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Development of Psychomotor Skill and Programme Outcome Attainment of Civil Engineering Students in Malaysia

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Abstract: A substantial amount of practice is required throughout an engineering programme to develop the psychomotor skill for a practice-oriented industry and fulfil the hands-on component of the accreditation requirements. This study aims to analyse the engineering students" psychomotor skill development based on psychomotor programme outcome (PO) attainment during their course of study and to determine the important suggestions on improvement in the learning and teaching processes in the programme based on the respondents" feedback. A quantitative research design was adopted using a questionnaire survey to record the students" opinions on skill development and PO attainment, classified under the psychomotor domain in an undergraduate civil engineering programme in Malaysia. Out of the 327 chosen students, who consisted of final year students enrolling in open ended laboratory (OEL) and final year project (FYP) courses, approximately 32% of them responded to the survey. It was agreed by most of the students that psychomotor skill assisted the development of their self-confidence and proficiency, which consisted of complex skill sets and movement. The students also agreed that they have attained the PO through usage of laboratory apparatus and data collection. As they agreed that their psychomotor PO attainment was influenced by the condition of the equipment in the laboratories, they proposed that the programme should increase the number of equipment and enhance the laboratory facilities by implementing new and up-to-date technologies relevant to the programme. It was shown from a direct PO measurement from the myCOPO system that the students attained the psychomotor skill required by the programme. This study contributes to the improvement in the engineering curriculum development and assists the Institute of Higher Learning (IHL) in fulfilling the requirements by the Board of Engineers Malaysia, which are related to psychomotor skill development. As it captures an important aspect of psychomotor skill acquired by civil engineering students, it would be a positive approach for IHL to apply a more practice-based learning curriculum to prepare them for future careers in design consultant office, contractor site operations, and other construction-related work environment.

Keywords: *Engineering student, programme outcome attainment, psychomotor skill development*

1. Introduction

The Institute of Higher Learning (IHL) in Malaysia has been implementing an education system known as Outcome-based Education (OBE) in curriculum growth over the previous decade. The engineering education model developed for Malaysia is expected to be capable of achieving global recognition and accreditation for excellence in engineering practice as well as educating future leaders (Megat et al., 2002). To develop the engineering students into competent engineers, they need to be equipped with the ability to apply the principles of mathematics and sciences, knowledge, modern tools, techniques, processes, and soft skills. Besides that, the profiles of professional competence should be acquired through the trilogy taxonomy (International Engineering Alliance, 2013). Three important learning domains namely; psychomotor, cognitive, and affective domains, are essential in programme outcomes (PO) as they serve as the elements of the evaluation of learning outcomes (Zainudin et al., 2012). Kasilingam, Ramalingam & Chinnavan (2014) proposed an assessment method for learning domains that encourage readers to use reliable and valid assessments in IHL by discriminating between assessing psychomotor (skill), cognitive (knowledge) and affective (attitudes) domains. Mohd Ghazali et al (2008) focused on engineering students" learning to determine the level to which these learning outcomes under the three domains have been achieved. In general, the students need to demonstrate the combination of all three domains, otherwise one would not be

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able to find a solution to complex engineering problems without problem-solving skills (cognitive), practical use of modern equipment (psychomotor), and communication skills (affective) (Markle & Banion, 2014).

Specific studies on psychomotor skill development in the past were perceived as less important compared to the many studies conducted on affective and cognitive skill development among engineering students during their early career as engineers. For example, Lashari et al (2012) proposed an affective-cognitive framework based on the proposed study for teaching and learning in engineering education that integrates the affective aspects of learning into teaching and learning (T & L) activities. Green & Batool (2017) focused on emotionalized learning experiences by tapping into the affective domain, while Atsumbe & Saba (2008) also carried out a study on affective work skills needed by engineering and technology education students in Nigeria. Morever, Akasah & Alias (2010) also emphasized learning of the affective domain for the realization of the engineering learning outcomes, while Bielefeldt (2013) focused on pedagogies to achieve sustainability learning outcomes in civil and environmental engineering students based on cognitive assessment. Similarly, based on problem-based learning as a facilitator of conceptual change, Loyens et al (2015) discussed the findings based on cognitive engagement.

There were issues in selecting the most appropriate method of evaluation due to the complex nature of psychomotor assessment in T & L which requires coordinated observation and action between protocols. In addition, the versatile and dynamic nature of psychomotor observation presupposes a careful analysis of the variables that may affect the action. Psychomotor skill assessment requires observation within the context of the situation, the conscious intention of neutrality of the observer‟s behaviour and its evaluation and also the need to understand the subjective aspects of motor behaviour (Viscione et al., 2018). Therefore, further focus has been placed on the cognitive and affective domains among many researchers where cognitive skills are developed within the traditional classroom instruction and assessed through assignments, tests or examinations. Similarly, affective skills can also be developed within classroom activities such as the structured leadership of group design projects (capstone), or outside classroom such as career development activities and events (co-curricular activities), competitions, cornerstone and final year project presentations (Baharom et al., 2015). On the other hand, psychomotor skills require a different and unique setting to provide a substantial amount of hands-on activity to fulfil the needs of the industry and the practice-oriented components of the accreditation requirements. This situation may lead to the inadequate ability of graduates to apply the psychomotor skill and knowledge acquired from their programmes to solve problems occurring within the industry.

