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ASSESSMENT OF PSYCHOMOTOR DOMAIN IN A PROBLEM-BASED CONCRETE LABROTARY

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Abstract

A rising awareness of the importance of professional skills for engineering students has led to increased attention being paid in engineering schools to the development of students' psychomotor skills. In the past, assessment of psychomotor skills was seen as being less important than assessment of knowledge and cognitive skills. Thus, this study discusses methods of implementation of psychomotor skills assessments in the teaching and learning process in concrete laboratory experiments. A combination of traditional and problem-based techniques of teaching is used, including lectures, tasks (using a problem-based learning format), flip demos, lab work, reports and surveys. Finally an overall assessment is conducted. Comparisons are made between the results obtained through psychomotor assessment and the final examination marks. It can therefore be concluded that the psychomotor domain of each student can be successfully measured. In comparing the results for psychomotor and cognitive performance using quadrant analysis, four categories of students can be observed, which are exam-based, technical-based, well-balanced and poor.

Keywords: Concrete laboratory experiments, Psychometric, Cognitive, Problem-based learning, Quadrant analysis, Assessment.

1. Introduction

Today one of the required criteria for accrediting engineering programmes is improving engineering education within a faculty [1]. Engineering students need to graduate with positive attributes in order to become great engineers. Therefore,

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in engineering education, laboratory experiments or practical work can be integrated into the curriculum in order to provide students with engineering experience and practice prior to their graduation. Laboratory experiments can provide students with knowledge and practical skills and expose them to the relevant engineering field [2]. In order to bring about improvements in the teaching and learning processes, 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 [3]. Most of the students' cognitive mental skills (knowledge) are developed through classroom instruction. The affective skills component, involving a growth in feelings or emotional areas (attitude), is developed through such activities as the structured leadership of group design projects (capstone), career development activities and events (co-curricular activities), competitions, cornerstone and final year project presentations. Students' psychomotor skills, commonly referred to as manual or physical skills (skills) are normally developed in the laboratory setting.

A number of published papers have reported on psychomotor implementations in engineering education. One such paper by Salim et al. [2] investigates the levels of practical skill acquired by students after conducting the laboratory experiments with reference to psychomotor domain taxonomy. This can be achieved by carrying out a practical laboratory test at the end of a semester. A skill assessment form was used as a checklist in order to identify the levels of students' practical skills. Four levels of practical skills were identified. The results indicate the presence of a number of variations in students' performance at each skill level. In the laboratory experiments, students have the opportunity to develop and practise both their practical and hands-on skills. The ideal place to do this within the psychomotor domain was during laboratory activities.

Numerous examples exist in the literature of the integration of laboratory experiments with the theoretical and practical aspects of a course, especially in the medical field. Medical students, especially future nurses and doctors, need the experience of practice in their schools or faculties which can be to applied hospitals. They must use laboratory experiments to develop and practice their practical and hands-on skills and to improve their technical abilities [4]. In the medical field, in order to make sure that a high quality of psychomotor skills is achieved, it is important to be able to measure and assess these skills. Therefore, it is necessary to determine the aspects that indicate the differences in performance at various levels of proficiency [5]. It is also necessary for students working within the psychomotor domain to be familiar with the tools used in the experiments. Therefore the various techniques involved in implementing the psychomotor domain must be discussed in detail to ensure that they are effective.

In 2002 a colloquy on learning objectives for engineering education laboratories agreed that the attributes of psychomotor development should include the ability to demonstrate competence in the selection, modification and operation of appropriate engineering tools and resources [6]. In 2005, Ferris and Aziz [7] proposed that there is a hierarchy of student learning outcomes in the psychomotor domain with regard to the recognition and handling of tools and materials, the basic operation of tools, the competent operation of tools, the expert operation of tools, the planning of work operations and the evaluation of outputs and planning ways of achieving improvements (increasing order) [6]. In 2012, a psychomotor domain model (PDM) was proposed by Salim et al. [2] which included the recognition of tools and materials, the handling of tools and materials, the basic operation of tools, the competent operation of tools and the expert operation of tools.

