Assessment of hands-on experience and practical know-how acquired through electronics laboratories

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Abstract: Although laboratory classes for engineering courses are designed to provide hands-on experience that is essential for future work as engineers, the acquisition of practical know-how from hands on experience is rarely assessed or evaluated. Assessments of the learning outcomes tend to focus on the achievement of explicit technical knowledge related to the cognitive domain. The implicit devaluation of hands-on experience could significantly impair engineering technology students' ability to acquire and value practical skills. Therefore developing new model to include effective assessment in psychomotor domain could be one way to overcome this problem. Thus the aim of this research is to validate the method for measuring the hands-on experience gained from laboratory classes via changes in practical know-how as indicated by skills acquired in the psychomotor domain. Practical know how was assessed using the method of novices-experts was used where the finding of students' attainment is compared to experts' acquisition. The results show that hands-on experience gained from laboratory classes can be accessed via psychomotor learning outcome. The finding can promote greater appreciation and better assessment practices of laboratory experiences.

Keywords: Hands-on experience; Practical intelligence; Psychomotor domain; Laboratory classes; Cognitive domain

1. INTRODUCTION

Laboratory works provides valuable opportunities for students to effectively establish links between theory and real-world behaviour of engineering systems and materials or to develop practical skills [1]. Work in an engineering laboratory environment specifically, provides students with opportunities to validate conceptual knowledge, to work collaboratively, to interact with equipment, to learn by trial and error, to perform analysis on experimental data, and how to operate tools and equipment safely [2]. The value of hands-on laboratory classes, however, has not been so easy to quantify. Virtual laboratories, simulation, and remote access laboratories offer alternatives from which students seem to learn as well or better. Although the main aim of laboratory work is to provide opportunities for students to learn and gain experience, there has been little systematic research on what actually happens in a typical hands-on laboratory class and how the hands-on beneficial element is actually measured (cognitive vs psychomotor domain).

The existing assessment of learning outcomes of laboratory experiences using reports and test can only inform teachers on students' achievement in the cognitive domain [3] but not in the psychomotor domain. There has been a rising concern to assess the learning outcomes of the psychomotor domain in engineering laboratory [4-6]. The existing method for assessing learning from laboratory experiences of engineering technology do not include the assessment of the psychomotor domain due to lack of suitable measuring tools [3]. The method of assessing hands-on or practical components of learning should be different from that used for assessing the cognitive domain as the acquired learning are inherently different in nature.

Thus the main aim of this research is to develop and validate a method for measuring hands-on experience and changes in psychomotor skills gained from engineering laboratory exercises.

1.1 Objectives

In this research, the objective is to develop ways to test changes in hands-on experience via psychomotor domain; in order to assess unintentional learning classic implicit knowledge in engineering technology laboratory classes. In other words, the aim of the study was to develop ways to measure the experiential and "hands-on" component of learning laboratory classes. In detail, the sub objectives are:

i. To develop automated measuring instrument (Engineers Automated Testing Kit) based on the students' behavior in performing laboratory classes
ii. To establish the reference score by administrating of the Engineers Automated Testing Kit to experts;
iii. To establish experimental score by administrating the Engineers Automated Testing Kit to experiment and control group of students; and undergraduates and postgraduates.
iv. To analyze the students' score of acquired hands-on experience by comparing to experts' reference score.

v. To make recommendations for enhancing assessment practices in engineering education to promote development of hands-on experience towards greater industry-readiness of engineering graduate.

2. THEORETICAL BASIS

2.1 Era of practical skill to scientific analysis

Over recent decades there have been periods of rapid change in engineering education. Until the 1950s engineering education was largely based on an empirical and practical education with many hours spent at drawing boards and in workshops. The 1960s marked the ascendancy of scientific analysis which was further strengthened in the 1970s with digital computers that made analytical methods far more accessible. Science, theory and analysis have almost completely displaced practical skills from the engineering curriculum with the possible single exception of hands-on laboratory classes. Together with these changes, there have been increasing reservations expressed about the practical skills and competencies of engineering graduates. These concerns led to the introduction of generic outcome definitions for engineering education in 2000 in several countries [7-8]. These changes have led to some improvements, but concerns about graduate abilities are still voiced by many practicing engineers.