Recently, there has been increasing attention towards the development of psychomotor skill, which creates professional skills for engineering students (Baharom et al., 2015). Besides, the importance of psychomotor skill development and stimulation during the students‟ early years in their academic programme was emphasised by Carretero & Romero (2015). Accordingly, this skill was assessed in terms of performance and other important elements related to it based on various stakeholders‟ perceptions (Viscione et al., 2018). Sajjad (2011) found that a perception-based study could be implemented as a method of enhancing the T & L procedures. Due to the insufficient research data regarding psychomotor skill that demonstrates the true measurement of PO under the psychomotor domain, this paper aims to enquire engineering students‟ opinions regarding psychomotor development and PO psychomotor attainment, and to determine the elements impacting the psychomotor PO attainment based on laboratory and final year project courses. Their opinions on this matter were further validated through an internally developed assessment system by the Civil Engineering faculty, known as myCOPO.

2. Literature Review

2.1 Psychomotor Learning Domain

Psychomotor learning domain emphasises on physical skills, which consist of style, strength, and speed incorporated in practice-oriented activities or skill acquisition (Gibbs et al., 2003). Furthermore, the development of psychomotor skill consists of skill acquisition, which involves cognitive and physical activities (Costa et al., 2015). Bloom & David (1956) described the psychomotor domain as a coordinated development of motoric or movement skill, which incorporates speed, repetition, precision, and execution. Additionally, this domain is characterised into seven (7) levels including origination, adaptation, complex overt response, mechanism, perception, guided response, and set (readiness). To provide clarity regarding psychomotor skill, two domains are commonly integrated, namely cognitive and affective domains.

Therefore, based on a behavioural perspective, the cognitive and affective domains have equally contributed to psychomotor skill development over time (Micklich, 2011).

Engineering education provides programmes to develop the engineering students into competent engineers; they need to be equipped with the ability to apply the principles of mathematics and sciences, knowledge, modern tools, techniques, processes, and soft skills. It was emphasised by many researchers that comprehensive practical or hands-on activities are essential for engineering students to fulfil the industry demand and enhance the rate of employability (Rahman & Mohd Zahari, 2016; Mishra et al., 2009).

Table 1 shows previous studies focusing on various aspects of psychomotor skill development for both engineering education and non-engineering education. These studies have been carried out on different types of students from pre-school, high school and tertiary levels on different learning domains as discussed below.

From non-engineering education perspectives, Costa et al (2015) investigated the influence of structured physical education on the psychomotor development of pre-school children and also assessed the students" psychomotor development profiles. It was found that the physical activities in education contributed to positive results in academic achievement. In a more recent study, Viscione et al (2017) carried out a qualitative assessment of the motor performance of pre-school children using the Movement ABC checklist. They observed the motor behaviour of the child, in reference to the relationship between the body and the environment and found that the highlighted features of everyday life and classroom activity could help in guiding teaching for the recovery, development and enhancement of psychomotor skills.

Usoro et al (2018) examined on how to assimilate psychomotor skills in Technical Vocational Education and Training (TVET) programme. The findings emphasised on the importance of TVET program in enhancing psychomotor skills among students to prepare them for effective performance on skills and competencies in industry. Rahman & Mohd Zahari (2016) empirically investigated the effectiveness of basic western cuisine as part of a modular programme in Malaysian community colleges toward culinary art students" psychomotor performance. On the other hand, perceptions from teachers were also sought by Borhan & Ismail (2011) to study their opinions toward environmental issues and it was found that there was no significant relationship between knowledge, attitudes and behaviours of the teachers on environmental issues.

With respect to engineering education, many researchers used various models and tools to develop psychomotor skills for engineering students to improve their academic achievement. Salih & Suleyman (2019) found that the integration of STEM disciplines into Toulmin's argumentation model can be used for increasing academic achievement of high school students (cognitive domain), developing reflective thinking (affective domain), and observing the development of psychomotor skills at the formation of arguments in the classrooms. Mishra et al (2009) addressed the issue of improvement in the psychomotor learning domain through computer aided instructions (CAI) to improve engineering students" psychomotor performance. It was found that the integration of practice-oriented teaching and learning approach results in an enhanced acquisition of hands-on skills, which subsequently leads to improved engineering students" performance (Mishra et al., 2009). Designing the assessment of the practical component in engineering programs will develop graduate engineers with a coherent set of practical skills that beneficial in the practice of the future profession (Ferris & Aziz, 2005).

