Journal of Engineering Research and Education
Volume 14, 2022 [34-43]

Self-assessing psychomotor skills using thinking-aloud technique via smartphone

NSS Mizam[1,] , ZB Razali[1,2] and MMA Kader[1,2]

[1] Faculty of Electrical Engineering Technology, Universiti Malaysia Perlis, Kampus UniCITI Alam,02100 Padang Besar, Perlis, Malaysia.
[2] Center of Excellence, Sports Engineering Research Center (Electronics), Universiti Malaysia Perlis, 02600 Arau, Perlis Malaysia.

ABSTRACT

This research aims to design and develop an automated device for self-assessing psychomotor skills without an instructor's observation. The lab assessment usually needs an instructor to observe, measure, and analyze the student's skills. It consumed much time to monitor each student. The problem of assessing psychomotor skills in the laboratory can be solved using the latest technology. Thus, the design of an Automated Psychomotor Testing Kit will be used to measure student psychomotor skills via a smartphone. The result can be transmitted to the instructor's smartphone via the Blynk application using the Arduino Mega and Bluetooth module. For this research, 17 students of Robotic and Automation Technology (Treatment Group) and 19 volunteered students from other engineering technology programs (Control Group) participated. The detailed methodology is described in this paper. The results show that there is a significant difference in mean scores between the treatment and control groups. Thus, the researcher can conclude that changes in students' Psychomotor Skills (P.S.) resulting from laboratory classes are statistically significant and be measured.

Keywords: automated device, lab assessment, psychomotor skills, thinking-aloud technique

1. INTRODUCTION

Psychomotor learning is illustrated by physical abilities such as movement, strength, manipulation, skill, grace, control, speed, and action [1][2]. Hands-on learning is a crucial foundation of what every student experiences. Laboratory courses may test intellectual and practical skills in the engineering sector and provide valuable learning opportunities. Research and learning in the laboratory can expose students to validate conceptual information, collaborate, interact with equipment, learn by test and error, interpret experimental data, and work safely on tools and equipment [3]. There are several laboratory classes alternatives, from virtual laboratories to simulation, which students seem to learn.

Moreover, doing or actively performing, versus listening or watching, stimulates heavier levels of brain activity. This makes for a more vital ability to recall facts and information and retain them in one's memory long after the activity is complete. However, the values of practical laboratory classes have not been easy to quantify and are time-consuming. While the purpose of laboratory lessons is to provide resources for learning and training, there is limited research on classroom and hands-on evaluation.

*Corresponding Author: zolbahri@unimap.edu.my

The traditional method used nowadays involves test and report elements to assess students' value and technical expertise, which involves instructors analyzing students' skills. This old laboratory assessment method consumes much time as the laboratory classes are usually longer, within two to three hours. Thus, the method by assessing the psychomotor domain using the thinking-aloud technique arose. Therefore, this project focuses on finding a way to self-assess without an instructor to gain theory on psychomotor skills. The seconds are to reduce time in laboratory classes without using an essential tool. Lastly, to replace the instructor with an alternative monitoring system for a laboratory purpose to measure psychomotor skills and experiences. As a result, the suggested practical or hands-on learning components are entirely different from the cognitive domain [4].

2. THEORETICAL FRAMEWORK

2.1 Concepts of Thinking-Aloud

Apart from the development project, problem-solving ability is an area that possibly can attract a high interest among mathematical educators; productive research has failed to keep pace with the development of the concerns expressed [4]. Researchers who have sought to progress in human problem solving have used many different techniques in their work. Some researchers even use specially designed problems to examine flexibility or rigidity in problem-solving [5], while others might evidence an analytical or global reaction to a problem [13]. ln many cases, problem-solving does not do much to show how the result is achieved. To obtain the result on the individual's problem solving, the researcher must find a suitable method to get the student to reveal the steps they followed so that a visible sequence of processes is available for analysis.

In recent years, the techniques requiring students to think aloud the resulting protocol have grown in popularity. However, there is always some disagreement about the thinking-aloud's effectiveness in giving sufficient information about a person's thinking process while solving problems. The question arises as to whether a student responds differently when asked to speak verbally since they have been working in which verbalization is not required [3].

