Effectiveness of Open-Ended Learning Method in Fluid Mechanics Laboratory Course

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***Abstract*— The theory of a principle could be further understood by performing practical analysis. Laboratory courses provide the practical application of the principle taught in lecture. Previously, laboratory courses were conducted through instruction style but with the evolving learning method, new learning method which emphasize on in-depth learning is introduced. This paper studies the effectiveness of open-ended learning method over the traditional method. The effectiveness of the activity is made through response from questionnaire and observation of both learning methods. It was noted that the open-ended method improves the students' understanding on the course, promotes collaborative learning, encourages creativity and innovative skills, independent thought, and communication skill. The students prefer the open-ended learning method over the traditional learning method.**

Keywords— learning method, open-ended, laboratory course.

I. INTRODUCTION

In the fast moving and high technology world, most of the engineering graduates are facing tougher opportunity to get a job. One of the reasons being so is the quality of the graduates are declining and missing on certain technical skills and trait as engineer. It was reported that most of the employers are concern on graduates' ability to apply their knowledge to real industrial problems. Traditionally, engineering students focus on dealing with advanced math, taking notes, working in isolated labs etc. Today, engineering is at core of so many complex global challenges in which the graduates have to incorporate cross-disciplinary, even multi-disciplinary programmes which is essential now to train new engineers. For example, students are required to learn product designing, considering the various conflicting elements needed to bring them to completion, form function, marketing and consumer behavior.

In order to improve the quality of engineering graduates, a new requirement has been set by the accreditation panel in assessing the ability of critical thinking, evaluating complex engineering problems and open-ended problems amongst students. Thus, teaching and learning method in universities needs to be adjusted in addressing these elements into all courses offered including laboratory courses. Few initiatives haves been taken by the university in handling this matter. In every courses offered, element of complex engineering problem is assessed by giving real case engineering problem where there is no one true solution is expected. In normal courses, these elements are assessed either through assignments, quizzes, projects, test or exam. As for laboratory courses, it is done through open-ended experiment.

Laboratory courses bridge the theoretical and practical aspects. Laboratory activities also prepare the students on the expectation in dealing real world problems. In common educational laboratories practices, students come to learn and apply something that practicing engineers are assumed to already know. The student just need to follow the instruction given, collect the necessary data and answer some questions based on the data collected. This learning method only promote surface learning method without compromising critical thinking, designing and evaluating the solution. Since the implementation of the new requirement, these laboratory courses are required to develop an in-depth learning method which students are required to design a method, evaluate the method and come out with a solution based on the problem given [1,2].

Through this open-ended learning method which has no exact method and solution is expected promotes the learners to have in-depth thinking [3] and to have more explorative learning method [4, 5]. Since there is no exact method, the students need to understand the fundamental of the problem and to work theoretically and practically in achieving the solution. In open-ended activities, only the objective of the task and brief explanation are provided. The students have to come out with their own methodology in evaluating the problem and thus no exact solution amongst the students is found. Through this method, the students are required to have an extensive background study on the task given. The students are required to understand the principles involve in generating the methodology to evaluate the objective. Therefore, learning abilities amongst the students could be improved [6], encouraging creativity and innovative skills, exposing the students to design elements and preparing for real world applications [5, 7]. Open-ended activities also increased independent learning [8] with minimal involvement from the

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instructor [9]. It was also said that this type of activity can be low cost and time efficient [9].

This paper aims to study the perception of students towards the new element introduced and assessment method on the Fluids Mechanics Lab course. Initially, the course was assessed through traditional lab activities ie by conducting experiments and practical test. Since the new implementation made by the accreditation board, changes were made by introducing the open-ended activity where the students have to come out with their own experiment and analysis based on the problem stated provided. The perception on both methods was done through a questionnaire which was given at the end of the semester. Based on this questionnaire, the preferable method either doing the traditional laboratory activities or the new introduced method was concluded. Besides that, observation on students' performance was made throughout the semester. Comparison on the ability to explain the result was made between the traditional method and open-ended activity. The study concludes that the students prefer the new introduced method over the traditional laboratory activities because the students were given the freedom to create their own experiment, apparatus and methodology. The students also mentioned that they could explore more on the principle learned and relate it to the current engineering problems besides understand the principle better as they have to have an extensive study on the problem given. This approach is suggested to be adopted in other courses as it promotes in-depth independent learning method which will be a valuable trait for the graduates.

