional and PBL students cover all same techniques and lab concepts of environmental measurements within the same frame time and using similar resources. The non-traditional of PBL approach however has increased student grade performance and higher course outcome (CO) achievement as analyzed in this paper. Though student perception were observed reduced in PBL laboratory approach, improvement will be made for the next implementation by incorporating non-traditional laboratory in the early year of study so that learners will appreciate and increase their preference toward the concept and purpose of the teaching and learning strategy.

Despite of some positive evidence on the transition effect, it is felt that this is at preliminary stage only, and need more investigation. Further research question identified in this work include the investigation on the student learning time and teacher's/instructor's work load, and also on the correlation on their teaching and learning experience. In spite of everything, the PBL approach is seen as a success in compared to traditional laboratory experience studied in this work.

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