With the development of ever more complex technologies, there has been an increasing need for new approaches to engineering education especially for global collaboration in engineering projects [9]. The modern university seeks to extend learning opportunities to its students anytime and anyplace, (for example via online laboratories), to be successful in the global educational marketplace [10].

2.2 From explicit to implicit knowledge

Studies of engineering practice [11-17] have shown that implicit and tacit knowledge is just as important as explicit technical knowledge. Tacit knowledge develops in research laboratory work and many authors have commented on its importance, particularly in troubleshooting [18-21]. Experienced trouble-shooters and technical investigators rely on significant tacit knowledge and the importance of unwritten know-how knowledge [22-25].

It is accepted that practical know-how is essential for high achievement in the workplace [26-29]. Furthermore, Sternberg and his colleague [30] proposed that this type of know-how or what they have called ‘practical intelligence’ is closely related to what Michael Polanyi [41] has called ‘tacit knowledge’, which it is not openly expressed or stated, and it usually is not taught directly.

Our research on engineering practice confirms the importance of unwritten know-how. Careful studies of engineering practice [31] have revealed that extensive technical knowledge is needed. Most of this knowledge is acquired after completing university courses and much of it is surprisingly basic. For example, engineers need to know the components and materials used in their discipline as practiced within a given firm, at least to the extent that they can recognize components and understand what they are used for. Much of this knowledge is so relatively simple on the one hand, and so specific to a particular firm or industry sector on the other hand, that it would not be appropriate to attempt to teach it in university engineering courses.

However, students need to appreciate the significance of this ‘implicit knowledge’ or ‘practical intelligence’ or ‘hands-on experience’ in engineering practice. Through their laboratory experience, it was expected that students may acquire some hands-on experience. It is possible they may learn enough for troubleshooting: to be able to detect and solve problems or diagnose faults in the equipment. This experience develops either intentionally or unintentionally and it was hypothesized that unintentional learning is an important aspect of laboratory work [2]. However, since engineering technology courses restrict most assessment to explicit knowledge (which is usually learning outcome in the cognitive domain where the students have to write or occasionally speak to convey their knowledge for assessment), it is possible that the perceived relative value of hands-on experience and tacit knowledge may be reduced in the view of students. This might help to explain why employers often criticize the quality of the practical skills of engineering graduates.

2.3 Assessing Hands-on Experience via Psychomotor Domain

Universities are placed under considerable pressure to produce employable graduates as the number of unemployed graduates is steadily on the rise. Industries are finding it increasingly difficult to find suitable candidates with good working skills, and experienced engineers are also lamenting that engineering graduates do not seem to be aware of the kinds of experience or “hands-on experience” needed in their work [32]. Hands-on experience as it is often referred to, is the ability of a person to solve practical challenges in a given domain. The lack of hands-on experience may be due to the way in which explicit knowledge is valued and subsequently assessed in engineering education namely, via examinations, tests, laboratory reports and tutorial exercises. The lack of effective assessments on hands on experience which falls under the psychomotor domain indicates implicit devaluation of hands-on experience which can significantly impair engineering students’ ability to acquire and value hands-on experience.

Therefore in this study, a new method of assessing the psychomotor domain of engineering technology students was proposed (and tested) that represents the outcomes of hands-on experience, after taking the fundamental electrical laboratory classes. Measuring the hands-on experience approach (novices-experts approach [33] will be used in designing the assessment instruments (Engineers Automated Testing Kit); based on the observation of behaviors’ of students (novices)/experts and novices/experts representations of work-related situations.

2.4 Novice-expert approach in circuit faults diagnosis

An on-going task in engineering work is to increase the reliability, availability and safety of technical processes. Monitoring equipment and troubleshooting is an important part of this measurement and in [34] the researchers stated that fault diagnosis is a special category of problem solving and indicate that when a system is not functioning properly, the trouble-shooter must attempt to locate the reason for the malfunction and then must repair or replace the faulty component. This is congruent with Halpern [35] who indicated that the key component of the problem solving process was the ability to recognize and select the most efficient solution path from among all possible solution paths and concluded that identifying and employing an effective strategy was the most difficult skill set for trouble-shooters to develop.