The most important skills that engineering students need to develop are technical skills. These skills are essential for all engineering students to ensure that they have a successful professional career after they graduate. They can be only applied outside the classroom, in situations such as a laboratory and in assignments. Lab work is a very important component for engineering students. The ability to perform and organise experiments without supervision are among the key skills that they need to acquire. These skills need to be developed in engineering schools. A proper methodology and form of assessment must be planned and performed adequately in order to ensure that the students experience a beneficial and rewarding educational experience in the lab. Thus, the purpose of this study was to describe the implementation of such techniques in the psychometric domain in a concrete technology class, the students' responses to the implementation and the results they achieved.

2. Methodology

Materials Technology is a compulsory subject for year two students in the Departments of Civil & Structural Engineering, Faculty Built Engineering and Built Environment at the National University of Malaysia. This course deals with the introduction of construction materials, the manufacturing processes involved and their characteristics and properties. It consists of lectures, projects and laboratory work on concrete mixing and testing. The mix design methods used with concrete (the most widely used construction material) are emphasised. Figure 1 shows the learning process flow in a material technology class with reference to cognitive and psychomotor domain indicators. The domain indicator demonstrates how cognitive development occurs at all the stages of the learning process flow. Students are only able to apply their skills (psychomotor) after they acquire the knowledge and information (cognitive). However the psychomotor domain is only relevant to a few of these processes because it is related to the student skills which need to be applied to selected activities.

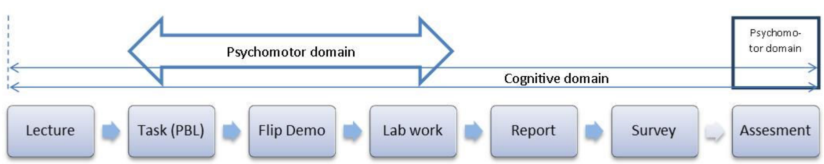

Fig. 1. Learning process flow in material technology class.

Problem-based was used as a teaching and learning method in concrete laboratory subject. At the beginning of this course, a conventional lecture was presented to the students. The purpose of this was to make sure that they had sufficient knowledge and information about the course (cognitive development).

Students were given a specific task in Problem-based Learning project laboratory work. In order to find solutions, they had to prepare and organise the laboratory information before they carried out their lab work. One of the examples of task given is to do concrete-mix-design for swimming pool structure. The students were required to decide on the suitable grade of concrete required according to the task given, as well as the water cement ratio, the slump and the wet density of the concrete. In order to carry out these experiments, students had to follow certain standard procedures such as the British (BSI) standard, which is an instructional technique by which students learn through facilitated problem solving. They also had to search for information from various sources in order to clearly establish the required parameters for producing an appropriate design solution. Thus, by using this approach, students would learn to become more disciplined and to plan their work properly.

To fulfil this task, students worked in collaborative groups in order to identify what they needed to learn in order 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 a problem. The implementation of psychomotor skills in laboratory work was executed using Problem-based Learning (PBL) methods. PBL is an instructional technique by which students learn through facilitated problem solving. This is a method of student learning that is focused on a complex problem that does not necessarily have a single correct answer [8]. It also reported that PBL implementation will affect the student performance by increased the independent learning, critical thinking, problem-solving, and communication skills [9]. Also, flip demonstrations (flip demos) were introduced. The flip demo was provided to the 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 see what they needed to do later in the lab work.

Finally students had to test their concrete specimens. Students needed to conduct experiments to establish the parameters required to solve the problem. They needed to understand the relationship between the laboratory experiments and the actual problem involved in designing the concrete-mix. The final objective of the lab work was to obtain concrete strength, as required in the problem given. Students needed to test whether the concrete grade was equal to the grade designed. The objective would be achieved if the difference between the design and actual concrete strength is within 5% [10]. After completing the lab work, the students had to complete a written report about their task before the evaluation of psychometric assessment could be conducted. A survey of the PBL implementation also was conducted to obtain feedback from students and an evaluation of the implementation of the PBL. However only results of the psychometric assessment test are presented in this paper.