II. METHODOLOGY

A. Background of Fluids Mechanics Lab)

In mechanical engineering programme besides taking core courses, it is necessary for the students to take laboratory courses and one of it is Fluids Mechanics Lab. This course is the laboratory course for the course Mechanics of Fluids that is taught in the second year of the four year programme. The two subjects were taken concurrently in the same 14 weeks semester however the subjects were assessed separately. In a week, three hours of lecture with one hour of tutorial were allocated for Mechanics of Fluids and another three hours for Fluids Mechanics Lab. This laboratory course provides practical application on the basic principles of fluids mechanics such as Bernoulli, measurement of fluid flow, principle of hydrostatic, losses in pipes and pump performance. There was a total of eight experiments to be conducted and the list of experiments is tabulated in Table 1. These experiments were conducted in groups. Typically in laboratory courses, there are 30 students per session and the students are divided into groups of 4-5 students per group. The system adopts by the university in conducting lab is rotational system which different group conducts different experiment each week. This is due to the limited number of apparatus where only one apparatus available for each experiment. In the beginning of the semester, the first two weeks were allocated to conduct introduction briefing where the students are informed on the assessments, lab activities, brief introduction on the experiments as well as the safety and code of ethic in the laboratory. During these sessions, explanation and discussion on the open-ended activity assessment is conducted. Sample of previous works were shown to the students as references. The detail of the activity was explained during the beginning of the semester to give ample time to the students to prepare and conduct the activity.

TABLE I. LIST OF EXPERIMENTS AND PRINCIPLES INVOLVE

No.	Name of Experiment	Principle Involves
1	Performance of Pelton Wheel	Measurement of Flow, Hydrostatic
2	Flow Visualization	Fluid Kinematics, Viscous Effect
3	Characteristics of Venturi Meter	Measurement of Flow , Hydrostatic, Bernoulli
4	Flow Condition	Viscous Flow
5	Head Loss in Pipes due to Friction	Viscous flow in Pipes
6	Head Loss in Pipes due to fittings	Viscous flow in Pipes
7	Performance of Single Pump	Compressible flow, Turbomachines
8	Performance of Double Pump	Compressible flow, Turbomachines

The course was assessed through few learning outcomes which are on conducting practical application, obtaining and analyzing data, designing and evaluating experimental methods, communicating through oral and written forms, working in team and demonstrating professional and ethical behavior as listed in Table 2. These learning outcomes were assessed through few assessment methods listed in Table 3. Initially, the laboratory course was assessed through traditional lab activities ie conduct experiments and practical test. Since the new requirement is introduced, an open-ended activity is introduced and assessed besides the common eight traditional laboratory activities. Majority of the current assessments was on the report produced which carries 60 %, another 20 % on the open-ended project and the rest was on graph assignment, peer evaluation and instructor's evaluation (based on students' originality of report and attendance) as tabulated in Table 3. As for open-ended project, the students were given either a problem statement, hypothesis or just a principle to explore. Based on the condition given, the students were required to design their own experiment. The students were required to develop the methodology, evaluate the method and come out with a solution. Even though the students were given the freedom to design the experimental method, the students need to consult with the instructor on the reliability of the method and safety issue. At the end of the semester, the students are expected to produce a laboratory manual of the experiment as well as present the findings in oral presentation. During the presentation, the students have to discuss the hypothesis, methodology of the experiment, data obtained and verify the analysis accordingly follows by with a question and answer session amongst other classmates and instructor. Oral presentation was done on week 12, thus ample time was given to the students to prepare and conduct the project prior to the project.

Through this open-ended project the course outcome (CO 5) which is to identify, design and evaluate experimental methods in solving fluid mechanics principles was assessed and CO 7 which is on the ability to communicate effectively through oral form was assessed in oral presentation. Although the laboratories activities are conducted in group however the students are assessed individually.