To know the behaviour of trouble-shooters in diagnosing experiment faults, researchers [22]; [36] studied novice and expert trouble-shooters extensively in order to understand their cognitive processes and skills. This and many other similar studies, researchers [22]; [37] demonstrated that trouble-shooters make extensive use of tacit and implicit knowledge (hands-on experience) which has to be developed through experience. This is a powerful argument in support of the need for engineering students to practice and value the acquisition of hands-on experience.

However, before this goal can be achieved and given the well-known influence of assessment practices on students learning, a reliable way to measure and assess the acquisition of hands-on experience is necessary. Research in psychology has provided the required methods of measuring tacit knowledge [28]; [38-39]. Thus, in this research, the authors will use the similar method by developing specific testing instruments in the context of circuit construction and faults diagnosis

2.5 Psychomotor Domain Model

Learning outcomes in the psychomotor domain refers to the ability to physically manipulate a tool or instrument like a hand or a hammer. Psychomotor objectives usually focus on change and/or development in behavior and/or skills. Thus, students' practical skills and hands-on experience in the laboratory are associated with the psychomotor domain. This domain focuses on manual task that require the manipulation of objects and physical activities [13]. In this study, the psychomotor domain model (PDM) proposed by Ferris & Aziz [2] was used as a framework for assessment. Each level in the PDM clearly describes the types of skills to be performed by students and can be easily mapped with the laboratory experiments demonstrated by the student's researchers [4].

The psychomotor domain model introduced by [14] have seven levels of psychomotor domain hierarchy related to laboratory experiment in engineering technology education (refer to Table 1). According to Kennedy, Hyland & Ryan [40], this psychomotor domain model is specific for engineering technology students and could be used to assess the physical actions of engineers.

Table 1: Psychomotor Domain Model (PDM)

	Level	Descriptions
1	Recognition of tools and materials	Ability to recognize the tools of the trade and the materials.
2	Handling of tools and materials	Handle objects without damage to either the object or other objects in its environment or hazard to any person.
3	Basic operation tools	Ability to perform the elementary, specific detail tasks such as to hold the tool appropriately for use, to set the tool in action.
4	Competent operation of tools	Ability to fluently use tools for performing a range of tasks of the kind for which the tools were designed.
5	Expert operation of tools	Ability to use rapidly, efficiently, effectively and safely to perform work tasks on a regular basis.
6	Planning of work operations	Ability of competent to do specification work and perform the necessary transformation
7	Evaluation of outputs and planning for improvement	Ability of competent to look at a finished output product and review the product for quality of manufacture

Source : [2]

3.0 METHODOLOGY

3.1 Develop the fundamental skills of practical electronics

In an introductory electrical and electronics engineering laboratory, students are required to perform 'hands-on' experiments. They are provided with experiment kits of parts, tools, related equipment and an experiment handout to guide them through the required tasks. The students had to follow the instructions in the experiment handout presented as explicit knowledge. Through their laboratory tasks, it is expected that students would be acquiring or using experience without necessarily realizing it.

The introductory laboratory classes in electrical engineering fundamentals (PLT105 Electrical Circuit Theory) was chosen because the course is offered twice annually, providing great opportunities for observations and testing. Approximately more than 50 students take these classes every academic semester, providing potentially large sample sizes for testing and evaluation. The purpose of these laboratories is to introduce engineering students to fundamental concepts and applications of electrical and electronic engineering in a practical and enjoyable way.

The laboratories build on theory covered in lectures, reinforcing the concepts needed in the design of circuit of the systems. The laboratory sequence consists of five experiments: component coding and multimeter; oscilloscope and function generator; series - parallel resistance; nodal analysis and mesh analysis techniques; r-l and r-l-c circuits with a dc source voltage. In these experiments, the students have to develop the fundamental skills of practical electronics: reading a circuit diagram and using it to construct a working circuit, understanding the fundamental components in electronic engineering such as resistors, capacitors, inductors, diodes, transistors, operational amplifiers, and constructing a control system capable of guiding a vehicle around a track.

