041

Reinstating the Soul in Engineering Laboratory Work: Direct Observation Assessment Method

Aishah Abu Bakar
Depertment of Civil Engineering, University of Malaya, 50603, Kuala Lumpur, MALAYSIA.
aishah_ab@um.edu.my

ABSTRACT

This paper explores a case on the implementation of a new assessment procedure in a second year undergraduate soil mechanics laboratory. This new method emerged as a result of an attempt to constructively align assessment to intended learning outcome when Outcome-based Education is implemented. The new method involves the introduction of direct observation as part of assessment as well the usual assessment via laboratory report. Constructive alignment between assessment and learning outcomes with embedded formative assessment were used as a strategy to ensure active learning to occur. Assessing the learning process of laboratory activities rather than the end product increases the chances for laboratory key objectives to be achieved; hence, this may yield desired learning outcomes from the laboratory experience. The case presented demonstrates that the soul of engineering laboratory work can be reinstated if assessment involving active learning is carefully planned and the skills required in its implementation are acquired.

Keywords: *laboratory work, constructive alignment, assessing process, formative assessment, inquiry skills.*

INTRODUCTION

An engineering curriculum by its nature is an experiential discipline. From the earliest days of engineering education, instructional laboratories have been an essential part of the undergraduate and graduate programmes. Indeed, it could be said that most engineering instruction takes place in the laboratory [1]. The critical role of laboratory activities as instruction/learning in an engineering curriculum has been argued convincingly by several author [2] [3] [4] in the early days. However, on the whole, there is not enough emphasis on, and relatively little has been written about, laboratory instruction [5] [1] [6]. Feisel and Peterson [7] raised several factors that might rejuvenate interest in the subject. The accreditation bodies for engineering education have been pushing for its implementation, and through outcome-based education (OBE), proper laboratory instruction is beginning to receive proper attention.

Laboratory abilities/skills developed through lab activities are emphasized in several Quality Assurance Agencies (QAA) in the engineering curriculum such as the UK-SPEC and QAA [8] under practical skills in the United Kingdom, the second Engineering Criteria 2000 by the Accreditation Board for Engineering and Technology (ABET) in the United States; the Malaysian recognized accreditation bodies; the Engineering Accreditation Council (EAC) and Malaysian Qualification Framework (MQF). It implies that laboratory activities are important in preparing students for engineering experiences prior to their graduation [9] [1] [10]. They are used to develop students' ability to integrate theoretical and practical aspects in their course [11] [12]. Based on this argument, laboratory work is claimed to be superior to lectures and tutorials in teaching manual skills, introducing the equipment and its applications, as well as developing enquiry skills [13]. Roppel et al. [14] further claimed that laboratory activities are the platform for developing teamwork, oral and written communication and engineering ethics.

It is important to distinguish the type of engineering laboratory and its intended objectives before discussing the role of laboratory activities and how they may be designed for learning in a programme. Table 1 [15] shows five types of engineering laboratory that differ in the extent to which they 'open' student learning (i.e., foster student's choice and autonomy), in which they progress from instructor-led demonstration, where all aspects of the laboratory are given by the teacher, to student-led projects in which all aspects of the design are open to the students [11].

ISBN 978-967-5995-11-8 @2015 FEIIC

TABLE I. TYPE OF LABORATORY ACTIVITY AND ASSOCIATED LEVEL OF AUTONOMY

Level of autonomy	Type of laboratory activity	Aims	Materials	Methods	Answer
0	Demonstration	Given	Given	Given	Given
1	Exercise	Given	Given	Given	Open
2	Structured Enquiry	Given	Given in part or whole	Open in part or whole	Open
3	Open-ended enquiry	Given	Open	Open	Open
4	Project	Open	Open	Open	Open

Source: from Davies [11], Learning and Teaching in Laboratories in Engineering. Subject Centre guide, the UK Higher Education Academy.

Carter et al. [5] classified laboratory activities into three types, namely, controlled assignment, investigations/experimentation and project, which agrees with the view of Davies [11] in respect of exercise, structured enquiry and open-ended/project laboratory type. Feisel and Rosa [1] pointed out that if the effectiveness of laboratory experience is to be evaluated, lecturers need to be clear in respect of the objectives of the laboratory activities. Table II shows the objectives of laboratory activities for the three types as defined by Carter et al. [5].

