Using e-tutor program and pre-lab assessment task to enhance laboratory experience of civil engineering students

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***Abstract**: Before attending a lab session, students are usually required to be familiarized with laboratory tasks through pre-lab preparation. While it was found pre-lab preparation was an effective way to promote student learning, the benefits of running pre-lab preparation were not fully investigated. Traditional lab description sheets may provide general information on safety operation procedures and pre-lab questions. However, if these pre-lab questions were not assessed, they could easily be ignored by students. In this research, pre-lab problems were designed to give unique parameters to each student. Students were required to solve the problems and obtain theoretical values which were verified later in a practical lab session. To minimize the marking load, the pre-lab submissions were automatically marked using the e-tutor program. Results showed that the pre-lab preparation program was successful in enhancing students' learning interests, in preventing plagiarism, and in increasing the efficiency of labs with the duration of a lab session being significantly reduced.*

Introduction

Involving students in laboratory activities is regarded as an important component in engineering education. Elaborately designed lab tasks will not only strengthen the theories learnt in lectures, but also help students gain analytical skills and develop practical intelligence (Razali and Trevelyan 2008). In discussing the role of laboratory in engineering education, Feisel et al (2005) enumerated a comprehensive list of objectives that serve as a basis in developing lab tasks. The fundamental objective of a laboratory program is to provide valuable hands-on opportunities for students to identify engineering problem, to explain observed phenomenon and to formulate a solution to the problem. From engineering career development point view, laboratory activities will help students gain engineering competency and develop professional attributes.

In order to assess whether a lab task is successful and how well the objects are achieved, effective assessment methods need to be developed. As a traditional assessment method, lab report plays an import role in assessing students' overall performance in a lab. Since report writing is a post-lab activity, the lab objectives may not be well understood if students do not spend time to familiarize themselves with the lab task before a lab session, until they start writing lab reports. Occasionally, a lab task may be repeated after a lab session in order to collect useful data. Without pre-lab preparation, students may solely focus on lab procedures about how to perform the experiment during a lab session. This requires the lab demonstrator to spend more time to explain the objectives, procedures, safety requirements and to answer students' questions, resulting in longer session time and increased number of lab sessions. This inefficiency in running a lab increases the costs and often discourage the implementation of laboratory in a unit, particularly for units with large cohort. To address this issue, educators are seeking innovative methods to increase the effectiveness of laboratory activities. Giving pre-lab preparation tasks is one of the approaches that encourage students to preview lab tasks. However, if these pre-lab questions are not assessed, they may be easily ignored by students. With the rapid development of computers and Internet technology, virtual labs and online simulations have been introduced to enhance the learning experience of undergraduate students (Lowe et al. 2009; Abdulwahed and Nagy 2009). Nippert (2002) developed a couple of online labs to simulate a chemical engineering laboratory. The virtual labs were designed to prepare students before attending actual experiments. Students' performance during virtual labs was recorded and assessed. Results showed that the pre-lab simulations were successful in familiarize students with lab tasks. With the help of pre-lab tasks, the average time in completing actual labs was decreased from 1.6 week to 1 week. Another example of using web based video as pre-lab lecture was reported by Hesser et al (2009). The pre-lab program was used at the sophomore level in Organic Chemistry laboratories. Data were collected from lab instructors and teaching assistant in order to assess the effectiveness of the pre-lab preparation. The research proved to be successful in saving laboratory instructors' time while enhancing students' laboratory experience.

In this research, pre-lab tasks were designed for Engineering Statics which was a first year unit with an enrolment of 113 students in the first semester of 2011. Students' performance was automatically assessed using the e-tutor program. Students' feedback revealed that the pre-lab assessment tasks were useful in helping students understand the lab tasks. As a result of the pre-lab assessment program, the time spent on each actual lab session was significantly reduced, making it possible to introduce more lab tasks in the unit.