Table 1: Previous Research on Psychomotor Skill Development

No	Author (year)	Focus of Research	Engineering Education (EE) non-engineering education (NE)	Variables related to psychomotor skill development							
				Level of Taxonomy	Assessment of Psychomotor Skills	Enhancement of Psychomotor	Learning tool for psychomotor	Evaluation on Assessment	Psychomotor Skill enhancement	Effectiveness in psychomotor learning	Psychomotor development profiles
1	Salih & Suleyman (2019)	To examine the effect of integration of STEM disciplines into Toulmin's argumentation model on students' academic achievement, reflective thinking, and **psychomotor skills**	NE	√							
2	Viscione et al., (2017)	To carry out a qualitative assessment of the **motor performance** of 379 preschool children residing in the province of Salerno was carried out using the Movement ABC checklist	NE		√	√					
3	Rahman & Mohd Zahari (2016)	To empirically investigate the effectiveness of basic western cuisine as part of the culinary arts modular program in Malaysia community colleges toward students' **psychomotor performance**.	NE			√					
4	Suesse et al. (2015)	To study the student evaluations **on psychomotor learning tool** and assessment and on how these evaluations relate to learning.	EE				√	√			
5	Baharom et al., (2015)	Focuses on the methods of implementation of **psychomotor skills assessments** in the teaching and learning process in concrete laboratory experiments.	EE		√	√	√				
6	Burhan et al., (2015)	Focuses on students' **psychomotor skill assessment** based on improvement on knowledge and **psychomotor skill** respectively when students use newly developed PIC modules for laboratory practical work.	EE		√		√		√		
7	Costa et al., (2015)	To investigate the influence of structured physical education on the **psychomotor development** of preschool children and to assess the students' **psychomotor development profiles**.	NE								√
8	Kasilingam et al., (2014)	Proposed **assessment method** for learning domains will encourage readers to use reliable and valid assessments in higher education by discriminating between assessing skills, knowledge, and attitudes.	EE		√		√				
9	Mishra et al., (2009)	This paper addresses the issue of improvement in **effectiveness of learning in the psychomotor** learning domain through computer aided instructions using 5 levels of taxonomy.	EE	√		√				√	
10	Salim et al., (2012)	This paper investigates the levels of **practical skills** acquired by students after conducting the laboratory experiments with reference to Psychomotor Domain Taxonomy.	EE	√	√	√					
11	Mohd Ghazali et al. (2008)	To study the OBE Implementation in Universiti Putra Malaysia with a focus on students' learning outcomes under Cognitive, Affective and **Psychomotor Domains**.	EE	√							
12	Ferris & Aziz, (2005)	**A psychomotor skills** extension to Bloom's taxonomy of education objectives for engineering education	EE	√							
13	Zaghloul (2001)	Assessment of laboratory work: A three-domain model; Cognitive, affective, and **psychomotor**	EE	√	√						

Laboratory work or experiment is one of the important elements in teaching and learning for engineering programmes and is commonly used as a tool to assess student"s performance. Thus, Zaghloul (2001) focused on the assessment of laboratory work of engineering students across three-domains; cognitive, affective, and psychomotor to identify the educational elements comprising the laboratory work which led to a properly structured assessment plan. Similarly, Burhan et al (2015) focused on students" psychomotor skill assessment based on improvement on knowledge and psychomotor skill when the engineering students used newly developed PIC modules for laboratory practical work.

In addition, Suesse et al (2015) studied on the student evaluations on laboratory experiment as the learning and assessment tools. The study found that student evaluation on the laboratory experiments was influenced by the perceived learning gain in both the cognitive (analytical skills only) and psychomotor domains. Prior to that, Kasilingam et al (2014) proposed an assessment method for learning domains to encourage readers to use reliable and valid assessments in higher education by discriminating between assessing skills, knowledge, and attitudes. The proposed method allows one to objectively evaluate whether the students have achieved the criteria, subsequently facilitating CQI implementation within the programme. Similarly, Baharom et al (2015) focused on the methods of implementation of psychomotor skills assessments in the teaching and learning process in concrete laboratory experiments. In terms of outcome attainment, the results for psychomotor and cognitive performance were compared using a quadrant analysis which resulted in four (4) categories of students: exam-based, technicalbased, well-balanced and poor.

Another important tool to measure student"s skill development is by using the level of taxonomy developed by Bloom & David (1956). For example, Ferris & Aziz (2005) studied the hierarchical taxonomy of psychomotor skills extension to Bloom's taxonomy of education objectives for engineering education to fulfil the roles as engineers to skilfully perform work related to developmental experimentation, prototyping or contributions to maintenance and construction. Then, Salim et al (2012) investigated the levels of practical skills acquired by engineering students after conducting laboratory experiments with reference to the psychomotor domain taxonomy. Four levels of students" practical skills in Basic Electronic laboratory were identified. The results indicate that there are some variations in students" psychomotor performance at each skill level.

It can be seen that most of the previous studies in engineering education involved laboratory experiments and computer-based teaching and learning activities as the tools to assess psychomotor skill development. In an engineering programme, laboratory experiments or practical works are integrated in the curriculum to prepare students for engineering experience and practice prior to their graduation. The accreditation body, Engineering Accreditation Council (EAC) under Board of Engineers Malaysia (BEM) requires that laboratory experiments must involve open-ended problems, enquiry based or investigative in nature. This is important to provide the students with knowledge and practical skills and exposure for them to select the relevant engineering field in carrying out their final year project (FYP). There has been an insufficient number of studies focusing on psychomotor skill in an OEL and FYP, specifically among engineering students. Accordingly, this study focused on the development and attainment of psychomotor skills in OEL and FYP courses based on engineering students' perspectives.