3.2 Administrating the Engineers Automated Testing Kit

In this study, the authors are in the process of developing and implementing specific testing instruments in the context of circuit construction and faults diagnosis; an automated hands-on experience measuring instruments (Engineers Automated Testing Kit) which complies with the psychomotor domain model introduced by Ferris & Aziz [2] (refer to Figure 1). The instrument was developed specifically to measure the hands-on experience gained from the introductory electrical engineering laboratory exercises.

The Engineers Automated Testing Kit consists of a set of domain-related psychomotor tasks, to construct simple electrical circuits and faults diagnosis. The practical task consisted of a partially completed circuit in which a power supply provides power for a LED light. Although it seems very simple, almost trivial, it was necessary to design a task for which the students' scores would provide sufficient variation to provide statistically meaningful results. A substantially more challenging task may have resulted in performance being more related to random chance than acquired hands-on experience

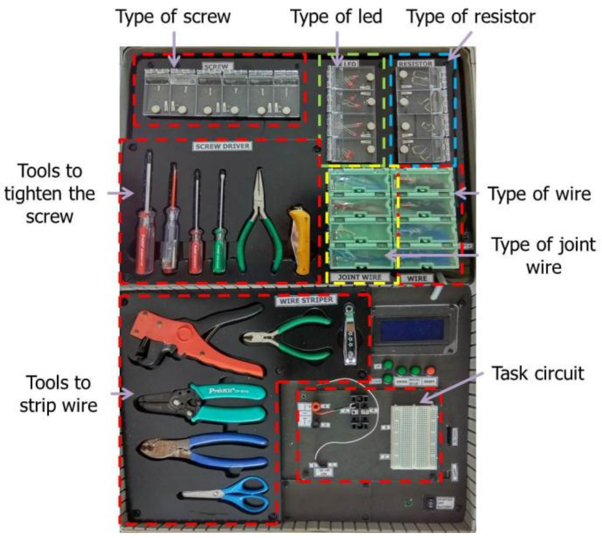

Figure 1- Engineers Automated Testing Kit for circuit faults diagnosis

Figure 1 shows a photograph of the Engineers Automated Testing Kit for the circuit construction and faults diagnosis task. This psychomotor task is required students to construct the circuit, based on the circuit diagram given, diagnose the faults on the circuit throughout the tasks and complete the necessary connections until the LED lights ON.

In completing the circuit, a student is given assorted of wires, wire stripers, screws, screw drivers, circuit board, resistors and connected wires, which each and every item can be used to complete the circuit. Each of the materials and tools are fixed in the Testing Kit box and connected to electronics sensor. Each of the assorted materials and tools indicated as response items, with random score between 1–7 (depend on the number of items). The response items were created as a result of careful observation of both students and experts and included highly appropriate responses and also common inappropriate responses made by students. The test starts by clicking the ON button. When the student chooses and takes any tool for the first time to do the task, the mark will calculate into his account. He/she has to choose the appropriate materials and tools, and there is no wrong answer or not trial and error.

Their performance was scored by calculating how many of the faults were diagnosed and corrected, which tools they *first* chose to use (appropriate or otherwise), which components they *first* chose to try using, and their time to complete (if they managed to before the 20 minute time limit). The circuit complete if the LED lights ON; by clicking OFF button, the LED display will show the marks collected. The student score was calculated by calculating the deviation from the average responses of a number of domain experts. The outcomes of hands-on experience can be measured by calculating the difference between novices' and experts' ratings; zero difference shows novices' close to experts' experience. The appropriate selection (appropriate score close to experts score) shows his level of hands-on experience and practical skills ability.

3.3 Establishing reference score

Objective
To establish the reference score by administrating of the Engineers Automated Testing Kit to experts.

Sample
The experts (N=7) such as lecturers, senior technicians, practiced engineers and experienced laboratory demonstrators. The distribution of expert:

Experts	Number
senior technician	2
assistance lecturer	2
lecturer	2
professional engineer	1
Total	7

Procedure
In developing the instrument, experts were recruited to undertake practical technical problem solving activities on fundamental electrical laboratory tasks. Their behaviors were observed while on tasks and in-depth interviews were carried out subsequently to establish a valid and reliable hands-on experience instrument. In

administrating of the Engineers Automated Testing Kit, the mean score of the experts group for each testing item is used as a reference score to calculate the level of hands-on experience for each respondents and groups.