Development of pre-lab assessment tasks

Practice before e-tutor program was introduced

Engineering Statics is a core unit that is offered in the first semester to the first year students. It consists of three practical tasks. In order to provide a smooth transition from college study environment to university learning style, students were provided with proforma type of lab task description. Each lab handout included lab objectives, list of apparatus, experimental procedures, theoretical calculations, suggested observation, discussion items and data record sheets. Apparently, there were large amount of information that was required to be understood and digested by students before starting the experiment. It also took the lab demonstrator much time and effort to explain the description to students and to answer their questions. Some students found it difficult to finish the lab task within the two hours block allocated for each lab session. Although preparatory readings and calculations were required to be handed in to the lab demonstrator at the start of a lab session, they were usually ignored since no marks were allocated to the preparatory work. Marking of preparatory work would bring extra marking load to a lab demonstrator.

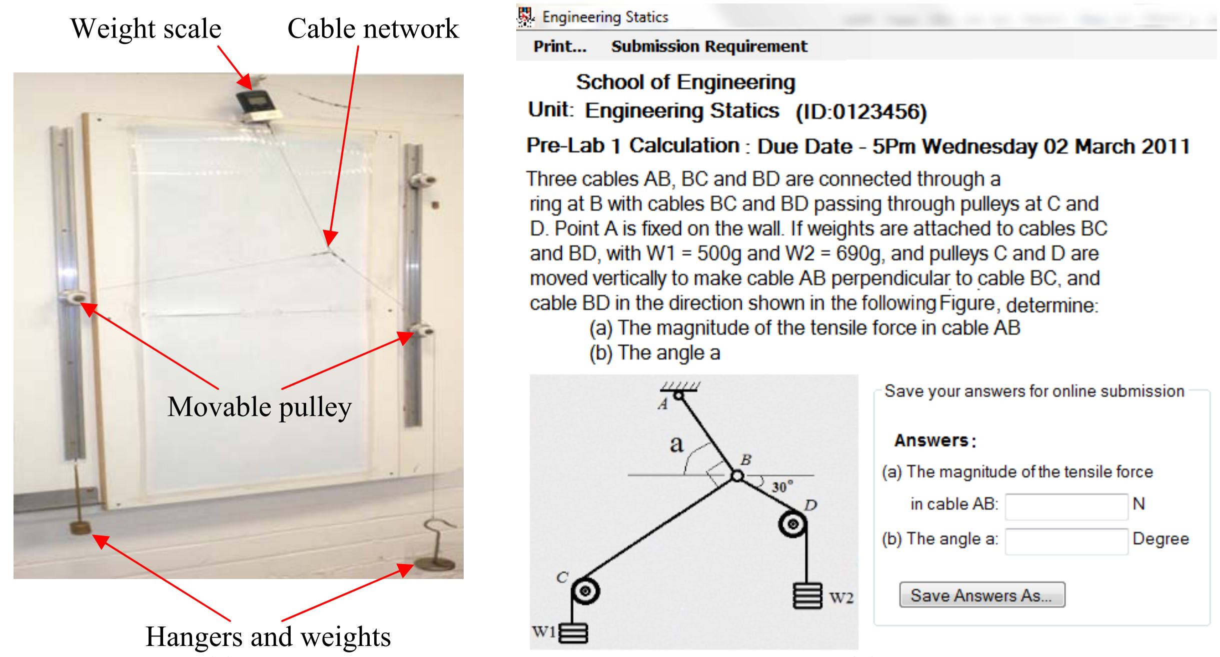
Introduction of e-tutor program

The e-tutor program was developed to automatically process students' online submissions (Jiao 2010). It consisted of student's end and lecturer's end programs. Main features of the program include randomized numbers being generated for each student within a meaningful engineering range. Answers were submitted online and automatically marked with feedback being displayed instantly. To encourage learning, re-submission was permitted before the due date if errors were made in the initial submission. The e-tutor program was successful in eliminating plagiarism, promoting students' learning interest in a subject. The e-tutor program was used to assess the pre-lab tasks in the first semester of 2011. Detailed examples are described below.

Application of e-tutor program on pre-lab tasks

Pre-lab task: Equilibrium of Forces

One of the labs implemented using e-tutor was the Equilibrium of Forces. The objectives of the lab were to observe the behaviour of a set of forces in equilibrium, to predict the direction of the forces by employing Newton's Laws and to verify the predictions by comparing the predicted answers with the measured values. The setup of the lab is shown in Figure 1(a). It consists of a wall mounted suspended cable network, a series of pulley bearing supports, a set of hangers and weights. The height of the pulleys can be adjusted. A weight scale was used to measure the force.