2.2 Psychomotor skill development tool based on taxonomy levels

Mishra et al (2009) in their study adopted five (5) levels of psychomotor skill developed by Dave (1967) extended from Bloom & David (1956) model together with the descriptors which are: (1) Imitation - observing and copying someone else; (2) Manipulation - guided via instruction to perform a skill; (3) Precision - accuracy, proportion and exactness exist in the skill performance without the presence of the original source; (4) Articulation - two or more skills combined, sequenced, and performed consistently; and (5) Naturalization - two or more skills combined, sequenced, and performed consistently and with ease where the performance is automatic with little physical or mental exertion. These psychomotor skills were imparted to the engineering students using computer aided instructions in the laboratory.

In this study, the perceptions of students on the psychomotor skill development focuses on the following seven (7) taxonomy developed by Simpson (1972) extended from Bloom & David (1956) model: which are: (P1) set: readiness - to enhance the level of student"s perception to detect non-verbal communication cues; (P2) guided response - to promote student"s preparedness for actions, which were specified into physical, mental, and emotional sets; (P3) perception - to improve student"s capability of developing complex skills through trial-and-error and imitation; (P4) mechanism - to improve student"s skills and confidence through the acquisition of complex skills; (P5) complex overt response - to assist students in effectively performing complex movements; (P6) adaptation - to modify students‟ patterns of movements to fulfil specific requirements; and (P7) origination - to create new and innovative movement patterns.

2.3 Programme Outcome Attainment under Psychomotor Domain using Open-ended Laboratory as a Tool

As required by the EAC Manual 2017, a balanced curriculum shall integrate theory with practice through adequate exposure to laboratory work. Thus, throughout the engineering programme, there should be adequate provision for laboratory or similar investigative work (Engineering Accreditation Council, 2017). This is important to develop confidence in future engineers in order to solve complex engineering problems. Out of twelve (12) programme outcomes listed by the EAC Manual 2017, the Civil Engineering programme (EC220) in UiTM chose Programme Outcome 4 (PO4) as a measurement under the psychomotor domain as reflected in its curriculum design for all laboratory courses. PO4 is measured to assess the student‟s ability to conduct investigation of complex engineering problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of information to provide valid conclusions (Engineering Accreditation Council, 2017).

Currently, the programme adopts a laboratory practical test as a tool to measure the engineering students‟ psychomotor skill which is reflected in their PO attainment. Open-ended laboratory works offer investigative or enquiry-based nature of activities. Thus, all OEL courses in the Civil Engineering programme in UiTM are designed based on enquiry models by Schwab (1962); Herron (1971); (Schwab & Herron, 2005).

Schwab (1962) outlined three (3) levels of inquiry: (1) Students use classroom materials, such as textbooks or lab manuals, to pose questions and describe investigation methods; (2) Classroom materials are used to pose questions, but the methods and answers are developed by the students; and (3) Students investigate scientific phenomena without the guidance of classroom materials. In addition, Herron (1971) suggested an inquiry model that outlined four (4) separate levels of openness: (1) Level 0 - The problem, procedure and methods are provided to the students in order to achieve the solutions. The student performs the experiment and compares with the manual given; (2) Level 1 - The problem and procedures are provided to the students. The students then interpret the data to propose the possible solutions; (3) Level 2 - The problem is provided to the student. However, the student needs to develop procedures, decide on data collection and interpret data so that possible solutions can be proposed; and (4) Level 3 - The student needs to choose the problem, develop procedures, decide on data collection and interpret data so that possible solutions can be proposed.

Under the non-engineering area, based on the Schwab (1962); Herron (1971) model, Bruck et al (2008) proposed a quantitative rubric designed to characterize the level of inquiry in the undergraduate laboratory activities and laboratory curricula for nursing students.

Similarly, based on the Schwab (1962); Herron (1971) model, Mat Isa et al (2019), proposed a performance criteria matrix or rubric, which was used during the practical test of the OEL in a civil engineering programme. Six (6) levels of difficulties were established in order to distinguish between the level of difficulties of psychomotor domain; namely identification of problem based on the scenario given is considered as the lower order skill (P1-P2), determining correct procedures for investigating problems (P3), demonstrating the usage of the apparatus/ machines to run the study / laboratory work (P4), determining data to gather and interpret data leading to the findings (P5) and finally, proposing viable solutions/ new movement patterns to account for problematic/ new situations (P6-P7) (Mat Isa et al., 2019).

Thus, in this study to enquire the students‟ perceptions on their psychomotor PO attainment, the survey instrument was developed based on the Schwab (1962); Herron (1971) model and followed six (6) steps (Mat Isa et al., 2019) observed during the OEL practical test to measure the student‟s ability to: (1) Identify the problems; (2) Determine the correct procedures; (3) Use of apparatus; (4) Collect data; (5) Interpret results; and (6) Propose possible solutions. Looking at the student performance, Haron et al (2013) studied the impact of OEL implementation in the Civil Engineering laboratory to reflect the overall students‟ grades and learning experiences. The findings indicate that the students understood the experimental concepts better as compared to the traditional experiment instruction, thus, students would be prepared for their undergraduate final year project (FYP). Furthermore, there are many factors that may contribute to the student‟s performance based on psychomotor skill development using the laboratory method such as teaching and learning process (Mishra et al., 2009), stakeholders involved such as lecturers or instructors, students and laboratory technicians (Baharom et al., 2015), learning environment (White et al., 2016) and equipment used during the T & L activities (Mat Isa et al., 2019). Thus, this study focuses on the final year students who have undertaken both the OEL and FYP courses to seek their perception on the psychomotor development and their psychomotor PO attainment, which is further validated by the direct psychomotor PO attainment.