Results

The outcomes of hands-on experience can be measured by calculating the difference between novices' and experts' ratings; zero difference shows novices' close to experts' hands-on experience. The anticipated outcome is that the results could demonstrate learning in the psychomotor domain of individual students; a novel method of laboratory classes' assessment by measuring individual hands-on experience acquired after performing the laboratory tasks.

3.4 Getting validation of testing on students' performance

Objective and hypotheses

To establish experimental score by administrating the Engineers Automated Testing Kit to experiment and control group of students; and undergraduates and postgraduates. The hypotheses tested were:

1. "*There is no statistically significant difference in the hands-on experience gained by students who perform the laboratory exercises and a control group who do not perform the laboratory exercises.*"
2. "*There is no statistically significant difference in the hands-on experience acquired between under-graduate who attended laboratory classes and postgraduate who involved directly in laboratory exercises.*"

Sample

In this study, the populations consisted of the engineering technology undergraduate students who studying in the Faculty of Engineering Technology, Universiti Malaysia Perlis. The sample population consisted of the first year undergraduate Robotics and Automation Technology students. Therefore, the samples chosen in this study are the first year engineering technology students, where the numbers of samples are approximately 70 have taken the PLT105 in every academic semester, are 'enough' to represent the research population, providing potentially large sample sizes for testing and evaluation. It is important to note that although the sample was drawn from various backgrounds, each of the participants shared many common similarities.

For the first hypothesis, there were 69 first year students (N=69) who enrolled in the course PLT105 were invited to participate in this research as an experiment group. Another 57 students (N=57) from other disciplines, but will enrol in this course in the next semester were also invited to participate as a control group. To avoid a bias in the samples, all the enrolled students for the both groups were invited to participate in this study.

For the second hypothesis, the participate in this study were postgraduate engineering students (N=22) who had been doing their research and project in laboratory environment and familiar in using engineering tools, parts and apparatus; and undergraduates (third year students; N=52) who had attended laboratory classes in every semester along their study.

Procedure and outcomes

As stated in detail in 3.2, paragraph 4 and 5.

Results

If the tested hypotheses were found to be false with a high degree of probability, it can be confidently said that the novices-experts approach is successful in assessing hands-on experience in the context of constructing circuit and diagnosing faults in the relevant equipment and that this psychomotor domain can be assessed. The method of measuring would then provide a powerful new means to assess the effectiveness of engineering technology laboratory classes.

3.5 Identifying hands-on experience acquired

In constructing the hands-on experience psychomotor instrument, laboratory worksheets in PLT205 were analyzed and reviewed. The common procedures and tasks for each laboratory worksheet were grouped according to the practical skills performed by students during the experiments. Next, the authors compared the practical skills that have been identified with the psychomotor domain model (PDM) listed in Table 2 in order to categorize the practical skills according the specified levels.

Task 1, 2, 4, 5 and 10 in Table 2 could be easily mapped to PDM Level 1 (recognize). For tasks 7 and 8 are combination level, are mapped to PDM Level 1 (recognize), Level 2 (handling) and Level 3 (basic operation). For these tasks, the student should recognize the material, able to handle or hold the material properly and do the basic tasks such as plug-in appropriately. Usually, the student will be able to do the tasks successfully. However, to do the tasks 3, 6 and 9 required student ability and competent (i.e practical skills and hands-on experience). For example, to strip wire insulator, the student should recognize the appropriate tools (Level 1), able to handle and use the tools (Level 2) and competent to strip wire insulator (Level 4) because in many cases, the entire wire is cut instead of the insulator is cut. Similar cases to the tasks 6 and 9.

Level 5, 6 and 7 (expert operation, planning of work and evaluate outputs) of the PDM are not related to any of the tasks because the practical skills in PLT105 only involve the use of basic instruments. Task 11 is just to display total time to complete the experiment.