Previously, the assessment of student achievement was conducted by means of video recording. The lab technician made the recordings while the evaluation was conducted separately by a nominated lecturer. However it was detected that some of the students appeared to be taking on the role of ‘sleeping partners’, in that one or two of them were not co-operating well as group members. They did not seem to know what exactly what they were supposed to be doing during the video assessment. Among the other issues that arose from the assessment was the perception that the lab environment appeared to be rather chaotic because the students did not seem to be ready to perform in a group, since they were not familiar with the tools being used in the experiments. Therefore it could be argued that the assessments being carried out were unfair because they had never actually performed the experiments in a hands-on way before.

Thus the re-evaluations were made by individual assessment. The second assessments were conducted by nominated lecturers at the same time as the video recording. In every application of a new technique there will inevitably be advantages and disadvantages. The proposed method may seem rather complicated as it involves a great deal of time and manpower to accomplish its objectives. However, in order to produce high quality student assessments, extra effort is needed to improve teaching and learning methods.

A psychometric assessment test is a test to evaluate students' ability to conduct concrete test experiments. It was conducted here as mock test because of the characteristic constraints of concrete. The concrete tests consisted of a slump test, a flow table test and a compaction test. The students were given the tests randomly. The evaluation involved inviting the judges for a live evaluation at the lab. The same rubric was given to the judges and the evaluation ran smoothly as desired.

An assessment rubric was developed for direct assessment using a Likert Scale for evaluation purposes. The direct assessment involved the creation of a rubric to evaluate student performance for few psychometric criteria. The psychomotor domain is evaluated via a psychomotor assessment test. The assessment of student performance was conducted by judges using the rubric shown in Table 1. The rubric uses a 4-point Likert Scale (3=advanced, 2=proficient, 1=functional and 0=developing) to evaluate four criteria, which are: ability to perform experiments successfully without supervision, ability to organise and perform experiments safely and with an awareness of priority in the laboratory, ability to show engagement in conducting experiments and ability to demonstrate care and respect for the equipment set-up. The results obtained are presented in the next section.

Table 1. Psychomotor performance rubric.

Criteria	*Advanced (3 points)*	*Proficient (2 points)*	*Functional (1 points)*	*Developing (0 points)*
Successfully performs experiments without supervision.	Successfully completes experiment procedures independently. Shows excellent understanding of procedure and theory taught.	Successfully completes experiment procedures with minimal supervision. Shows good understanding of experiments procedure and theory taught.	Successfully completes experiment procedure with moderate supervision. Show minimal understanding of experiments procedure and theory taught.	Cannot completes tasks and standard procedures Show no understanding of experiments procedure and theory taught.
Ability to organise, performs experiments safely and aware of	Practices safely, can work independently and take initiative as well as	Practices most procedures safely conforms to the lab regulations with minimal	Minor flaws in safety. Requires constant supervision.	Fails to notice important information and safety factors in the workplace.

priorities in the laboratory.	cooperating effectively in a team.	supervision.		
Ability to show engagement in conducting experiment.	Shows excellent performance with unusual energy, is very focused, shows confidence and full commitment.	Shows good performance with confident, energy and commitment.	Performs with some energy, focus and commitment	Performs with little energy, focus and no commitment-needs support.
Ability to demonstrates care and respect in equipment set-up.	Always demonstrates respect and care for equipment.	Good demonstration of respect and care for equipment.	Acceptable demonstration of respect and care for equipment.	No demonstration of respect and care for equipment.

3. Result and discussion

Table 2 presents the holistic result of the cohort 2013/2014 based on the psychomotor domain within each category in the rubric. After the individual judging process, the student marks were compiled and the average for each category was calculated. The average marks indicated that all the results of all the psychomotor categories were between advanced and proficient levels. Most of the students' marks were just below advanced level. Their ability to organise and perform experiments safely while maintaining their awareness of the priorities in the laboratory got the higher mark for most of the students, while the lowest marks obtained by students are ability to perform experiment successfully without supervision.