TABLE II OBJECTIVES OF LABORATORY ACTIVITIES

Controlled Assignments
To reinforce theory learned from lectures, tutorials, directed and non-directed readings, etc.
To develop manual dexterity in the intelligent use of equipment, apparatus and tools.
To develop the ability to observe, check and systematically record data.
To provide training in formal report writing.
To provide the means for the development of awareness of the difference between theory and practice.
Experimental Investigation
To encourage the understanding of and ability to define precisely, those questions that require to be answered
To foster the ability to determine what measurements will be required.
To ensure that the students may gain confidence in the selection of the appropriate apparatus and strategies required to obtain such measurements.
To promote initiative in the ability to select the correct measurements and to arrange them in such a form as will give precise answers to the question posed.
To inculcate an intelligent appraisal on a proper assessment of the significance of the results obtained.
Project
To enable the student to better appreciate the existence of a problem that is capable of solution and the extent and nature of the likely scale of time and material resources required for such a solution.
To demonstrate a greater range of thought that is necessary in determining the possible solutions to the problem as well as the extent of the difficulties that intervene.
To underline the crucial role that decision making assumes in such an exercise.
To develop and improve interpersonal relations and the social skills essential for successful coordinated corporate activity.
To demonstrate the depth of constructive criticism required for both the solution adopted and the methods used.

It is clearly shown that if assessment is used as the means to drive the curriculum objectives, then the assessment of laboratory activities should not be confined to those related to the 'product of learning' such as laboratory report or a prototype. Davies [11] argues that in laboratory activities, it is the learning process that matters. As the process involves various stages and elements, assessing end products may be argued as not aligning assessment methods with learning objectives. Biggs [16] has argued that curriculum objectives, teaching methods and assessment processes should be aligned. Thus, the variety of assessment methods that are more appropriate to measure students' ability of intended learning objectives should be considered. To emphasize this important point the Malaysian code of Practice for Programme Accreditation, COPPA [21] stated:

> Assessment principles, methods and practices must be aligned with learning outcomes and programme content.
> (MQF Code of Practice for Programme Accreditation COPPA: 3.1.1: bullet 1, 2008, p19)
>
> A variety of methods and tools must be used appropriately to assess the learning outcomes and competencies.
> (MQF Code of Practice for Programme Accreditation COPPA: 3.2.1: bullet 3, 2008, p19)

It is clear that the new curriculum demands a shift from the traditional means of assessing laboratory work and welcome new innovative methods for intended learning outcome to be achieved.

MATERIALS AND METHODS

The case presented in this paper used mixed-method research approach and was part of the bigger research project of the electronic-assessment system for tertiary learning – EASTeL [17]. The direct observation assessment procedure was first introduced for second year students for the session 2008-2009. Qualitative data were collected, which includes field notes, videos, photos, personal communications, and the students' reflective log and focus group post interviews. Discussion in this paper mainly utilizes the author's qualitative data and focus group interview data as many learning issues emerged from these resources.

RESULTS AND DISCUSSIONS

A. Issues on Previous Practice

Soil Mechanics I is the first in the series of geotechnical engineering modules offered to second year civil engineering and environmental engineering students. It is a three-credit subject intended to introduce students to the mechanics of soil as civil engineering structural materials. The laboratory activities are embedded in the subject and delivered in a three-hour laboratory session. It contains two laboratory tests, which are directly related to the two main topics in the subject; that is, soil classification and compaction. The two laboratory tests are the Atterberg Limit Test (MT1) for soil classification and the Proctor Test (MT2) for soil compaction. These are British Standard tests, as specified in BS 1377 Part 2 and Part 4: 1990. These tests fall into type 1, the exercise [11], or control assignment [5] as previously defined. The new assessment procedure consists of assessment by direct observation as well as lab report. This procedure has been introduced to replace the lab report alone as the assessment method employed in the previous practice. From consideration of the nature of the exercise type laboratory work where the level of autonomy and enquiry skills of the students are low, formative assessment and feedback have been used as strategies to develop thinking and self-directed learning.

Previously, the assessment of the laboratory activities was solely based on group laboratory reports submitted two weeks after the laboratory activity. The previous practice raised several issues. First, there is an issue of conforming to OBE implementation; that it is whether the assessment method employed is constructively aligned. Second, is an issue on the ability of the previous practice in students' development of enquiry and practical skills when means of facilitation is limited. Third, is the assessment practice employed in the previous practice fulfilled assessment principles and drives learning as it should be.