2.2 Psychomotor Domain Assessments

The psychomotor domain represents the ability to physically manage a tool or instrument such as a hand or hammer. Psychomotor targets usually focus on behavioral and skill changes. Thus, the psychomotor domain is related to students' professional skills and practical experience in the laboratory [8]. This domain focuses on the manipulation of the object and physical activity. The types of skills that students can demonstrate are suggested in each level of PDM and can be easily shown by study students with laboratory experiments. Five psychomotor structure levels related to the study of laboratory experiments in engineering technology education have been introduced. Concerning engineering technology students, this psychomotor model can test the physical activity of engineers [7]. This Psychomotor domain model (PDM) is unique to engineering technology students (Table 1).

Table 1 Level of Psychomotor Domain [1]

Level	Description
1: Recognition of tools and materials	Ability to recognize the tools of the tools and trade and materials.
2: Handling of tools and materials	Ability to appropriately handle tools and materials.
3: Basic operation of tools	Ability to set the tool in action and to the operation of tools perform elementary tasks
4: Competent	Ability to use the tools for operating tools range of tasks fluently.
5: Expert	Ability to use tools rapidly, efficiently, operation of tools effectively and safely.
6: Planning of work operation	Ability to take a specification of a work operations output and perform the necessary transformation
7: Evaluation of outputs and planning for improvement	Able to look and review a finished outputs product to identify particular planning for deficiencies

2.3 Assessing Practical Experience through Psychomotor Domain

Nowadays, it is tough to find experienced and good job skills candidates to work in the industry while the number of unemployed graduates is increasing consistently. The engineering field graduate needs to determine the type of training or hands-on experience in demand related to their job scope [7]. The ability to solve practical challenges is called practical experience. The decline in having practical experience among graduates is due to the lack of physical training. This may be because the routes by which express learning are valued and, in this way, surveyed in building exercises become specific through tests, trials, laboratory reports, tutorial exercises running [6].

Another research involves evaluating the psychomotor domain through practical experience. The related skills followed by the table are displayed in the psychomotor domain. Perceptions, sets, guided responses, and mechanisms are focused on this research. In this situation, researchers do not seek to make predictions about the basic measurement of practical experience. Researchers only want to measure skills in the field of psychomotor [10].

2.4 Thinking-Aloud Technique in Diagnosing Faults

Students are expected to earn greater appreciation by taking laboratory courses and operating equipment. These laboratory activities enhance understanding similar concepts that students have theoretically learned in regular laboratory courses [3]. Olson et al., while choosing thinking aloud as a research method, it has been reported that using hard-thinking technology is one of the most effective methods for evaluating high-level thinking procedures (which require working memory).

Fault diagnosis is one of the most important methods to ensure proper circuit operation, software sequence, and system. Fault diagnosis and several related studies indicate that problem solvers typically use hidden and implicit information that experience must achieve [9]. In the field of modern engineering, it becomes a significant field. This provides prerequisites for fault tolerance, reliability or safety, fundamental design features in complex engineering. In a diagnostic system, the engineer or diagnostic specialist must have a clear understanding of overcoming the shortcomings and the results that need to be learned from experience [13]. Knowledge of this self-improvement is generated through their work background, either explicitly or implicitly, but most practical experience is expected. This self-improvement knowledge is caused by their work background, either explicitly or implicitly, but most practical experience is desired. This is an important statement favoring engineering students' need to perform and appreciate the accumulation of practical knowledge [2].

3. METHODOLOGY

3.1 Research Design

In an engineering technology laboratory, students perform a practical experiment that introduces to electrical engineering. During the practical sessions, an experiment handout is presented to lead students through the appropriate tasks. The student was expected to follow all the instructions as specified in the handout as their guide. Thus, simultaneously, the student might acquire practical experience through the laboratory task without necessarily realizing it.

For this research, the course PLT108 (Engineering Skills) was chosen. These classes are selected because they primarily include practical tests and a range of evaluation, research, and troubleshooting opportunities.

A "Quasi-experimental Design of the Non-equivalent Control Group" design was used where two groups of students made comparisons to see achievements were needed [11][12]. For this study, 17 of the volunteered first-year Robotics and Automation Technology students attended the laboratory practices on constructing domestic electrical wiring. In contrast, 19 students were not registered with PLT108 (from other courses within the Faculty of Engineering Technology, UniMAP).

