DEVELOPMENT OF AUTOMATED TESTING KIT FOR ASSESSING PSYCHOMOTOR SKILLS ACQUIRED BY PERFORMING THINKING-ALOUD TECHNIQUE

by

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LIST OF ABBREVIATIONS

BCD	Binary Coded Decimal
CG	Control Group
CM	Concept Map
IC	Integrated Circuit
LCD	Liquid Crystal Display
LED	Light-Emitting Diode
MMC	Memory Card
PCB	Printed Circuit Board
PDM	Psychomotor domain model
PS	Psychomotor skill
PIC	Peripheral Interface Microcontroller
SD card	secure data card
SPI	Serial Peripheral Interface
SPSS	Statistical Package for the Social Sciences
TG	Treatment Group
USART	Universal Synchronous Asynchronous Receiver Transmitter
VTS	Vienna Test System

LIST OF SYMBOLS

H_1	Alternative hypothesis
H_0	Null hypothesis
α	Level of Significance
μ	Mean
Ω	Ohm
V	Volt

Pembangunan Kit Pengujian Berautomatik Untuk Menilai Kemahiran Psikomotor yang Diperolehi Dengan Menggunakan Teknik Meluahkan Pemikiran

ABSTRAK

Kajian terdahulu menunjukkan bahawa kecekapan dalam kejuruteraan, juga dirujuk secara akademik sebagai 'kemahiran psikomotor,' boleh dinilai dengan membezakan kepakaran individu dalam bidang tersebut. Kaedah penilaian semasa, menggunakan laporan dan ujian bertulis, terutamanya mengukur pencapaian pelajar dalam domain kognitif, gagal dalam menilai kecekapan mereka dalam domain psikomotor. Kaedah penilaian yang lebih baharu diperlukan untuk menilai komponen pengalaman makmal yang sukar difahami dalam eksperimen makmal teknologi kejuruteraan. Kajian ini bertujuan untuk merangka kaedah untuk mengukur kemahiran psikomotor khususnya dalam konteks eksperimen makmal teknologi kejuruteraan. Alat pengukur, 'Kit Ujian Jurutera Automatik' terdiri daripada beberapa paparan LCD yang mengandungi paparan cadangan "berfikir-kuat" dan beberapa butang untuk tujuan pemilihan. Kotak Litar dengan litar separuh siap dan alat asas untuk mencipta litar elektrik telah digunakan semasa eksperimen penyelidikan sebagai sebahagian daripada rancangan penyelidikan. Instrumen ini telah direka bentuk dengan dua pilihan bekalan kuasa (mod penyesuai dan bateri) dan data yang dikumpul disimpan dalam kad memori untuk menjadikannya lebih mudah alih. Penyelidikan eksperimen adalah berdasarkan eksperimen diagnosis kesalahan menggunakan teknik reka bentuk kuasi eksperimen iaitu "Reka bentuk kumpulan kawalan bukan setara" digunakan untuk mengumpul data daripada kedua-dua kumpulan rawatan dan kawalan. Sejumlah 60 pelajar bagi kumpulan rawatan dan 60 pelajar bagi kumpulan kawalan telah diambil untuk mendiagnosis litar yang tidak lengkap dan membina litar dengan sambungan yang diperlukan. Kajian eksperimen ini telah menunjukkan bahawa terdapat perbezaan yang signifikan secara statistik dalam kemahiran psikomotor menggunakan teknik berfikir- lantang kumpulan rawatan yang diukur sebelum (min ujian pra = 60.45) dan selepas (min ujian pasca = 89.31) pendedahan kepada pengalaman eksperimen makmal, dan antara kumpulan kawalan. Dapatan kajian ini mendedahkan perkaitan antara tahap kemahiran psikomotor dan kecekapan dalam membina litar. Kejayaan pembangunan dan penggunaan 'Kit Pengujian Jurutera Automatik' memberikan jalan yang menjanjikan untuk menekankan penilaian hasil pembelajaran praktikal dalam eksperimen makmal kejuruteraan.

Development of Automated Testing Kit for Assessing Psychomotor Skills Acquired by Performing Thinking Aloud-Technique

ABSTRACT

Earlier studies indicate that proficiency in engineering, also referred to academically as 'psychomotor skill,' can be evaluated by contrasting the expertise of individuals within the field. The current evaluation methods, utilizing reports and written tests, primarily gauge students' accomplishments in the cognitive domain, falling short in assessing their proficiency in the psychomotor domain. The newer assessment method is needed to assess the elusive component of laboratory experiences in engineering technology laboratory experiment. This study aims to devise a method for quantifying psychomotor skills specifically within the context of engineering technology laboratory experiments. The measuring instrument, an Automated Engineers Testing Kit consists of a several LCD displays containing a thinking-aloud suggestion display and a few buttons for selection purpose. A Circuit Box with partially completed circuit and a basic tool to create an electric circuit was used during the research experiment as a part of the research plan. The instrument has been designed with two power supply options (adapter and battery mode) and the collected data is stored in the memory card to make it more mobile. The experimental research was based on an experiment using the quasi-experimental design technique that is "Non-equivalent control group design" is used to gather data from both the treatment and control groups. A number of 60 students for treatment group and 60 students for control group were recruited to diagnose the incomplete circuit and construct the circuit with necessary connections. This experiment research has shown that there is a statistically significant difference in psychomotor skill using thinking- aloud technique of treatment group measured before (pre-test mean = 60.45) and after (post-test mean = 89.31) exposure to laboratory experiment experience, and between the control group. The findings of this study reveal correlations between psychomotor skill levels and the proficiency in constructing circuits. The successful development and deployment of an 'Automated Engineers Testing Kit' present a promising avenue for emphasizing practical learning outcomes assessment in engineering laboratory experiments.

