Think-aloud Technique in Assessing Practical Experience:
A Pilot Study

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Abstract. The learning domains such as cognitive, affective and psychomotor for
Engineering Technology programs should be identified and valued. The acquisition
of hands-on experience in workplace settings and laboratory classes is just as
important as explicit technical knowledge, and should be measured in psychomotor
domain. However, the explicit knowledge is valued in engineering technology
education. Furthermore, practically all assessments measure cognitive value. This
implicit devaluation of hands-on experience could significantly impair engineering
technology students’ ability to acquire and value practical skills. Therefore,
developing a new model to include effective assessment in psychomotor domain
could be one way to overcome this problem. Thus, the aim of this project is to find
ways to measure changes in hands-on experience in engineering laboratory classes.
The second aim is to test the relationship between hands-on experiences acquired
in laboratory classes with the ability to diagnose simple experiment faults in
laboratory arrangements. The method of think-aloud is used in the research where
the finding of students’ attainment is compared to experts’ acquisition. The results
show that the value of psychomotor domain in laboratory classes via hands-on
experience can be assessed and valued between two groups of students which is
experiment and control group. Methodologies and detail results for this research
are described in this project.

Keywords. Think-aloud technique; Psychomotor domain model; Constructing
electrical circuit; Practical experience; Measuring experience; Hands-on laboratory
exercises.

1. Introduction
Laboratory classes are valuable learning experiences, which can be used to effectively teach the link
between theory and real-world behavior of engineering systems and materials or practical skills. Work
in an engineering laboratory environment 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 [1]. The value of hands-
on laboratory classes, however, has not been so easy to quantify. Presently, the way of assessment
laboratory classes using reports and test for assessing laboratory experiences can only assess students’
achievement in cognitive domain. The concern of assessing psychomotor in engineering laboratory
still arose by many researchers [2]. The exist method to evaluate laboratory experiences of engineering
technology students do not include the assessment of psychomotor domain due to lack of suitable
measuring tool. Therefore, the proposed method of assessing psychomotor domain by using think-
aloud technique is to prove that the method of measuring hands-on or practical components of learning is totally different to cognitive domain [3]. Thus the aim of this research is to find ways to measure changes in hands-on experience in engineering laboratory classes. The second aim is to test the relationship between hands-on experiences acquired in laboratory classes with the ability to diagnose simple experiment faults in laboratory experience.

2. Assessing practical experience
The practical experience can be affectively measured in psychomotor domain. Proponents of general intelligence as the best predictor of job performance argue that practical experience is simply the result of on-the-job learning. In addition, general intelligence is the best predictor, and fast learners will acquire job-specific knowledge faster [4]. Requirement for high levels of cognitive and psychomotor ability to comprehend the questions correctly are expensive to research and create in job specific tests. The recruitment for selection tool is still not widely accepted in testing practical experience. The researchers are not attempting to make forward predictions on the basis of practical experience measurement. The researchers only wish to measure skills in the psychomotor domain [5].

2.1 Developing practical and hands-on skill of engineering students
Experience in the engineering laboratory is a vital segment of their preparation for hand-on skill for engineering students. The students are likely to have greater appreciations towards them by attending laboratory classes and handling the equipment. These laboratory experiences are just as likely to enhance understanding of related concepts for which students have learned in theory as traditional hands-on laboratory classes [1].

The researchers have seen in typical hands-on laboratory classes, students are generally separate into groups of four or five people and they accomplish a task together. Sometimes, not every student has contact with or handles the equipment. Thus, the aim of the laboratory work is to give opportunities for students to learn and understand engineering concepts, but it is not known that actually happens in a typical laboratory class [6]. Furthermore, the current research on engineering practice indicates that there are few detailed reports on engineering practice. Thus, it is not easy to decide which laboratory experiences contribute towards the foundation for engineering practice. When the researchers move from hands-on labs to on-line labs or simulations, the researchers cannot be sure about what students will miss or gain [7].

The careful studies of engineering practice have revealed that extensive technical knowledge is needed. After completing university courses, most of this knowledge is acquired and much of it is unexpectedly basic. For instance, engineers need to know the components and materials used in their discipline as practiced within a given firm, at least to extent that they can recognize components and understand what they are used for.

2.2 Psychomotor Domain Model (PDM)
Skills in the psychomotor domain portray the ability to physically control an apparatus or instrument like a hand or a hammer. Psychomotor targets usually concentrate on change in improvement with behavior and skills. Thus, the psychomotor domain is associated with students’ practical skills and hands-on experience in the laboratory [8].