3 Methodology

3.1 Research Approach

A quantitative approach was employed using a survey questionnaire regarding psychomotor skill development and psychomotor PO attainment in an undergraduate civil engineering programme. The target respondents consisted of 393 final year students, who undertook open-ended laboratory (OEL) and final year project (FYP) courses. The Academic Office, Faculty of Civil Engineering Universiti Teknologi MARA provided a sampling frame for the sample selection of respondents.

3.2 Design of Instrument and Measurement

The survey was designed to fulfil the three (3) research objectives; (1) To seek engineering students‟ perceptions on their psychomotor skill development and psychomotor PO attainment during their course of study; (2) To determine the factors contributing to PO attainment; and (3) seek their suggestions for the improvement in the learning and teaching processes in the programme.

The questions are divided into the following five (5) sections. Section A covers the respondents‟ background while Section B enquires student‟s perception on their psychomotor development. The instrument was developed using seven (7) Bloom‟s taxonomy level under the psychomotor domain, namely Level 1: Set (readiness), Level 2: Guided response, Level 3: Perceptions, Level 4: Mechanisms, Level 5: Complex overt response, Level 6: Adaptation, and Level 7: Origination. Section C requires the students‟ perceptions on their psychomotor PO attainment where the survey instrument was developed following six (6) steps observed during the OEL practical test to measure the student‟s ability to: (1) Identify the problems; (2) Determine the correct procedures; (3) Use of apparatus; (4) Collect data; (5) Interpret results; and (6) Propose possible solutions. Section D requires the students to select the contributing factors impacting psychomotor PO attainment, which are related to conduciveness of environment to conduct experiment, condition of the laboratory equipment, adequacy of the laboratory equipment and the instruction given by the lecturers or person in charge prior to the conduct of experiment. Finally, Section E requires the students‟ feedback on suggestions for improvement in learning and teaching processes.

The measurement for the items incorporated a five-point Likert rating questions comprising of a range of responses from „strongly agree‟ to „strongly disagree‟, including open-ended qualitative questions to determine the respondents‟ background such as their age, semester etc. The perception of student‟s psychomotor PO attainment was further validated based on actual PO attainment marks obtained through direct assessment, which involved a practical test, laboratory report, and project presentation. The marks were extracted from a software system known as myCOPO.

3.3 Analysis

The acquired data were then analysed through descriptive, reliability, normality, Pearson‟s correlation tests and relative important index (RII) to rank the respondents‟ feedback. In this study, a parametric test, which involved a Pearson product-moment correlation coefficient (r), was used for normal data. For this analysis, the direction and strength of the linear association between two variables were the basis of Pallant's (2011) description of an inter-correlation analysis.

Specifically, this analysis indicated the association between the dependent (psychomotor PO attainment) and independent variables (the contributing factors) and the strength of it. Either positive or negative direction was indicated from the test, including the significance of the association between the variables, which incorporated values ranging from –1.0 to +1.0. A positive association between the variables was observed when a similar direction was present from the trend, regardless of the direction is an increase or vice versa. The interpretation of the results are based on Cohen (1998) as shown in Table 2.

Table 2: Strength of correlation between the variables using Pearson coefficients (Cohen, 1998)

Pearson correlation coefficients (r)	Value	Strength of Correlation
.10 > r < .29	Small	Poor relationship
.30 > r < .49	Medium	Medium relationship
.50 > r < 1.0	Large	Strong relationship

3.4 Relative Important Index

Relative Importance Index (RII) was applied to determine the ranks of the importance of the statements related to psychomotor skill development, psychomotor PO attainment, contributing factors and suggestion for improvements, which was indicated by the index values in the questionnaires, where the Likert rating scale was incorporated. The RII ranged from 0 to 1.

Following is the formula of RII, which was inputted in Microsoft Excel 2016 to calculate the index:

$$\text{Relative Importance Index} = \frac{\sum W}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where:
w = The range of weight provided by the participants, which is from 1 to 5;
n_1 = The number of participants who chose „Not Important";
n_2 = The number of participants who chose „Less Important";
n_3 = The number of participants who chose „Moderately Important";
n_4 = The number of participants who chose „Important";
n_5 = The number of participants who chose „Very Important";
A = Maximum weight (5); and
N = Overall number of participants.

The results for response rate, reliability, normality, correlation analyses and relative important index are discussed in the following section.

4 Results and discussion

This section presents the analysis and discussion of the results on the students" psychomotor skill development, their psychomotor PO attainment, the contributing factors to psychomotor PO attainment, and their suggestions for improvement in learning and teaching processes. The findings from the perceptions on the psychomotor PO attainment are compared with the direct attainment of the psychomotor PO.

4.1 Respondents

Out of 393, 32% or 127 of the target respondents participated in the survey. The profile shows that the respondents were final year students with a similar percentage distribution based on gender, have taken the required open-ended laboratory (OEL) and final year project (FYP) courses that measure programme outcomes under psychomotor domain and the majority of them are above 24 years old.