Table 2: Psychomotor tasks vs. mapping of the skills to the PDM

	Appropriate tasks	Hands-on experience acquired	Mapping to PDM level
1	turn ON the circuit panel	start the test to count the marks	Recognize (Level 1)
2	choose wire	choose appropriate wires to be striped	Recognize (Level 1)
3	choose and apply wire striper	choose appropriate wire striper and strip the wire insulation	Recognize (Level 1)/ Handling (Level 2) / Competent operation (Level 4)
4	choose screw	choose appropriate screw based on a diameter of nut.	Recognize (Level 1)
5	choose screw driver	choose appropriate screw driver	Recognize (Level 1)
6	choose, apply and connect the wire	connect the uninsulated wire to the circuit board using the screw and screw driver chosen	Recognize (Level 1)/ Handling (Level 2) / Competent operation (Level 4)
7	choose and apply LED	choose the appropriate in LED and insert into the circuit board	Recognize (Level 1)/ Handling (Level 2) / Basic operation (Level 3)
8	choose and plug-in resistor	choose the appropriate resistor and plug into the appropriate hole	Recognize (Level 1)/ Handling (Level 2) / Basic operation (Level 3)
9	choose and apply joined wire	choose the appropriate joined wire and complete the circuit	Recognize (Level 1)/ Handling (Level 2) / Competent operation (Level 4)
10	turn OFF the circuit panel	if the LED lights ON, the score will appear on the LED display.	Recognize (Level 1)
11	total time completed	LED display shows total time	Not available

Table 4: Means, Standard Deviations, and t-Test

Tasks	G1 (N=57)	G2 (N=69)	t-test	G3 (N=52)	G4 (N=22)	t-test
1. turn ON the circuit						
2. choose wire						
M	1.82	2.37	2.19*	2.95	3.58	2.19*
SD	0.74	0.66		0.80	0.65	
3. choose wire striper						
M	2.94	3.57	3.17	3.25	3.90	2.67***
SD	0.79	0.64		0.74	0.75	
4. choose screw						
M	3.24	3.89	2.01*	1.56	1.96	2.26*
SD	0.73	0.74		0.72	0.69	
5. choose screw driver						
M	1.55	1.95	2.13*	1.78	2.38	2.23*
SD	0.61	0.71		0.75	0.64	
6. connect the wire						
M	3.41	4.01	1.99	1.83	2.38	2.79***
SD	0.80	0.86		0.65	0.74	
7. choose LED						
M	2.21	2.76	3.95***	3.58	2.95	3.09
SD	0.73	0.65		0.81	0.95	
8. plug-in resistor						
M	2.51	3.01	3.97***	3.55	3.90	3.02
SD	0.72	0.83		0.94	0.71	
9. choose joined wire						
M	2.22	2.64	1.52(ns)	1.65	1.91	2.66***
SD	0.88	0.80		0.74	0.72	
10. turn OFF the circuit						
11. total time complete						
M	4.60	5.20	2.59*	1.83	2.38	2.96***
SD	0.67	0.64		0.75	0.67	

Note: *p < .05; ***p < .001
Note: G1 – Control group; G2 – Experiment group; G3 – Undergraduates; G4 - Postgraduates

4. RESULTS AND DISCUSSIONS

This section discusses the data obtained from the Engineers Automated Testing Kit which was analyzed using descriptive statistics for frequencies.

4.1 Verifying the reference score

This testing is to verify the reference score "*that there is no significant difference in experts score between each expert"*. The author used a model of Compare Mean for One-Sample *t*-Test. In this model, the author needs to have a Test Value, the value to be compared with the score of all experts score. Therefore, the author accumulated a hypothesized score by testing the components of each response of the hands-on experience instrument and deep discussion with one of the most experience senior technician who involved in electronics field for more than 30 years. The hypothesized score as a Test Value is 56 points.

Table 3: The significance test for experts score

	N	Mean	SD	Std. Error Mean
	7	54.286	11.191	4.22979
	t	df	Sig. (2-tailed)	Mean Difference
Score	-1.351	6	.225	-5.71429

Referring to Table 3, "Mean difference" is the difference between the observed samples means (54.286) and the hypothesized mean (56). The results of the *t*-test show that *t*=-1.351 with 6 (N – 1) degree of freedom. The two-tailed *p*-value for this result is 0.225 (rounded off to three decimal places). The results are considered statistically significant if the *p*-value was less than the chosen level of significant (usually 0.05). But in this case, *p* was definitely greater than 0.05, so the results was considered **statistically insignificant** and the null hypothesis is accepted.