The focuses of this domain are the manipulation of objects and physical activities. The psychomotor domain model (PDM) proposed by clearly describes the type of skills to be performed by students in each level in the PDM and can be easily mapped with the laboratory experiments demonstrated by the research students. The psychomotor domain model introduced have five levels of psychomotor domain hierarchy related to laboratory experiment in engineering technology education (refer Table 1). This psychomotor domain model is specific for engineering technology students and could be used to assess the physical actions of engineers[9].
2.3 Evaluating Hands-on Experience through Psychomotor Domain

The quantity of unemployed graduates is consistently on the rise as universities are put under significant weight to deliver unemployed graduates. Nowadays, it is very difficult to find suitable candidates that have experienced and good working skills in industries. The engineering graduates to be aware of the kinds of experience or “hands-on experience” needed in their work [9]. The ability of a person to solve practical challenges in a given domain is often referred as hands-on experience. The absence of hands-on experience might be because of the route in which express learning is esteemed and in this manner surveyed in building training to be specific, by means of examinations, tests, laboratory reports, tutorial exercise works out.

Table 1: 5 Level of Psychomotor Domain Model(PDM)[1]

| Level | Description |
|-------|-------------|
| 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. |

The absence of effective assessments on psychomotor domain shows understood depreciation of hands-on experience which can essentially impede engineering students to procure and esteem hands-on experience. Thusly in this research, the creators proposed another technique for appraisal psychomotor domain for designing innovation understudies to speak to the results of hands-on understanding, in the wake of performing key electrical laboratory classes. The measuring hands-on experience approach (or learner’s specialists approach) will be utilized as a part of outlining the evaluation [10].

2.4 Thinking-aloud as a research tool

In choosing thinking-aloud as a research tool, Olson et al. [11] stated that using think-aloud technique is one of the most effective ways to assess higher-level thinking processes (those which involve working memory) and that it could also be used to study individual differences in performing the same task. Ericsson and Simon [12] conclude that even if their view of thought processes is necessarily incomplete, verbal reports such as those from think-aloud data are a “thoroughly reliable” source of information about thought processes (p. 247). Nonetheless, before designing a research plan which involves think-aloud methods, researchers need to decide on the type and level of difficulty of the research task, the degree of prompting which is appropriate, the use of other data to support inferences from think-aloud protocols, and the method of analysis.

2.5 Diagnosing faults by thinking-aloud

There has been broad research on troubleshooting and faults diagnosing in engineering practice over the most recent 20 years, particularly studies on thinking-aloud troubleshooters in order to comprehend their cognitive processes and skills. This and numerous other similar studies showed that troubleshooters make broad use of tacit and implicit knowledge which must be produced through experience [13]. Additionally, in the diagnosis system, the diagnostic engineer or specialized individual must have well self-improving knowledge of how to relate fault and implications, which
one needs to learn from experience. This self-upgrading knowledge is produced through their working background, and either explicit or tacit, but is expected mostly practical experience. By using this knowledge, they will be required to give data of diagnostics for failure localization, arranged preventive maintenance and administration staff. This is an effective contention in support of the need for engineering students to practice and esteem the acquisition of practical experience.

3. Methods and Materials

The aim of this project is to test the relationship between practical intelligence acquired in laboratory classes with the ability to diagnose simple equipment faults in laboratory experienced. Next, find ways to measure changes in practical experience in engineering laboratory classes.

In laboratory, for an introduction of electrical and electronics engineering, students are required to perform ‘hands-on’ experiments. Experiment kits of parts, tools, equipment and an experiment handout are provided to guide them through the required tasks. In the experiment handout, the student had to follow the instructions as explicit knowledge. Thus, at the same time students might acquire or have to use experience through their laboratory tasks without necessarily realizing it. The introduction of laboratory classes in electrical engineering fundamentals PLT105 Electrical Circuit Theory was chosen in this project. This choice was determined partly by our own interests in robotics automation and partly because these classes are offered twice annually providing plenty of opportunities for observation and testing.

The experts will undertake practical technical problem solving activities in a fundamental electrical laboratory tasks by using the think-aloud technique in developing the instrument. Next, novices will test the instrument by using the same technique after the instrument fabricated. 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 [1]. The anticipated outcome is that the results could demonstrate 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.

3.1 Materials

At first, in order to do a project on this development instrument for measuring psychomotor domain in constructing electrical circuit, the basic concept must be studied and researches in order to gather more specific information. The simulation should be done before implemented the hardware part. The simulation included is the circuit design and program coding for PIC 18F4580. As the simulation success then the hardware part can be developed. With the completion of software and hardware parts the overall design will be done until it fulfills the desired design.

After completing the circuit by using Proteus software, the simulation is successfully run according to the desired condition. The scored collected will display at LCD after the student pick three types of different tools. The connections at PIC18F4580 consist of limit switch as the input and LCD as the output. The tools such as screw 1, 2 and 3 connected at RB0, RB1 and RB3. Next, wire striper 1, 2 and 3 connected at RB3, RB4 and RB5. Screw driver 1, 2 and 3 connected at RC0, RC1 and RC2. **Figure 1** shows the prototype of the hardware.
3.2 Population and samples.