Therefore, the first group of 17 students is a treatment group (T.G.) (which is processed), and the second group of 19 students is a control group (C.G.) (which is not processed). Using the Automated Psychomotor Testing Kit via the thinking-aloud technique method, both groups conduct the same psychomotor testing assessments.

The practical experience results are calculated by measuring the difference between the treatment group (T.G.) and control group (C.G.) students with experts' ratings; zero difference shows beginner level close to professional level hands-on experience [3]. The psychomotor domain by individual students could demonstrate the anticipated result by calculating the individual hands-on experience, a novel approach for assessing laboratory classes gained following the completion of laboratory tasks. This concept is as same as the expert-novices experiment concept.

3.2 Hardware and Software Design

In developing the instrument for measuring the psychomotor domain in electrical circuits, a basic definition and analysis need to be explored to gather more precise knowledge. The hardware part should be completed before implementing the software part. The hardware included Arduino mega, 4x4 matrix keypad, and HC-06 Bluetooth module. After the hardware part is assembled, the project moves to the simulation part. The simulation included circuit design, Arduino mega program coding, and program for application Blynk. The troubleshooting will be done with the completion of hardware and software until it fulfills the desired design.

To make the testing instrument automated and linked to a smartphone, two types of software are used: the system software and the application software. The system software used for coding design performs the ma chine's sequence due to the programming sequence. The next one is the application software used to create an interface to communicate through the machine. The application software is designed by using the Blynk application.

3.3 Identifying Practical Experienced Acquired

In developing the Automated Psychomotor Testing Kit, the lab worksheet course PLT108 was evaluated. This course (Engineering Skills Laboratory 2) has been grouped into skills and knowledge levels. The standard method and tasks for each laboratory worksheet were grouped by students' practical skills. Next, the practical skills found were compared with the psychomotor domain model (PDM) shown in Table 2.

Table 2 Psychomotor Domain Model Mapping

	Tasks	Hands-on Experience	Mapping to PDM level
1	Choose wire	Choose wire by size	Recognize (level 1)
2	Choose and apply wire stripper	Choose appropriate wire stripper and strip the wire insulation	Recognize (level 1)/Handling (level 2)/Competent operation (level 4)
3	Choose screw type	Choose appropriate screw by length	Recognize (level 1)
4	Choose and apply the screwdriver type	Choose a screwdriver and connect the screw	Recognize (level 1)/Handling (level 2)/Competent operation (level 4)
5	Choose bulb	Choose bulb according to the voltage	Recognize (level 1)

Task 1, 3, and 5 in Table 2 is mapped to PDM level 1 (recognize). For task 2 and 4 are combination levels mapped to PDM level 1 (recognize), level 2 (handling), and level 4 (competent operation). The student should identify the appropriate tool and material for tasks 1, 2, and 3. While for tasks 2 and 4, the student should be familiar with handling the tool, which required competency, practical skills, and hands-on experience. For example, the student should know the right tool for using the strip wire insulator (level 1), handle the tool (level 2), and, lastly, strip the wire insulator. In most situations, an inexperienced student instead damages the wire insulator.

3.4 Use of thinking-aloud while applying the Testing Kit

The selected students will show off their mind (thinking -aloud) while performing the psychomotor testing that involves them building a circuit according to the given task to demonstrate their skills. The students will be given basic tools to create an electrical circuit such as wires, stripper wires, screws, screw drives, and light bulbs. Each wire, wire stripper, screw, and screw driver are provided with four options with different shapes and sizes, while the light bulb is equipped with three options with varying measurements of voltage required. Each material and tool are installed in the Automatic Psychomotor Test Kit toolbox for them to use. While thinking aloud (by selecting the answer on the keyboard), students must choose one for each tool to diagnose and construct the circuit. Each keyboard button represents a given material and tool. All materials and tools were shown as response items with random scores ranging from 1–4.