Assessment that is only based on written laboratory reports ignores the importance of specific skills and abilities related to laboratory work. Skills, such as handling and setting up lab equipment, observation and linking theory to practice, cannot be taken for granted. As these skills are present in the process of doing laboratory work, the ability for it to be evidenced in the written lab report is not always possible. Again, if these skills are important, then undoubtedly they need to be assessed. Because they were not being assessed in the previous practice, the actual learning process were not focus on as students knew that they only need to produce good lab report to score regardless whether they do well or are even aware of the lab work they are attending. The implication from this unaligned assessment is that it was unable to produce key objectives of the laboratory activities, as listed in Table 2; moreover, it also failed to motivate students in learning practical skills. Students observed behaviour fits those 'cue-seekers' [18] that is students who only work when they are being assessed. Since the lab process was not given any marks, the extrinsic motivation of students has been removed. This could be the main reason for the students not treating the lab session as one of the most valuable learning experiences. Poor facilitation planning and organization of the laboratory activity may also contribute to students' showing lack of interest except for the 'feel for engineering' experience [19].

The repetitive nature of the previous lab work, described as 'a cook-book style' instruction, often demands less intellectual contribution from the demonstrator or lecturer and is often designed to run itself with minimum intervention. Consequently, staff attitudes, are often characterized as frequent boredom and even absence [5].

> *Very little interaction occurred by the middle of the session between staff and students. I and other staff seems to have plenty of time to ourselves. I cannot blame for this to happen as we were not trained in how to facilitate lab classes. I suppose the way we play our role was based on our informal past experiences.*
> (Field note: July - August 2008)

Facilitation skill is obviously different than teaching skill as the former requires one to exercise questioning skills as part of its role as an inquirer. Davies [11] suggested that demonstrators also need to be given initial training in learning, teaching and assessment that provides a basic understanding of the underpinning pedagogy to enable them to undertake the duties required. If it's not done, the old laboratory habit of students just following the lab 'cook book' procedure and recording the required data without much thinking remained evident.

Davies [11] argument concerning the disadvantages of assessing the lab report rather than the laboratory process was clearly demonstrated when random sampling of students' lab reports in this study showed unsatisfactory data sets and/or wrong results altogether which conform with observation during the lab session.

> *I am more concerned when students were not using the graph area provided in the form as a mean to either monitor the progress of their lab test or check whether their recorded values fall within the intended range of the test.*
> (Field note: 24th July 2008)

B.Direct Observation Assessment Method

The inclusion of direct observation or on-the-spot appraisal of student performance in the lab was intended to measure the laboratory process and student's practical skills [5]. As a result, new marking criteria were developed for direct observation of lab work (Table III). The presence of the lecturer in the laboratory was found to have an impact on the student's motivation.

TABLE III. DIRECT OBSERVATION ASSESSMENT MARKING CRITERIA

Criteria for direct observation measuring practical skills		
Manipulation:	5 – Outstanding	Shows high ability in manipulating laboratory or demonstration tools/ equipment / measuring apparatus especially on setting up and performing experimental / demonstration procedures. Also shows high ability in manipulating materials according to availability, needs and skills
	4 – Excellent	Shows ability to manipulate laboratory or demonstration tools/ equipment / measuring apparatus well, especially on setting up and performing experimental / demonstration procedures. Able to manipulate materials well according to availability, needs and skills.
	3 – Good	Able to manipulate laboratory or demonstration tools/ equipment / measuring apparatus, especially on setting up and performing experimental / demonstration procedures. Able to manipulate materials according to availability, needs and skills.
	2 – Satisfactory	Average manipulation of laboratory or demonstration tools/ equipment / measuring apparatus, especially on setting up and performing experimental / demonstration procedures. Average manipulation of materials according to availability, needs and skills.
	1 – Needs help	Difficult to manipulate laboratory or demonstration tools/ equipment / measuring apparatus, especially on setting up and performing experimental / demonstration procedures. Difficult to manipulate materials according to availability, needs and skills.
Observation	5 – Outstanding	Shows high ability in observing, paying more attention in important procedures, able to spot changes or unusual occurrence/behaviour. Record observation correctly and does extra notation on what has been observed.
	4 – Excellent	Shows ability in observing, paying attention on important procedures, able to spot changes or unusual occurrence/behaviour. Record observation and make small notation on what has been observed.
	3 – Good	Shows average ability in observing, paying attention on important procedures, average ability to spot changes or unusual occurrence/behaviour. Minimal records on observation provided.
	2 – Satisfactory	Shows little ability in observing important procedures. Minimal records on observation provided.
	1 – Needs help	Does not pay attention to important procedures or make any record on observation.
Marking criteria for the lab report		
Report writing format and layout Data presentation and handling tables and graphs Experimental notes and observations Presentation of results and conclusions		