Samples in this research are the first year students who studying Robotics and Automation Technology Program; experimental group (N=5) is who had already taken the course and the control group (N=5), is who yet to take up the course. The both groups will test the following question: “Do laboratory experiments have an effect on a person’s experience in circuit development test”. It is expected that while performing their research work, the students acquired practical experience and had some experience of using engineering tools, parts and apparatus[6].

Since troubleshooting or diagnosing equipment faults has been suggested as a task that requires a high degree of hands-on experience and practical skills, thus the hypotheses are chosen to explore the relationship between hands-on and ability to diagnose. This project can be done and succeed in assessing hands-on experience in the context of diagnosing faults in the relevant equipment assessed if this automated instrument for measuring psychomotor domain in constructing electrical circuit can prove that the hypothesis is false with a high degree of probability. The method of measuring would then provide a powerful new means to assess the effectiveness of engineering technology laboratory classes.

4. Results and Discussions

The pilot study is to test the hypothesis $H_1$: Laboratory experiments have NO effect on a person’s experience in circuit development test.

Ten volunteer subjects were randomly divided into two groups. Subjects in group A (treatment group-TG) were subjected to laboratory experiments, while subjects in group B served as controls, without attending any laboratory experiment (control group-CG). At the end of the experimental period, the exercise of circuit development test is done and the marks was measured. The results were as follows:

1) Research findings on Pre-test (TG) vs. pre-test (CG)

The purpose of this study is to compare the original PI-owned level of the students for both groups before the completion of the process. Therefore, the researcher has compared the mean value of the TG and the CG by using the Compare Means Model with Independent-Sample T-Test. In this case, the researcher is testing the null hypothesis where it is hypothesized that there is no statistically significant difference between the mean of the Pre-test (TG) and Pre-test (CG) score. The researcher hypothesized that the mean difference between the conditions in the population from which the sample is drawn is zero.
Table 2: Independent sample test for the Pre-test (TG and CG) scores

| Levene's Test | t-test for Equality of Means |
|---------------|-----------------------------|
| F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Lower | Upper |
| mark Equal variances assumed | .111 | .740 | 1.900 | 47 | .064 | 1.597 | .840 | -.094 | 3.287 |

Table 2 presents an overview of independent sample test for the Pre-test (TG and CG) scores. The \( p \)-value = 0.74 > \( \alpha = 0.05 \), the null of Levene’s test is accepted and the researcher was assuming that the variance in mark of both groups is significantly equal. The result in t-test for equality of means shows that \( p \)-value = 0.064 greater than the level 0.05. The mean difference (1.597) is calculated by subtracting the mean of the CG from mean of TG. The positive \( t \)-value in this result indicates that the mean of TG is significantly greater than the mean of CG.

2) Research findings on Post-test (TG) vs. post-test (CG)

Even though the previous analyses showed that there are differences between the TG and CG, this analysis is to double check whether there is a difference between the post-test (TG) and post-test (CG). Therefore, in this case, the researcher is testing a null hypothesis that there is no difference between the post-test (TG) with post-test (CG).

Table 3: Independent sample test for the Post-test (TG and CG) scores

| Levene's Test | t-test for Equality of Means |
|---------------|-----------------------------|
| F | Sig. | t | df | Sig. (2-tailed) | Mean Difference | Std. Error Difference | 95% Confidence Lower | Upper |
| mark Equal variances assumed | 3.503 | 0.67 | 18.041 | 47 | .000 | 13.005 | .721 | 11.555 | 14.455 |

Table 3 illustrates that \( p \)-value = 0.67 > \( \alpha = 0.05 \), the null of Levene’s test is accepted and the researcher was assuming that the variance in mark of both groups is significantly equal. The result in t-test for equality of means shows that \( p \)-value less than the level 0.05. The mean difference is calculated by subtracting the mean of the CG from mean of TG. The positive \( t \)-value in this result indicates that the mean of TG is significantly greater than the mean of CG.

5. Conclusion

In this research, the researcher developed a pilot testing instrument appropriate for a first-year electrical engineering laboratory experiment to measure experience in the context of simple electrical and electronics circuits. Constructing the pilot testing kit was not an easy exercise. Subsequently, testing on large samples of students has demonstrated that it is possible to measure practical experience acquired through laboratory experiment.

Finally in this pilot study, the researcher succeeded in demonstrating the possibility of measuring the acquisition of practical experience by using the think-aloud technique, that has not been assessed or measured in the past when evaluating different in laboratory experiences. The results confirmed that the hypothesis \( H_1 \) is false with a high degree of probability. There is a statistically significant
difference in practical experience of students measured before and after exposure to laboratory experiment, and between the control group. The researcher is confident that hands-on activities in the laboratory experiment influence practical experience in the context of diagnosing and constructing electric circuit in the relevant experiments and that this change in practical experience can be measured and assessed. Therefore, the think-aloud technique for measuring practical experience provides a successful way to measure that elusive component of engineering laboratory experiences referred to by most people as "hands-on practical experience".

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