The test will start when the switch button is switched on while simultaneously thinking about it. And when the student chooses the tools and material, the overall mark will be calculated. The student needs to select the appropriate tools and select the answer on the keypad (to represent their thinking-aloud). Their performance was scored by choosing a suitable tool; there is no wrong answer or error. All the tools selection can be used to construct the circuit, and the appropriate tool has a higher mark. After the circuit is done, the overall mark can be seen on the smartphone's Blynk application. The student score is calculated by adding the total mark divide by 19 and multiplying by 100 to get the mark's percentage. Figure 1 shows the wiring diagram of the circuit construction, and Figure 2 shows the schematic diagram for the testing instrument.

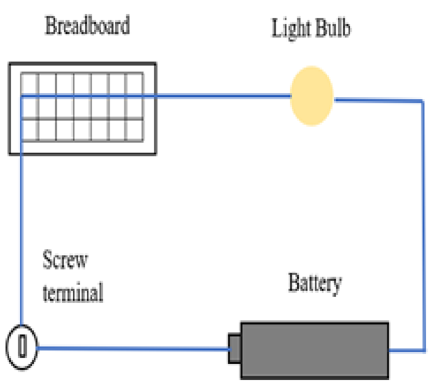

Figure 1. Wiring Diagram of Circuit

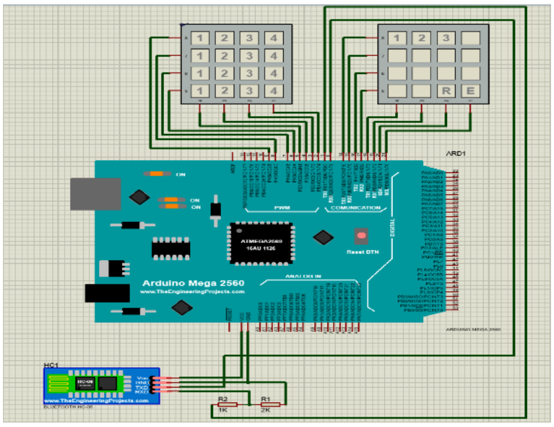

Figure 2. Schematic Design

4. RESULTS AND DISCUSSIONS

Students were divided into the treatment group (T.G.) and the control group (C.G.). The treatment group (T.G.) consisted of N = 17 students who had attended lectures and practical workshops PLT108 (Engineering Skills 2) and completed the module electrical circuit. For this T.G., Psychomotor Test Kit was used to test the solution of electrical circuit problems. Students of the control group (C.G.) consisting of N = 19 were also given a test of solving electric circuits using the same Psychomotor Test Kit. The researcher prepares a set of instruments for testing and test handling. Students are given guidance on how to perform the test.

The data collected through this study for both groups T.G. and C.G., such as a summary of mean, mode, and standard deviation for pre and post-electrical circuit fault test values, will be compared between the groups. The T-test was used to detect critical output variables. A series of analyses using statistical inference ANOVA was performed to look at the variables' main causes, relationships, and variations. All research involved used the latest edition of Statistics Product and Service Solutions (SPSS) software in Windows 10 environment software.

4.1 Use of thinking-aloud while applying the Testing Kit

This project aims to evaluate the contribution of psychomotor skills to the PLT108 (Engineering Skills) student experience. The purpose is to measure psychomotor skills (P.S.) changes among students who perform practical laboratory work. This raises the issue of the project posed in this study:

Can the changes in students' psychomotor skills (P.S.) resulting from laboratory classes experience be measured?

Researchers would clarify and test the evidence supporting the hypothesis for this study. The test hypothesis is:

H_1: "The change in students' psychomotor skills (P.S.) resulting from laboratory experiments is statistically insignificant."

To prove **H_1** this open up to another research question.

Question 1: Are the evidence that changes in psychomotor skills (P.S.) can be measured?

Changes in psychomotor skills (P.S.) can be measured by comparing student (novice) values with experts' mean scores. Expecting that experts (N = 4) have a high level of P.S. in their field of expertise, the mean Electric Circuit Fault solving score was used as a reference for the Automated Psychomotor Testing Kit. To explore the experts' mean score, the researcher tested the null hypothesis that there is a statistically significant difference in expert scores between them.

The researcher used one T-test sample and data from a given sample to see whether the sample's mean from which the sample is taken corresponds to the hypothesized mean.

Question 2: Test (treatment - TG) vs. test (control - CG).