Table 2. Average marks of psychomotor domain category.

Psychomotor domain category	*Average marks*
Ability to perform experiment successfully without supervision.	2.3
Ability to organise, performs experiments safely and aware of priority in the laboratory.	2.6
Ability to show engagement in conducting experiments.	2.4
Ability to demonstrate care and respect in equipments set-up.	2.4

Based on the lowest ranking, it was demonstrated that are some of the students were not ready to conduct the experiment without supervision. They still needed extra supervision, although various types of explanations about the laboratory activities were given. Thus it could be they lacked self confidence. The ability to engage in conducting experiments and demonstrating care and respect in equipment set-up were both in the second ranking with an average mark of 2.4. In other words, only 80 percent of the students had learned these skills. This problem can be overcome by adding extra information and effort in conducting lectures or forms of video or manual development. Finally, 87 percent of the students were able to organise and perform experiments safely and were aware of the priorities of the laboratory.

The second type of analysis consists of dividing the students in terms of performance marks, as shown in Fig. 2. The marks are categorised as follows: from 0 to 3 are poor, 4 to 6 are weak, 7 to 9 are average and 10 to 12 are good. 27 out of 47 students were in the ‘good’ range, 16 were in the ‘average’ range, four were ‘weak’ and none were classified as ‘poor’. This indicates that the majority of the students were able to demonstrate the positive attributes of psychomotor skills in order to conduct an experiment. It is need to be highlighted, 9 percent of the students were not able to conduct experiments well. These students were weak in first criteria, 'Ability to perform experiment successfully without supervision'. They could not complete tasks and standard procedures and showed no understanding of experimental procedures and the theory that had been taught. Some of the students did not recognise the tools well. During the test they had used the wrong tools to conduct the experiment. Apart from that, few students were not able to answer basic questions about the objectives of each experiment. This shows that their cognitive development was limited here. Although this only applied to a minority of students, this problem needs to be overcome before the next semester.

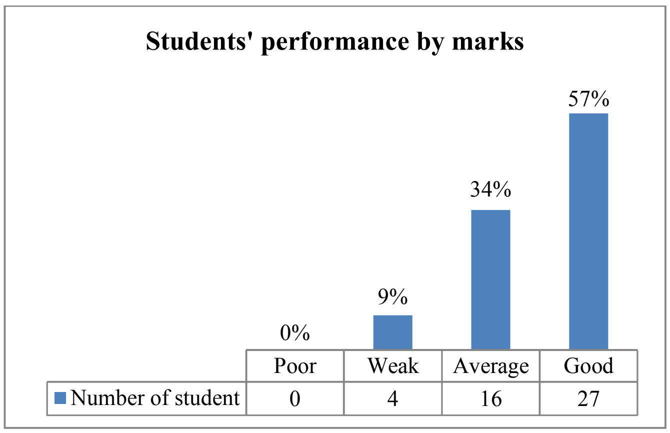

Fig. 2. Students' performance by marks.

The next analysis of results is a comparison between the marks for the lab work and those gained in the examination. Results of final examination and psychomotor performance obtained from cohort 2013/2014 are plotted into a graph final examination vs. laboratory work mark in order to relate cognitive and psychomotor performance. The graph is divided into four quadrants which each quadrant are named as poor students, technical based student, exam-based student and well-balanced student as shown in Fig. 3. This graph can differentiate the performance of students between cognitive based and psychomotor based oriented.

Figure 3 shows the distribution of students into four quadrants. Applying the method proposed, which is measuring the individual psychomotor performance, it is proved that clear category of students can be differentiated. Most of the students felled in either category exam-based students or well-balanced student. About 60% of students considered as well-balanced student, whereas, about 36% considered as exam-based students. This shows quite significant number of students are not perform well is psychomotor domain even though they got good mark in final examination. Furthermore, in other categories, poor student and technical-based student can be considered as isolated cases where only one student felled in each category. Comparing the graph with previous cohort (2012/2013) as shown in Fig. 4, shows the same pattern occurred, where most students felled between these two categories, exam-based and well-balanced students.