TABLE II. LIST OF EXPERIMENTS AND PRINCIPLES INVOLVE

No.	Upon completion of this course, the student should be:
CO1	Conduct experiment and obtain required data
CO2	Illustrate experimental data in graphical form
CO3	Manipulation data in various form to clearly explain the solution
CO4	Analyze and apply appropriate fluid mechanics principles
CO5	Identify, design and evaluate experimental methods in solving fluid mechanics principles
CO6	Communicate effectively through written form
CO7	Communicate effectively through oral form
CO8	Work in team effectively to complete the experiments
CO9	Demonstrate professional and ethical behavior while experiments

TABLE III. SUMMARY OF ASSESSMENTS AND ITS WEIGHTAGE

Assessment	Weightage (%)
Graph Assignment	5
Reports	60
Open-ended Project	20
Oral Presentation	5
Peer Evaluation	5
Instructor Evaluation	5

B. Assessment on the effectiveness of Open-ended Lab Activity

The evaluation of open-ended lab activity was done by comparing the effectiveness of open-ended lab activity method with the traditional laboratory method. Both methods were categorized into three stages which are the conceptual, experimental work and analysis and report as shown in Fig 1. The main difference between both cases is the guidance coverage given by the instructor to facilitate the students in performing the experiment. In the traditional laboratory method, detail procedure and analysis approach were outlined while the open-ended lab activity, the students were have to design the methodology for the experiment based on their understanding. In this study, a total of 40 students were selected as sample of study. The perception on the open-ended lab activity and its effectiveness were collected through a questionnaire given out at the end of the semester. The questionnaire was divided into two parts which measure the satisfaction and perception of (i) traditional laboratory method and (ii) open-ended lab activity. The advantages and disadvantages of both methods were also listed down. The measurement of satisfactory and perception on the traditional laboratory method was done through the eight experiments listed in Table I. On the other hand, the measurement of the second method was done through the open-ended project. Besides conducting survey, observation on the ability to carry out the experiment with minimal guidance was done through oral presentation. Even though changes were made on learning approaches, the course utilizes the same topic, existing experiments and learning outcomes. Additional learning implementation was adopted to diversify students' learning method.

III. RESULT

The satisfaction and perception on the learning approaches were compared between the traditional laboratory method and open-ended lab activity which was done by conducting a questionnaire at the end of the semester. Based on the result, the satisfactory and perception on the traditional method is found to be low compared to the newly implemented open-ended method. As shown in Fig 2, only 27 % of the students were satisfied with the traditional learning approach compared to 73 % for the open-ended learning approach. Through the open-ended learning method, the principle involves in the experiment is understood better (66 %) and the creativity and innovative skills were enhanced (88 %). Majority of the students (54 %) prefer to have the open-ended method to be implemented in the laboratory courses compared to the traditional method.

The students' perception on the traditional laboratory method was unexciting and rigid. The activity was done in a controlled environment, limited to the objective set and the students were unable to explore other parameter even though the apparatus is able to do so. Some of the students commented the impact of the practical activities on the understanding of the subject was minimal. Since the procedure was provided, analysis method and discussion questions were prepared, the activities were too rigid by just following the steps without knowing the purpose of doing so. Little effort was put by the students in evaluating and justifying the result obtained and thus understanding on the principle was minimal. As commented by the students, the principle involves could be better understood if the freedom on conducting and analyzing the data is given.

On the other hand, the feedback on the newly introduced open-ended method can be summarized that the students prefer this method than the traditional laboratory method. As mentioned, the students were given the freedom to pick the hypothesis, design the apparatus and methodology and analyze the result. Even though it is stated that the students faced challenges in the beginning of the activity, the students enjoyed the experiment performed and believed that the open-ended project has helped them to understand the concept better than the traditional method. The students need to perform extensive studies in order to come out with a topic either based on the topic learned, engineering application such as demonstrating on the working a hydro turbine and the usage of house pump, or current events such as factors of aircraft crash incident or the occurrence of tornado. Usually, the theory picked was based on the students' curiosity which then evolves to a systematic study. Besides that, the students were required to come out with a proper justification of the result obtained to validate the data. The students also commented that the creativity skill was enhanced through this learning method since the students were required to design the apparatus with limited resources ie low cost and recyclable materials. Thus this learning activities has increased students' understanding on the principle and getting students to use higher cognitive skill in producing creative, innovative, cost effective and systematic process. Besides learning on how to develop a systematic experimental method, the students also appreciated the design process such as time management and cost management.