This behaviour could also be due to the increased awareness of the assessed practical laboratory session, which students can no longer take for granted as their marks depended on how well they performed during the session.

> *During lab sessions, it was an opportunity for me to experience OBE when the lecturer observed us on how we conducted our practical lab work in order to enhance our soil mechanics knowledge. I have learned a lot through these lab sessions as I can see what is really happening and how it is useful in practice. It is easier for me to apply theory to my future real work....*
> (Student 11: Log real time account)

Although this method made marking criteria available well ahead before the assessment, it was found that students were actually having difficulty in translating their understanding of the criteria into the expected behaviour. They were as if trapped in their old lab habit where the lab session was just meant to give them the 'feel for engineering' [19]. The best intervention for such situation is to facilitate students using structured inquiry as recommended by Davies [11] in which open questions is used to encourage students to think and talk. The example of structured questions used and their intended purposes is shown in Table IV. The outcome of the facilitation through enquiry technique was very encouraging in which many students were observed making good observation notes and several students attempted to develop questions for themselves on the test procedures they were engaging in. The positive impact of an effective facilitation and assessment was indicated by the improved quality in a student's lab report.

TABLE IV. QUESTIONING APPROACH ADOPTED FOR MT1 THE LABORATORY

Sequence	Question	Intended Purpose
1	What are the required data to be filled at the top part of the form?	To create awareness on the need to complete and follow the intended procedure in the form provided.
2	Why do you think these data are important?	To trigger an awareness on the importance of materials information to the test objective.
3	What is the colour of the soil?	To guide student to fill in the first required information.
4	Does the soil belong to the fine or course-grained family?	To help students link theory to practice – what is being observed and what is being said in theory
5	How do you justify your answer? (This is normally the hardest part and the subsequent question is used to facilitate further thinking)	To develop confidence and to encourage students to recall part of the subject content already taught in the classroom.
6	If you rub the material between your fingers, how does it feel?	To help students to confirm their answer by a technique called rapid test in the soil mechanics as described in the theory.
7	How do you think this information relates to what you will observe or how you will handle the material during the test?	To encourage students to use information to plan appropriate technique for the test. The kneading method, for example should be used in preparing fine-grained soil sample.

One of the biggest challenges in implementing the direct observation assessment method is to match observed individual students behaviour to suitable descriptor as in the marking criteria. This is because in this lab work, students work collaboratively; that is five students per group using a set of equipment. Hence, each student involves in a different task. This research has revealed that this method of assessment requires special assessing skills that may be acquired through several cycles of practices. This research suggests that such assessment requires assessor to grade each students based on their unique individual task although similar marking criteria is being used. It is also highly recommended for those who like to explore this method to develop the rubric first, followed by piloting the rubric and refining it before formally employing this method.

The time when to finalise the grade can also be another challenge and need to be carefully planned. As some groups may complete their work faster than other, planning to grade at the end of the lab session may not be suitable. It was found that it is best to grade students work two to three times; that is in progressive manner and only finalised the grade at the end of the session.

To ensure the effectiveness of this 'cook-book' type assessment activity, embedding true formative assessment will ensures active learning [19]. This assurance demands lecturers to upgrade their skill to scholarly practice in assessment. The practice of true formative assessment requires reflection-in-action and the skill to facilitate using structured inquiry which often seen as much harder than reflection-on-action and unstructured inquiry. Schön [20] argued that reflection-in-action was the core of 'professional artistry' and indeed is a difficult skill as it requires prior knowledge and experience before a decision can be made to change the course of implementing a planned activity. Such attributes are not often natural to all lecturers and demonstrator and therefore need to be learned and practiced from time to time.