The results of null hypothesis testing show that *there is no significant difference between each expert in their score*. Therefore, the mean value of the experts (54.286) can be used as a reference for hands-on experience score throughout this research.

4.2 Validation of testing on students' performance – hypothesis 1

The instrument was tested to the experiment group (N=69) and the control group (N=57). Participants merely applied what they thought was the most appropriate response tasks. The mean scores of the psychomotor tasks inventory are listed in Table 4. Firstly, it was hypothesized that the results of this study could recognize the students who are able to give an appropriate response to the situations through their hands-on experience that they acquired during the activities in engineering laboratory, such as projects or research work.

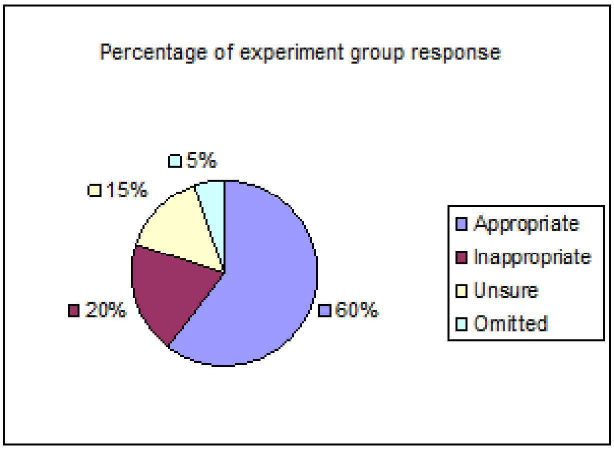

Figure 2 - Percentage of experiment group's responses

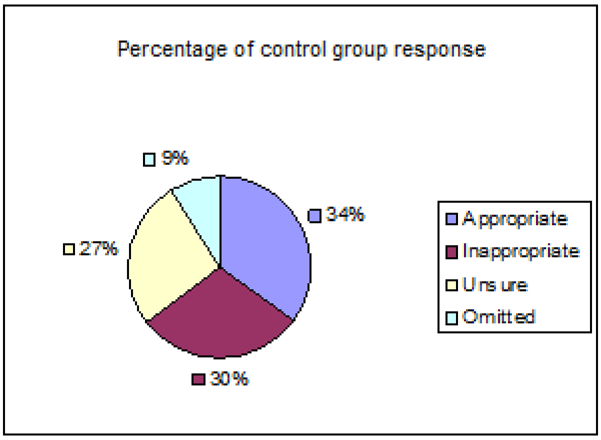

Figure 3 – Percentage of the control group's responses

The pie charts in Figure 2 and 3, show the comparison between the experiment group and control group participants' achievement, respectively.

After administrating the instrument, compiling and analyzing the results, and comparing the both pie charts, the results demonstrated that the experiment group participants have slightly more hands-on experience than the other group (by having more experience to choose appropriate tools and techniques). The experiment group achieves 60% appropriate action while the control group achieves only 34%.

It was also observed inappropriate actions taken by both groups (includes unsure and omitted responses) are also high; 66 % for the control and 40% for the experiment group. Therefore, the results cannot use as an evidence to say that the experiment group is better than the control group.

This is supported by using a t-test to analyze the effect of psychomotor tasks (Table 4). The results indicated there is no significant difference between experiment and control groups of students in psychomotor tasks. However, in the Level 3 of PDM (basic operation); item 7 (t=3.95, p<0.001) and item 8 (t=3.97, p<0.001), the advantages of hands-on experience and skills are very helpful for the experiment groups' students to solve the tasks more appropriately. Thus it is assumed that the control group students did not have the advantages.

Tasks 2, 4, 5 and 11 demonstrated that the experiment group had slightly higher on psychomotor tasks, however there is no significant differences between the two groups (p<.05). Similarly, the mean scores of the time taken to complete the overall tasks were higher for the experiment group.