(a) **(b)**

Figure 1: (a) Lab setup of equilibrium of forces (b) Pre-lab task interface

The theoretical component of the lab was extracted from the lab description when designing the pre-lab task. Each student was required to calculate the predicted force in the cable connected to the weight scale, as well as the angle between the cable and the horizontal direction. The weight values W1 and W2 were randomly generated by the e-tutor program in a range between 260grams and 900grams. This weight range was determined by taking into account the availability of the number of weights in the laboratory, the angle when weights were applied and the capacity of the weight scale. Due to the different weight values, the calculated force and angle were unique for each student. As a result, it was impossible for a student to copy other students' work. If difficulties were encountered, students could either use discussion forums to discuss how to solve the problem, or approach to the lecturer or tutor for help. In this way, the e-tutor program efficiently prevented the plagiarism and increased students' learning enthusiasm in the unit. The answers to the pre-lab task were input in the textbox and saved to a file that was submitted online for automatic marking. One issue reported by Hesser et al (2009) was that students did not seem to retain the information obtained from a pre-lab task if an actual lab session was not scheduled directly after the pre-lab task. Therefore, the due date of the pre-lab task was set just before the date of the actual lab so that students were still retaining the objectives and the calculated values in mind when attending a lab session. During an actual lab session, students were required to apply the weights specified in the pre-lab task, and to compare the measured force and angle with the theoretical calculations. Since students were already familiarized with the objectives and procedures of the lab, they could concentrate on observations, measurements and the development of technical skills. The lab description hand out was also simplified with data record sheets being removed and related theory being relocated to the pre-lab task interface as shown in Figure 1(b). Another document called "Lab report format and marking criteria" was created to hold generic information and requirement regarding observation and discussion topics. With these changes, the Lab description handout was simplified to one page comparing to previous six pages. Each pre-lab task weighs 20% with the other 80% being allocated to a lab report. The answers to the re-lab problem were released to students immediately after the due date so that students could check and correct any wrong calculations before attending an actual lab session. With the pre-lab preparation, students were given the opportunity to solve a problem on paper by applying the theory learnt in lectures. They were eager to apply the knowledge and verify the theory in actual laboratory environment.

It can be seen that the values in a lab task could be pre-set and used as the actual values applied in a lab session so that the theoretical prediction could be verified in an actual lab session. However, in some scenarios, it might be difficult or impossible to keep the same values in a pre-lab problem as those in the actual lab. One example is illustrated below.

Pre-lab task: Force on a Submerged Plate

The main purpose of this lab was to study the hydrostatic pressure on a plate being submerged in water and to verify the predicted values in laboratory. The setup of the lab is shown in Figure 2.