4.2 Reliability Test

Cronbach"s alpha value was first determined for the test of internal reliability, which aimed to ensure the consistency between the ratings in the student" feedbacks. The alpha values for the variables obtained to identify the students" psychomotor skills development resulted in 0.9 coefficients, while the coefficient for the psychomotor PO attainment amounted to 0.922. Overall, the results proved the reliability of the instruments as the values, which exceeded 0.70, were accepted (Nunnally & Bernstein, 1978).

4.3 Normality Test

Statistical tests used by Skewness & Kurtosis, including a graphical method (Q-Q plot), were involved to evaluate the normality of the data set for model distribution. The standard error is the range of possible error which occurs in data (good standard error value < 1.0). The results show a normal data distribution regarding psychomotor PO attainment was obtained when the values by Skewness & Kurtosis were reaching zero.

4.4 Correlation Analysis

The correlation between students" psychomotor PO attainment based on the six (6) learning outcomes under the psychomotor skill and the factors contributing to it is illustrated in Table 3.

Table 3: Correlations between psychomotor PO attainment and its contributing factors

Variables	Environment	Condition	Adequacy	Instruction
Identification of problems	**.405***	.390	.354	-.002
Determination of the right procedure	**.416***	**.461***	**.404***	.021
Usage of apparatus	.412*	**.413***	.374	.018
Data collection	.379	.307	.328	-.050
Interpretation of results	.334	.268	.323	-.053
Proposal of solutions	.335	.269	.259	-.064

Based on Cohen (1998), for .30 > r < .49, the strength of relationship is medium. Thus, the following significant relationships are observed:

- Medium and positive relationship between determination of the right procedures and the condition of equipment used ($r = 0.461$, $p < 0.05$).
- Medium and positive relationship between determination of the right procedures and conduciveness of laboratory environment to carry out experiments ($r = 0.416$, $p < 0.05$).
- Medium and positive relationship between the usage of the right equipment and the equipment condition ($r = 0.413$, $p < 0.05$).
- Medium and positive relationship between the usage of the right equipment used and the conduciveness of laboratory environment to carry out experiments ($r = 0.412$, $p < 0.05$).
- Medium and positive relationship between identification of problem and the conduciveness of laboratory environment to carry out experiments ($r = 0.405$, $p < 0.05$)
- Medium and positive relationship between determination of the right procedures and adequacy of laboratory equipment ($r = 0.404$, $p < 0.05$)
- However, there are no significant relationships between any of the learning outcomes and instruction given by lecturer prior to the laboratory experiment carried out by the students.

4.5 Programme Outcome (PO) Attainment under Psychomotor Domain

Section C of the questionnaire survey requires the respondents to state the level of agreement on the statement related to learning outcome attainment under six (6) psychomotor skills that they have acquired throughout the T & L activities. Overall, the rankings of the statements made by the students on their abilities that reflected the PO attainment under psychomotor skill are illustrated in Table 5.

Table 5: The rankings of psychomotor PO attainment

Psychomotor PO attainment	Index	Ranking
Identification of problems	0.737	5
Determination of the correct procedures	0.747	3
Demonstration of equipment usage	0.752	2
Data collection	0.756	1
Interpretation of results	0.747	3
Proposal of solutions	0.744	4

The first psychomotor skill ranked by the students was their ability to collect data to report and analyse results (0.756). This was followed by the ability to use the correct apparatus to perform the given tasks in the laboratory (0.752). As indicated in the correlation analysis, an improved equipment condition positively assisted students in making clearer demonstrations of the use of the equipment influencing their psychomotor skill performance.

The third-ranked statement regarding PO attainment under psychomotor skill was agreed by the students in terms of the interpretation of results to discuss important findings, which was followed by determining the correct procedures to investigate problems (0.747). As shown in the correlation analysis, the determination of the right procedures using adequate laboratory equipment improved their psychomotor skills.

The second last psychomotor skill attainment was the ability to propose possible solutions to the problems (0.744) followed by problem identification (0.737) which was ranked last by the students. The students perceived with less confidence that they have acquired the ability to identify problems and propose viable solutions or new movement patterns using clear and structured justifiable findings to account for problematic situations. As indicated by the industry, many engineering graduates once hired, are said to be lacking in higher-order and lateral thinking skills, creativity, analytical skills and other skills required to make them efficient and proficient problem solvers and decision makers (Mohd Ghazali et al., 2008).

4.6 The Contributing Factors of PO Attainment

Table 6 illustrates the rankings of the factors contributing to students‟ PO attainment under psychomotor skills.

Table 6: The ranking of contributing factors related to students‟ psychomotor PO attainment

Factors related to psychomotor PO attainment	Index	Ranking
Conducive environment to carry out the experiment	0.757	3
Good equipment condition	0.769	1
Adequacy of equipment	0.754	4
Clear instructions by lecturers	0.759	2

The students agreed that their psychomotor PO attainment was influenced by the condition of the equipment in the laboratory (0.769). As indicated in the correlation test, an improved equipment condition positively assisted students in using the equipment and determining the correct procedures, which subsequently influenced their psychomotor skill. This was followed by the next factor, which was the clear instruction provided by the lecturers before the experiment (0.759). Therefore, preparation for designed laboratory activities by the lecturers is essential for the integration of psychomotor skill demands. Instructions should be designed by the lecturers in accordance with the desired programme outcomes to achieve relevant psychomotor skills with high standards of achievement by the students (Mohd Ghazali et al., 2008).