Besides evaluation through questionnaire, both methods were also evaluated through instructor's observation on how the students conduct the experiment as well as the quality of report produced. Through observation made throughout the

semester, positive reaction was found either on how the students conduct the lab activity or quality of report in the open-ended learning method. The respond when conducting the traditional laboratory method ie conducting the eight experiments listed in Table I, was unexciting and less participation by the students. In every lab session, an interview session is done prior conducting the experiment. The basic principle, methodology and the expected outcome from the experiment were discussed between the students and instructor. It was observed that, the students were unprepared and had little understanding on the experiment. Poor performance was also reflected by the report submitted for each experiment. Poor justification with little reference on the principle was made on the results obtained. Discussion was made on the surface without proper explanation.

However, during oral presentation for the open-ended project, the justification of result was improved where the students could relate and discuss the results obtained with proper validation on the principle. The performance of discussion and analysis part for oral presentation was found better than the same part for the report which both assessments have the same assessment criteria. The students could relate the results obtained and properly discuss it based on the stated objective. The students also could answer the questions more confident compared interview session during traditional laboratory activities. Teamwork amongst the students were also improved. It can be observed that, the open-ended method promotes collaborative learning, encourage creativity and innovative skills, independent thought, and communication skill. The oral presentation session allows demonstrating the students' expertise in a dialogue manner, getting immediate feedback from instructor and peers, and also developing the ability to present information professionally.

Overall, the students prefer to have the open-ended method in laboratory courses than the traditional method as the freedom in conducting the experiment is given. Since the freedom in selecting the hypothesis is given, the selected topic usually based on the students' curiosity either on a particular incident or on the preferred application.

However, constant monitoring by the instructor is important in making sure the decision made by the students is correct and not mislead from the actual principle. Even though the learning capability and student understanding have increased, facilitation by the instructor is still important. On the other hand, traditional laboratory method encourages the students to follow instruction systematically which is the most important aspect in dealing with engineering applications. In either ways; traditional method or open-ended method, the learning outcome of the course should be emphasized. Balance approach between the traditional and open-ended methods should be incorporated in the course to have good learning outcomes.