For question 2, the researcher used "Non-equivalent control group design" [13] with the project design of Pre-test – Post-test Control Group Design (Table 3). The researcher analyzes the difference between the group and the independent group of variables. There are two independent variables:

- testing: pre-test and post-test, and
- grouping: a treatment group and the control group

There is one dependent variable (mean score) involved in this project.

Table 3 Post-test and Pre-test table for Treatment and Control group

Pre-test Treatment	Post-test Treatment
Pre-test Control	Post-test Control

Four (4) comparative analyses are involved in this section, which is correlated with a null hypothesis. However, the researcher could only perform one SINGLE test for both groups due to time constraints.

The question is, "Is there any difference in the achievement of test for both treatment groups (T.G.) and control group (C.G.)."

Before the evaluation test was conducted, the treatment group (T.G.) underwent the PLT108 laboratory, while the control group (C.G.) did not experience the PLT108 laboratory. To support Hypothesis **H_1**, TWO (2) accompanying questions had to be tested based on the experiment. Therefore, this study's main part is a comparative analysis of point accumulation between the control and treatment groups. Student performance with the Automatic Psychomotor Test Kit for Electrical Circuit Fault is calculated based on the expert mean score. The Comparative Means Model is used for most data analyses. The researchers analyzed the data in many ways, and, regardless of the study method, the results were almost identical.

4.2 Mean value of the experts

Results of the significance test indicated in Table 4 and Table 5. "Mean difference" (the difference between the observed samples means (18.43) and the hypothesized mean (19)) is -0.571, shows that the score is close to each expert and the hypothesized mean. The table also displays the 95% confidence interval for the difference between the means, which goes from -1.07 and -0.08.

Table 4 One-Sample Statistics

	N	Mean	Std. Deviation	Std. Error Mean
Each Expert	4	18.43	0.535	0.202

Table 5 Results of One-Sample Test

	Test Value = 19					
					95% Confidence Interval of the Difference	
	T	df	Sig. (2-tailed)	Mean Difference	Lower	Upper
Each Expert	-2.828	3	0.030	-0.571	-1.07	-0.08

**Correlation is significant at the 0.05 level (2-tailed)

The result of the t-test shows that t = -2.828 with the degree of freedom is 3 (N − 1). The two-tailed p-value for this result is 0.030 (0.015 for one-tailed - rounded off to three decimal places), less than the level 0.05, so the null hypothesis is rejected. The results were considered statistically insignificant. The results show that there is no statistically significant difference between each expert in their score. Therefore, all the experts agreed with the response items, and the mean value of the experts (18.43) is valid to be used as a reference for Psychomotor Skills (P.S.) score throughout this project.

4.3 Analysis of Data

Table 6 shows each group's number of cases separately, mean, standard deviation, and standard error on the dependent variable. In this case, the variable Cond. (1 = Treatment-group, 2 = Control-group) is described by the two classes.

Table 6 Descriptive statistics for the Pre-test (treatment and control) scores

		N	Mean	Std. Deviation	Std. Error Mean
Score	1 (TG)	17	17.8621	2.7350	0.5078
	2 (CG)	19	19.7500	3.4163	0.7639

**Condition: 1 = Treatment-group (TG), 2 = Control-group (CG)

The most widely used test is called "Equal variances assumed" (see Table 7). The researcher presumed that the two population variances were equal; a pooled variance calculation was used to combine the two samples of the variances to produce the most reliable estimate of the variances common to both populations.

Table 7 Independent Sample Test for TEST (Treatment and Control) Scores

	F	Sig.	t	Df	Sig. 2-tailed	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
								Lower	Upper
Equal variances assumed	0.082	0.776	-1.77	35	0.068	-4.1121	-0.2561	-18.920	1.0195
Equal variances not assumed			-1.77	35	0.068	-4.1121	-0.2561	-18.920	1.0196

4.4 Discussion

While there is a difference in the treatment group's mean (17.8621) and the control group's mean (19.7500), the difference is insignificant. The equality of means for t-test N = 36 (degree of freedom for the T.G. and C.G. is equal to 35) is proven. The chance of 0.068 two-tailed is higher than 0.05, and the test is thus statistically insignificant at 0.05.