The third factor agreed by the students was the conducive environment in the laboratory (0.757), followed by adequate equipment (0.754) provided for them to perform the experiment. As indicated by the medium and positive correlation value between the "conduciveness of laboratory environment to carry out experiment" and the "equipment usage", the gradual psychomotor skill development results in better

learning environment which enhances engineering students‟ satisfaction on their accomplishments (Mishra et al., 2009). This result is consistent with the study by Nikolic et al (2015) who found the conducive environment plays important role in enhancing student‟s psychomotor skills. Furthermore, the analytical skills of students that gained in the cognitive domain and psychomotor skills will influence the students‟ evaluation of the laboratory experiments (Nikolic, 2015; Suesse et al.,

2015). Thus, the students‟ psychomotor skills, in fact assume a constant relationship with the surrounding environment (Viscione et al., 2018).

The last ranked factor influencing students‟ performance was the availability of sufficient equipment to conduct laboratory tasks (0.754). As indicated by correlation analysis, equipment adequacy positively assisted students in improving their ability to determine the correct procedures. It shows that they have the ability to engage in conducting experiments and demonstrating care and respect in equipment set-up (Baharom et al., 2015).

4.7 Psychomotor Skill Development

Section B enquires the students to state their level of agreement on the statement related to psychomotor skill development based on the seven (7) levels of psychomotor domain. Overall, the rankings using Relative Important Index (RII) on the psychomotor skill development based on Bloom‟s seven (7) levels are illustrated in Table 7 below.

Table 7: The rankings of psychomotor skill developments

Psychomotor skill developments	RII	Rank
Level P1: Set (readiness) -To enhance the level of student‟s perception to detect non-verbal communication cues	0.766	5
Level P2: Guided response - To promote student‟s preparedness for actions, which are specified into physical, mental, and emotional sets	0.781	3
Level P3: Perceptions - To improve student‟s capability of developing complex skills through trial-and-error and imitation	0.757	6
Level P4: Mechanisms - To improve student‟s skills and confidence through the acquisition of complex skills	0.786	1
Level P5: Complex overt response - To assist students in effectively performing complex movements	0.786	1
Level P6: Adaptation - To modify students‟ patterns of movements to fulfil specific requirements	0.783	2
Level P7: Origination - To create new and innovative movement patterns	0.778	4

It was agreed by the engineering students that psychomotor skill improved their skills and confidence through the acquisition of complex skills (RII = 0.786). Bloom‟s taxonomy classifies Level P4: "mechanism" as an intermediate phase of developing complex skills. This shows that by the end of the engineering programme, the students will be able to assemble laboratory equipment appropriate for experiments. At the same time, confident and skilled movements should be performed when the developed responses become habitual, while "complex overt response" is considered a higher phase to assist students in effectively performing complex movements (RII = 0.786). This shows that by the end of the engineering programme, students will be able to demonstrate proper use of engineering tools or equipment in solving problems.

The students also opined that a higher order of skill (Level P5) which is "adaptation" is a psychomotor skill that assisted them in modifying the movement patterns required to fulfil the specific requirements to solve the problem (RII = 0.783). The findings show that the students believed they have the ability to respond effectively to unexpected experiences. Thus, by the end of this engineering programme the students are able to adapt their lessons on OEL and FYP to solve engineering problems.

The third ranked psychomotor skill is at the lower order in terms of their preparedness for actions also played a role in this matter, which were specified into physical, mental, and emotional sets (RII = 0.781). However, the students ranked "origination" which is the highest order of psychomotor skill, as the fourth agreed statement where this psychomotor skill assisted in the development of new patterns of movement (RII = 0.778).

The fourth ranked psychomotor skill is "set" or student‟s readiness to detect non-verbal communication cues (RII = 0.766). It indicates that the students are mentally, physically, and emotionally responsive in a certain way to a situation.

The last ranked psychomotor skill is "perceptions" which reflect the student‟s ability to develop complex skills through trial-and-error and imitation (RII = 0.757). The findings show that students indicated their readiness to take a particular type of action prior to an act that has been demonstrated or explained, and it includes trial and error until an appropriate response is achieved (Dave, 1967).

4.8 Students' Recommendations for Improvement in the OEL Learning and Teaching Processes

Accordingly, based on Section E, the respondents are required to determine the level of agreement on the statements related to suggestions to improve teaching and learning activities. Table 8 illustrates the rankings of suggestions proposed by the students for psychomotor PO attainment.

Table 8: Recommendations to improve teaching and learning activities

Recommendations	Index	Ranking
To increase the provisions of equipment	.810	1
To enhance and improve the facilities with new equipment and up-to-date technology	.797	2
To adopt non-conventional approaches in teaching and learning activities	.793	3
To adopt flexible assessment mode	.774	4
To hire competent technical staff in the laboratory	.769	5

The first ranked recommendation agreed by the students was the increase in the provisions of equipment for the improvement in learning and teaching processes for psychomotor PO attainment (0.810), which was followed by improvement in facilities (0.797). Therefore, increasing the provisions of equipment, including good working and learning environment and facility enhancement, is highly important in the development of psychomotor skills (Yogesh, 2006). In this case, the industry emphasised the importance of equipment and infrastructure as the support in handson learning (Björkqvist et al., 2016). Moreover, the laboratory is an important and effective learning space in engineering programmes to ensure that students can apply the lessons they have learnt throughout the programme and receive an adequate amount of support (Turner & Amirnuddin, 2019) and assistance by the technical staff.