4.3 Validation of testing on students' performance – hypothesis 2

The group of undergraduate (N=52) and research-mode postgraduate students (N=22). The researchers performed a uni-variate analysis of variance (ANOVA) to determine whether there was a difference among the two groups (undergraduates and postgraduates) with regard to the psychomotor domain variable.

The authors have used a t-test to analyze the effect on psychomotor tasks. Results indicated that there are significant differences between postgraduates and undergraduates in psychomotor tasks scores in cases 3, 6 and 9 (p <.001). The results shows for the tasks 3, 6 and 9, the students apply up to the Level 4 PDM (competent operation). In this PDM level, the advantages of hands-on experience and skills are very helpful for the postgraduate students to solve the tasks appropriately.

The results indicated that the postgraduates performed better probably because they had advantages of longer time involved in hands-on environment research tasks than the undergraduates, especially for the tasks 3, 6 and 9 and also for the task 11, total time to complete the hands-on experience test.

4.3 Discussion

For testing the hypothesis 1, the participants were first year engineering technology students. Even the experiment group had attended the laboratory classes for a few times, the performing in lab session could not significantly develop hands-on experience and change their behavior compare to the control group. During the lab session, might be there is some lacking in experience development, for example; some students asking help from technician, or just follow other friends, or doing by trying and error.

It was also seem that some participants omitted to give responses to a few items suggesting that they did not understand the questions which could be due to multiple interpretations of the items. Some participants (mostly control group students) also gave unintelligible responses to the exercises. This raises two possibilities, either participants are unable to relate the hands-on experience they gained through their project or research work in laboratory with the practical situation or they just opted for the easy option without proper thoughts.

However, for testing the hypothesis 2, the participants were third year engineering technology students who had attended lab classes at least 5 continuous semester. This gives them advantages in facing laboratory testing. Similarly to postgraduate students who spent most of their in laboratory environment. Therefore during the testing, the both group were manage to apply their hands-on experience in practically construct the circuit and diagnose any equipment faults, and the results show the difference of level of hands-on experience between them.

6. CONCLUSIONS

Without further analysis, the results demonstrated that hypothesis 1 is inconsistent with expectation. The results demonstrated that the original null hypothesis 1 is correct; *there is no statistically significant difference in the hands-on experience gained by the experiment and the control group*, although there are higher score for the experiment group.

The authors predict that the amount of experience gained by the experiment group in few laboratory classes is very less and unable to compare experimentally to the control group. The factor of living or surrounding might also have an effect to their know-how and experience. It is also expected that the longer time they spend in laboratory environment will develop their hands-on experience.

The outcome on hypothesis 2 is as expected; i.e., *There is statistically significant difference in the hands-on experience acquired between under-graduate who attended laboratory classes and postgraduate who were involved directly in laboratory exercises."* Longer time in laboratory environment develop their hands-on experience and change their behavior in psychomotor domain.

In conclusion the results supported the claim that hands-on experience via psychomotor domain can be measured by calculating the difference between participants' ratings and the experts' ratings. Thus this study has demonstrated the feasibility of measuring hands-on experience via psychomotor domain which has not been assessed or measured in the past when evaluating different laboratory experiences for engineering technology students. The psychomotor domain model proposed by Ferris and Aziz [2] was used to develop the hands-on experience instrument (Engineers Automated Testing Kit) in categorizing the practical skills. As mention by Salim and her colleague [4], results of the study highly recommended that the current assessment method which only relies on the laboratory report is revised.

The new assessment method should specifically assess students' experiences and practical skills with respect to laboratory experiments. It is possible that techniques for measuring hands-on experience that have emerged from attempts to improve selection in recruitment processes may provide a way to measure that elusive component of engineering laboratory experiences referred to by most people as "hands-on practical experience". This would provide a third means to evaluate engineering laboratory class experiences, beyond the established methods of comparing student performance in explicit assessment tasks (e.g. reports, tests) and measurement of student perceptions of their laboratory experience. A comprehensive assessment of students' performance in the laboratory is important in producing graduates who are able to integrate between the theory and practice of the electronic engineering courses as well as to perform the practical skills expected from them.

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