For both groups, we can see that the standard deviation is equally low (2.7350 (T.G.) and 3.4163 (C.G.), respectively). This indicates that the TEST score is close to the mean range of values but not as high as the expert score.

The researcher accepted the null hypothesis in this case. While there is a difference between the mean scores, the study indicates no significant difference in the initial Psychomotor Skills (P.S.) between the two groups. The mean difference between the two group's samples was drawn is zero.

5. CONCLUSIONS

The results demonstrate that the author can devise effective ways to measure psychomotor skills acquired by engineering technology students from laboratory experiences. This would provide a third means to evaluate engineering laboratory class experiences beyond the established methods of comparing student performance in explicit assessment tasks and measuring student perceptions of their laboratory experience.

Constructing a psychomotor testing instrument was not an easy exercise. The author was surprised by the students' lack of practical knowledge, and it was not easy to construct a test that would result in meaningful scores. The author may be able to alter student learning behavior by including psychomotor skills tests in assessment processes. The testing may motivate students to acquire the ability to learn practical skills, which could ultimately make them more effective as practicing engineers.

ACKNOWLEDGEMENTS

The author would like to acknowledge the support from the Fundamental Research Grant Scheme (FRGS) under a grant number of FRGS/1/2019/SSI09/UNIMAP/02/1 from the Ministry of Education Malaysia.

REFERENCES

[1] Z.B. Razali & J.P. Trevelyan. Assessing engineering students' practical intelligence as the outcome of performing 'hands-on' laboratory classes. Jurnal Teknologi (Social Science) UTM, 64(1) (2013) p11-16.

[2] M.H. Daud & Z.B. Razali, "Novel Approach for Assessing Psychomotor Domain in Engineering Technology Courses," Soc. Sci., vol. 12, no. 3, pp. 406–412, 2017.

[3] M.H. Daud, Razali, Z. B. & M.M.M.A. Kader (2018). Effective ways to test changes of practical intelligence in order to assess unintentional learning in laboratory classes. In MATEC Web of Conferences (Vol. 150, p. 05003). doi.org/10.1051/matecconf/ 201815005003

[4] J.A. Jacko & K. G. Ward, "Toward establishing a link between psychomotor task complexity and human information processing," Comput. Ind. Eng., 1996, doi: 10.1016/0360-8352(96)00192-1.

[5] C.Y. Wang et al., "A review of research on technology-assisted school science laboratories," Educ. Technol. Soc., 2014.

[6] G. Kasilingam, M. Ramalingam, & E. Chinnavan, "Assessment of learning domains to improve student's learning in higher education," J. Young Pharm., 2014, doi: 10.5530/jyp.2014.1.5.

[7] I. E. Achumba, D. Azzi, V. L. Dunn, & G. A. Chukwudebe, "Intelligent performance assessment of students' laboratory work in a virtual electronic laboratory environment," IEEE Trans. Learn. Technol., vol. 6, no. 2, pp. 103–116, 2013, doi: 10.1109/TLT.2013.1.

[8] K. Radin Salim, M. Puteh & S. Mohd Daud, "Levels of practical skills in a basic electronic laboratory: Students' perceptions," in 2011 IEEE Global Engineering Education Conference, EDUCON 2011. doi: 10.1109/EDUCON.2011.5773142.

[9] A.A. Aziz, K. M. Yusof & J. M. Yatim, "Evaluation on the Effectiveness of Learning Outcomes from Students' Perspectives," Procedia - Soc. Behav. Sci., 2012, doi:10.1016/j.sbspro.2012 .09. 628.

[10] M.A. Baharom, R.H. Khoiry, A.A. Mutalib & N. Hamzah, "Assessment of psychomotor domain in a problem-based concrete laboratory," J. Eng. Sci. Technol., 2015.

[11] S. Isaac & M. William, "Handbook in research and evaluation," Behav. Ther., vol. 7, no. 1, 1971, doi: 10.1016/s0005-7894(71)80129-6.

[12] N. L. Campbell, D. T., Stanley, J. C., & Gage, "Experimental and quasi-experimental designs in prevention research.," NIDA research monograph. 1963.

[13] H. J. Eysenck, "Practical intelligence: Nature and origins of competence in the everyday world," Pers. Individid. Dif., 1988, doi: 10.1016/0191-8869(88)90172-9.