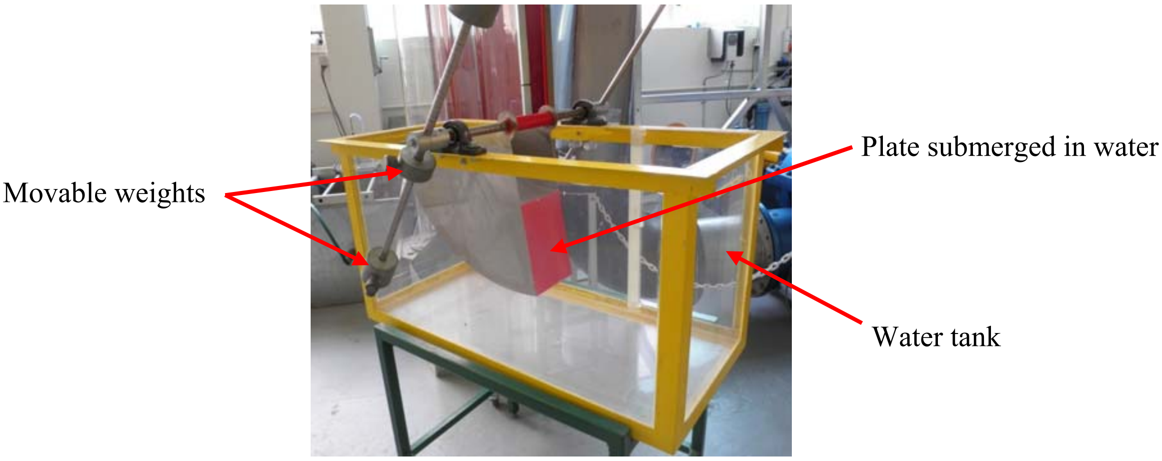


Figure 2: Lab setup of hydrostatic pressure on a submerged plate

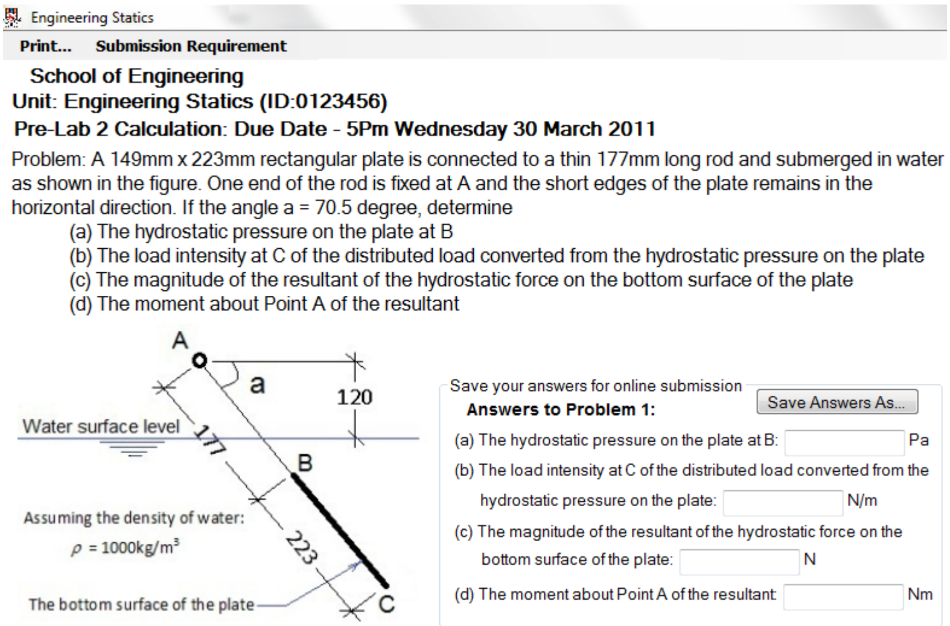


Figure 3: Pre-lab problem of the hydrostatic pressure on a plate

Four sets of equipment were manufactured to facilitate four groups of students (with four students in each group) to perform the experiment in one lab session. Each setup consisted of a water tank and an assembly with a plate being fixed to it. A number of weights were attached to the bars in the assembly. The moment due to the hydrostatic pressure on the plate could be balanced by changing the positions of the weights along the bars. Since the dimension of the plate in each assembly was different, it was impossible to pre-set the parameter values when designing a pre-lab problem. In this case, assumed values were used. Figure 3 shows the designed pre-lab problem, in which the plate dimensions and the water level were assumed. Students were reminded that the plate and the rod dimensions, other than the angle ‘a’, given in the pre-lab calculation must be measured during an actual lab session. When writing lab reports, the predicted values should be calculated based on the actual measured dimensions. Although similar calculations were repeated when writing a lab report based on the measurements, the pre-lab task served well in familiarized students with the objectives of the lab tasks. Particularly when errors were made in the pre-lab calculation, it gave students a chance to correct the errors when writing lab reports. Positive feedback from students and lab demonstrators about the pre-lab assessment program were received.

Evaluation of the pre-lab assessment tasks

Student’s view on the pre-lab assessment program was obtained through an online survey. There were 48 students completed the questionnaire, representing 42% of the total enrolment in the class. It can be seen from the result shown in Figure 4 that about 64% of students agreed or strongly agreed that “The pre-lab calculations helped me understand the lab tasks”. Around one third of students were not sure if they had experienced any difference. This may be due to the fact that the first year students did not have much experience on labs that was run before pre-lab tasks were introduced.