CONCLUSIONS

The role of laboratory activities in preparing engineers for the real world is no longer in question. However, the actual objectives of laboratory activities and how they are assessed are still debatable depending on how far

ISBN 978-967-5995-11-8 @2015 FEIIC

constructive alignment is being applied. An aligned assessment that includes assessing the laboratory process and the end product was found to yield desirable outcomes as intended. The direct observation method and laboratory report with improved assessment criteria and embedded formative assessment tested in the soil mechanics laboratories resulted in improved student learning behaviour. However, as no one method is perfect, other methods equally able to assess laboratory process such as group interview, extended critical lab report or poster presentation need to be explored.

REFERENCES

[1] Feisel, L.D. and Rosa A. J. (2005). The role of laboratory in undergraduate engineering education (pp. 121-130), Journal of Engineering Education.

[2] Hammond, P. (1971). The case for the teaching laboratory (pp. 77-79), Electron and Power .

[3] Sturley, K. S. (1967). Is laboratory work really necessary? (p63-66), Vol. 5, International Journal of Electrical Engineering Education.

[4] Halder, A.K., Jordan, T.A., and Carter, G. (1977). 'A survey of industrial attitudes to undergraduate electrical engineering courses' (pp. 11-16), Vol 14, International Journal of Electrical Engineering Education.

[5] Carter, G., Armour, D. G., Litt, M., and Sharples, R., (1980). Assessment of Undergraduate Electrical Engineering laboratory Studies. International Journal of Electrical Engineering Education, Vol. 127, Pt A, pp. 460-474.

[6] Wankat, P. C. (2004). Analysis of the first ten years of the journal of engineering education (pp. 13-21), Vol. 93 (1), Journal of Engineering Education.

[7] Feisel, L. D., and G. D. Peterson. 2002. *A Colloquy on Learning Objectives for Engineering Education Laboratories*. Proceedings of the American Society for Engineering Education Annual Conference, June, Mission Bay, CA.

[8] QAA (2006). Code of practice for the assurance of academic quality and standards in higher education. Section 6: assessment of students. (Mansfield: Quality Assurance Agency)

[9] Al-Bahi, A. (2008), *Designing Undergraduate Engineering Lab Experience To Satisfy ABET EC2000 Requirements*. Paper presented at 2008 Annual Conference & Exposition, Pittsburgh, Pennsylvania. https://peer.asee.org/3416

[10] Krivackas, R. and Krivickas, J. (2007). Laboratory instruction in Engineering Education (pp. 191-196), Global Journal of Engineering Education.

[11] Davies, C. (2008). Learning and teaching in laboratories. Retrieved from http://www.engsc.ac.uk/teaching-guides/laboratories.

[12] Aufschnaiter, C. and Von, A. S. (2007). University students' activities, thinking and learning during laboratory work, S51-S60. doi:10.1088/0143-0807/28/3/S05, European Journal of Physics.

[13] Edward, N. (2002). Evaluation of student-centred approach to first year undergraduate engineering laboratories (pp. 210-319), International Journal of Electrical Engineering Education, 39(4).

[14] Roppel, T., Hung, J., Wentworth, S. and Hodel, A. (2000). An interdisciplinary laboratory sequence in electrical engineering: Curriculum design and assessment results (pp. 143-152), Vol 43(2) IEEE Transaction on Education.

[15] Hazel and Baillie (1998), *Improving Teaching and Learning in Laboratories*, HERDSA Gold Guide No. 4, HERDSA Higher Education Research and Development Society of Australia.

[16] Biggs, J. (1999). *Teaching for Quality Learning at University*. UK, Buckingham: SRHE and Open University Press.

[17] Abu Bakar, A., Raja Hussain, R.M. and Idris, N.(2010). Driving culture change in Malaysian engineering education through EASTeL (pp 1537-1543),Vol 9, Procedia Social and Behavioral Sciences

[18] Miller, C.L., and Parlett, M. (1974). Up to the mark: A study of the examination game. Guildford: Society for Research into Higher Education.

[19] Moore, D.J., and Voltmer, D.R. (2003). Curriculum for Engineering Renaissance (pp.452-455), Vol.46 (4), IEEE Transaction on Education.

[20] Schön, D. A. (1983) The Reflective Practitioner: how professionals think in action London: Temple Smith.

[21] Code of Practice for Programme Accreditation. (2008). Malaysian Qualification Agency.

ISBN 978-967-5995-11-8 @2015 FEIIC