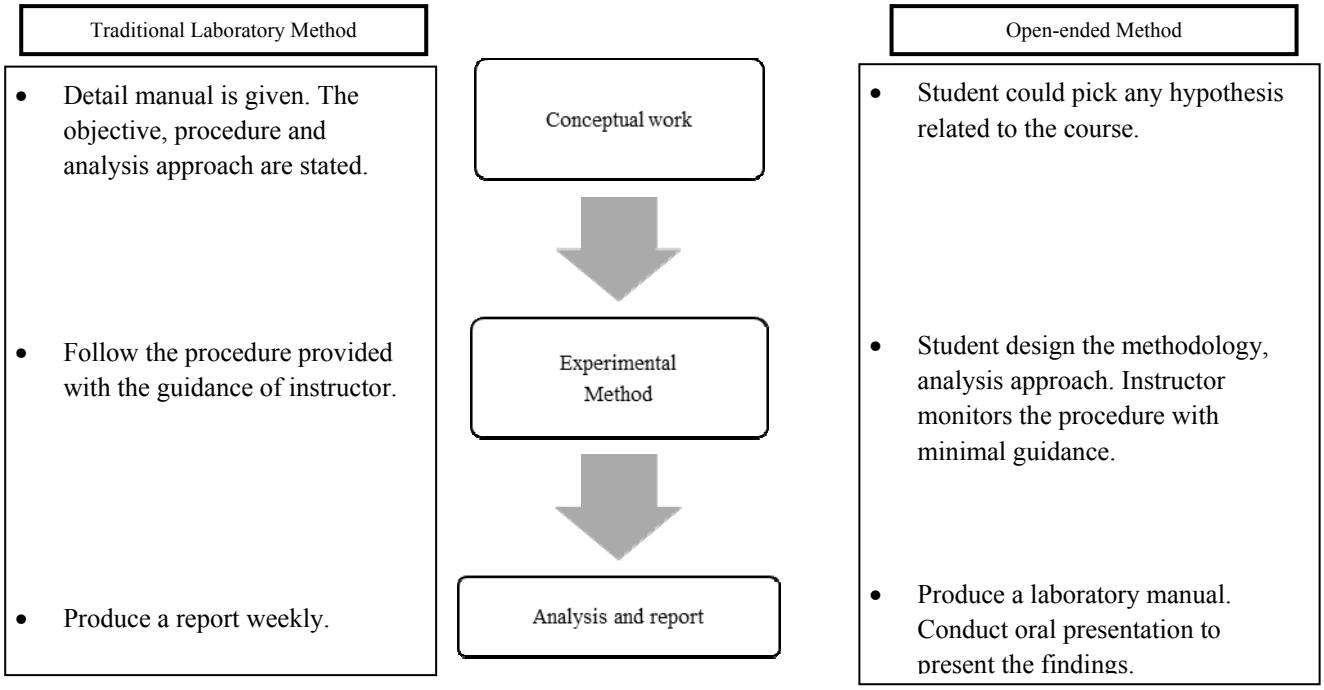

FIGURE I Stages of the traditional method and open-ended method for the Fluids Mechanics Laboratory course.

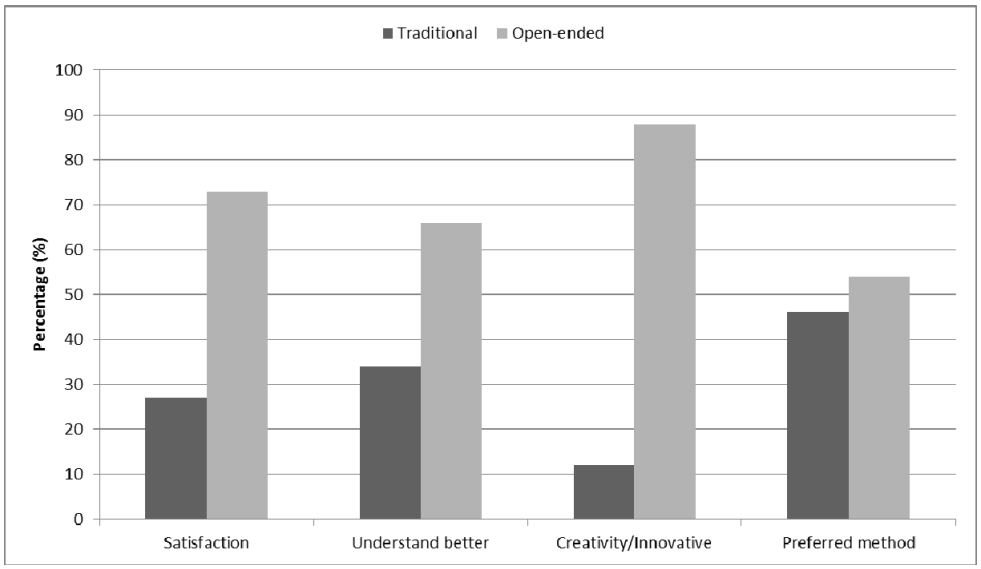

FIGURE II Distribution of students' opinion on the traditional learning method and open-ended learning method

IV. CONCLUSION

The effectiveness of open-ended learning method is compared to the traditional learning method in a laboratory course. Based on the questionnaire conducted and instructor's observation, it is concluded that the open-ended method has increased the students' understanding on the particular subject and giving the students a platform to the students to be creative and innovative in designing the experiment. Students' ability on analysing, discussing and validating the data obtained has increased through this method. Although the open-ended method is preferred by the students, balance learning method should be integrated in the course in order to achieve the learning outcomes outlined. However, not all laboratory courses can be transformed due to the nature of the course.

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