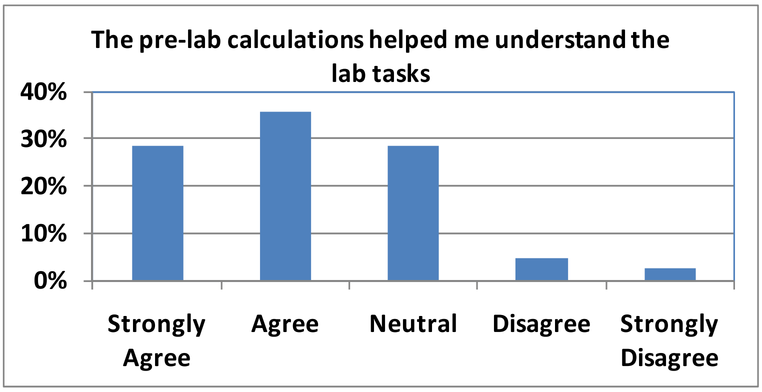


Figure 4: Students’ response on the role of pre-lab tasks

Some comments received from students include: “I really enjoyed the course; especially the lab reports on which a couple of us made a competition in creative writing. It was great fun!”; “Pre-lab tasks personalized lab activities, since different values were allocated rather than the same set of numbers”. Other comments included “It was interesting to see the theory played a part in the real world when I did lab practicals”; “Laboratory tasks provided interesting and more insightful uses of the knowledge we were trying to learn”. The hands on aspect was regarded as one of the best aspects in the unit in the finial student survey. One student suggested that “it would be good to have even more labs”.

Lab demonstrators also reported that they enjoyed each lab session that was short and very efficient. Detailed comments included “The pre-lab tasks look impressive and smart”; “students showed enthusiasm to verify their unique values and analysed possible sources of errors”. Through pre-lab preparations, students had enough time to finish the lab task within the allocated time session although the time spent on each lab session was reduced. A comparison was made on the laboratory data obtained in 2010 and 2011 as shown in Table 1.

Table 1. Comparison of data obtained in 2010 and 2011

Year	Time of each lab session (Hour)	Number of enrolment	Total time for one Lab task (Hours)
2010 (No pre-lab task)	2	96	12
2011 (with pre-lab tasks)	1	113	7

It can be seen from Table 1 that five hours was saved for the time spent on each lab in 2011 although the number of enrolled students was increased. The improvement in lab running efficiency due to the introduction of pre-lab tasks makes it possible to design more lab tasks in a unit.

Feasibility of applying e-tutor to other civil engineering units

The e-tutor program was applied to automatically mark assignments for a number of civil engineering units, including Steel Structures and Concrete Structures (Jiao 2010). It is worthwhile to explore the feasibility of applying e-tutor program to pre-labs of other civil engineering units.

Steel structures

Designing steel beams often involves an elastic analysis of a beam in bending. The distribution of the internal forces and the deflection of a beam subject to loads can be calculated using the beam theory. With the help of the e-tutor program, the section properties, the bending moment corresponding to the applied load and the theoretical deflections of a simply supported beam can be calculate through a pre-lab task and verified in an actual lab session.

Fluid mechanics

Theoretically the head lost through friction in a pipe can be expressed by Darcy-Weisbach equation. The head loss of a flow through a pipe can be calculated if the pipe friction factor, pipe length and pipe diameter are known. Based on this theory, a pre-lab task can be designed by assuming the friction factor, the length and diameter of pipes. The head losses in an isolated pipe can be predicted.

Conclusion

The e-tutor program was used to automatically assess pre-lab tasks in Engineering Statics. Results showed that the program was successful in promoting students' learning interests, eliminating plagiarism, enhancing students' laboratory experience and increasing the efficiency of laboratory activities. It should be noted that while pre-lab tasks can be used as a tool to stimulate students' interests in lab activities, students' overall performance in a lab session needs to be assessed using comprehensive assessment approaches.

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