The third-ranked recommendation agreed by the students was the importance of lecturers to implement more engaging approaches in teaching and learning processes (0.793). This is an important initiative, considering that active learning approaches to acquire skills, including cooperation between students and lecturers, will lead to more effective teaching and learning processes (Palacios et al., 2011). Meanwhile, the fourth-ranked recommendation was the flexible mode of assessments (0.774). Therefore, upon the completion of the laboratory courses, innovative assessments should be effectively conducted to acquire lessons from the teaching and learning activities (Björkqvist et al., 2016). The last ranked recommendation was the hiring of technical staff to assist in the experiment (0.769). To illustrate, any engineering programme needs to be supported by an appropriate institutional environment, which includes good leadership, competent faculty, and support staff, with a conducive learning environment (Björkqvist et al., 2016).

4.9 Direct Attainment of Psychomotor Programme Outcomes from myCOPO System

Direct measurement of psychomotor skill from the laboratory and final year project courses was obtained from the measurement software system in the civil engineering faculty, which is known as myCOPO. Internally developed in 2012, the system is aimed towards the facilitation of POs assessment for every student in every semester. The system enables average POs measurement by courses, semester, and cohort. Notably, it has been undergoing continuous improvement since its development. A snapshot of the system is shown in Figure 1 below.

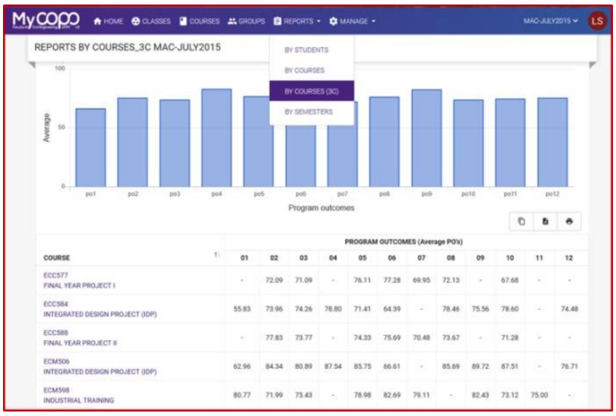

Figure 1: The average PO measurement by courses for all 12 PO attainments for civil engineering students

Meanwhile, Figure 2 indicates that the students acquired from 63% (lowest) to 80% (highest) of psychomotor skills, a percentage higher than 50% of the baseline set by the programme. Thus, this indicates that the OEL and FYP activities in the civil engineering programme contributed to positive results in the psychomotor PO attainment.

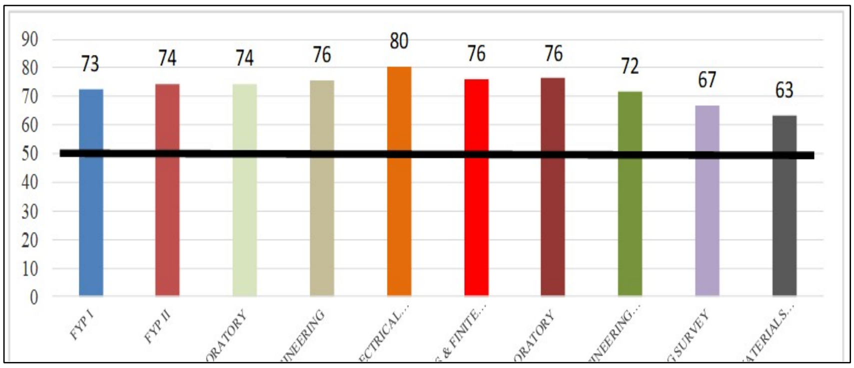

Figure 2: Students‟ direct psychomotor PO attainment based on OEL and FYP courses

5 Conclusions

This study adopted a quantitative approach using a survey questionnaire to record students‟ opinions on the development and attainment of programme outcome (PO) under psychomotor domain. It also determined the contributing factors of psychomotor PO attainment through open-ended laboratory (OEL) and final year project (FYP) courses. As a result, it was indicated from the students that the psychomotor-related activities performed in courses improved their skills and confidence by acquiring complex skills and making complex movements. Furthermore, the students believed that they developed the essential characteristics of psychomotor skills in data collection and apparatus usage. It was also found that better equipment condition assisted them in providing a better description regarding the usage of apparatus through the open-ended laboratory course and final year project activities. The findings were further validated by direct measurement of the programme outcome (PO) under the psychomotor domain obtained from myCOPO. Notably, the most important factor influencing the students‟ psychomotor skill performance was the equipment condition, which positively assisted them in the usage of apparatus and determining the correct procedures. A particular recommendation agreed by the students was the addition of the number of tools in the laboratory for improved teaching and learning activities, including the acquirement of psychomotor skill. Overall, this study has determined the psychomotor skill development and psychomotor PO attainment among civil engineering students, which are essential in preparing them for a career in design consultant offices, contractor site operations, and other construction-related work in the construction industry.

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