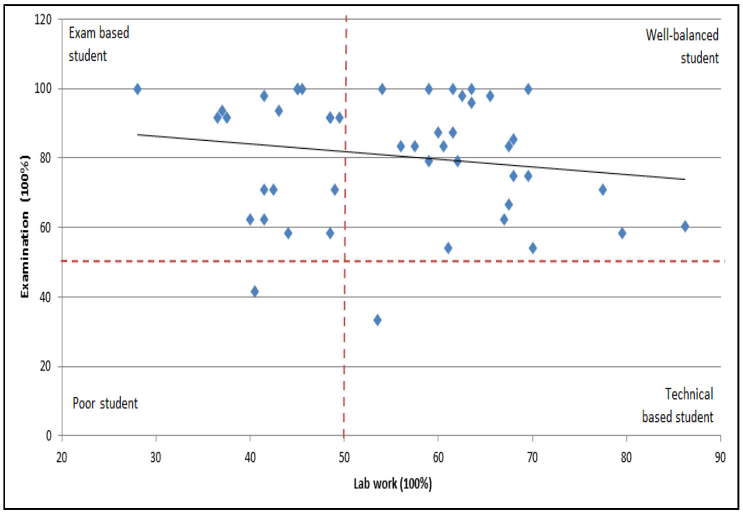

Fig. 3. Quadrant analysis of students' performance- cohort 2013/2014.

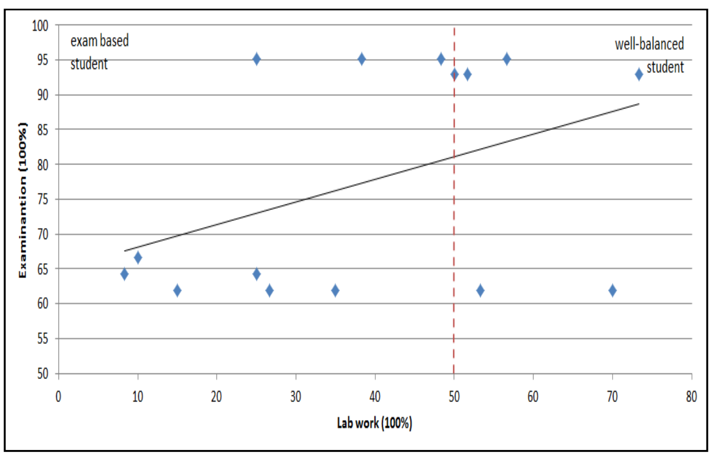

Fig. 4. Quadrant analysis of students' performance- cohort 2012/2013.

Based on the results, continuous quality improvement needs to be carried out to tackle students who felled in exam-based category. Amongst step which can be considered is to enhance the problem-based laboratory to open-ended laboratory. This will give more opportunity to students to get involved in planning, thinking and practical work. Whereas for student felled in poor student category, he or she need to repeat the course in order to achieved the standard university level in term of cognitive and psychomotor level.

4. Conclusions

The implementation of psychometric domain in teaching and learning is not something new and easy. It has been done before, but the lack of stress on the psychometric domain perspective. The implementation technique of in the psychometric domain in concrete technology class has been described. In quadrant analysis carried out, four categories has been classified which are well-balanced, exam-based, technical-based and poor students. The result obtained shows that most students felled within well-balanced and exam-based categories. An additional effort by the students, lectures, and laboratory technicians must be made to ensure the effectiveness of the implementation. The positive outcome and responses towards the implementation can be seen. The majority of the student getting the best grade, however not balanced with psychometric domain. Hence a few improvements must make to increase the student awareness about the importance the psychometric attributes.

Acknowledgement

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