CHAPTER 1 : INTRODUCTION

1.1 Research Background

Enhancing the quality of engineering education stands as a prerequisite for accrediting engineering technology programs (Engineering Technology Programme Accreditation Standard, 2019). Aiming to produce proficient engineers, it is essential for students to graduate with robust character traits. Therefore, integrating laboratory experiments or practical work into the curriculum becomes imperative to provide hands-on experience and practice. Students can gain information, practical skills, and awareness of the significant challenges in the field of engineering by engaging in laboratory activities (Mayuze et al., 2023).

The practical components are mostly related to laboratory classes where laboratory experiments become crucial; to prepare students for psychomotor skills (PS) before graduation(Razali & Trevelyan, 2013). Moreover, mastering psychomotor skills is important for aspiring engineering students aiming to excel as professional engineers or technicians. These physical and manual abilities are commonly honed within a laboratory setting. Psychomotor learning is depicted through physical aptitudes, including motion, strength, manipulation, skill, grace, control, speed, and action(Razali etal.,2019). Choosing think-aloud as a research tool, it has been observed that employing think-aloud technology is one of the most efficient methods for assessing higher-level cognitive processes that involve working memory(N. Mizam et al., 2022) .

This research introduces a fresh method for assessing psychomotor skills to efficiently gauge the acquisition of hands-on experience, preparing students effectively for the industry. In this research, students exposed their minds aloud using the thinking-aloud technique while performing hands-on skills. The psychomotor measuring instrument consists of devices that automatically detect the students' psychomotor behavior through their thinking-aloud technique. Therefore, through this new approach, this research examines the levels of hands-on experience acquired in laboratory experiments by students.

When designing the psychomotor measuring instruments, a database comprising thinking-aloud keywords is proposed, derived from thorough observation of both novice and expert behaviors in representative work-related scenarios. The hands-on skills are measured by calculating the difference between novices' and experts' ratings. The results could show that it is possible to evaluate and value the value of students' hands-on skills; the impact is students' awareness to acquire and value psychomotor skills to prepare them as graduates ready for industry.

1.2 Problem Statement

In order to ensure that the future generation is ready to face the era of changing the whole industry profile to become a developed nation, university must be responsible by ensuring that the students get enough know-how, in particular, to deal with the disruptions of the said revolution, such as industry-ready graduates. However, currently, there are no appropriate tools or approach for measuring the hands-on skills in psychomotor domain, where the assessment of practical components can be proved (Razali et al., 2019).

Furthermore, engineering managers and seasoned engineers have expressed concern that engineering graduates appear to lack awareness of the practical experiences necessary for establishing themselves as industry-ready professionals (NST, 2019).

This may result from the way in which explicit knowledge is valued in engineering education, almost all hands-on skills assessments focus on measuring explicit knowledge or utilize rubric-based methods (Majid, 2019).

The implicit undervaluing of the psychomotor domain may convey a message that psychomotor skills are less crucial than cognitive abilities, potentially hindering engineering students' motivation to acquire and appreciate practical experiences. Hence, suggesting a new method for measuring psychomotor skills that can evaluate the competency of engineering and technology students could serve as a solution to this issue

1.3 Objectives

The expected result is that the findings may reveal a new approach to evaluating laboratory experiments by assessing individual psychomotor skills acquired during task performance. Specifically, the subsidiary goals include:

1. To develop an Automated Engineer Testing Kit by using a thinking-aloud technique for assessing hands-on experiences acquired, aimed at evaluating hands-on experiences gained through students' behaviors during laboratory experiments.

2. To generate reference and experimental score based on the Automated Engineer Testing Kit applied to experts, treatment group (TG), and control group (CG) of students.

3. To analyze the score of the hands-on experience acquired using the thinking aloud technique between the Treatment Group (TG) and the Control Group (CG) for the Pre-Test and Post-Test Experiment using Statistical Package for the Social Sciences (SPSS).

1.4 Research Scope

The scope of the study is to design and develop the measurement tool (Automated Engineer Testing Kit). In developing the tools, it consists of developing the electronics circuit for the Automated Engineer Testing Kit that could measure the PS in engineering education. This project implements the Arduino Mega microcontroller to make the kit automatically stored the data into the secure data card (SD card).

The measurement tool was used in comparing psychomotor skills between experts and novices, consists of sixty student of treatment group (TG) and sixty student of the control group (CG) .The TG are the first-year students from Faculty of Electrical Engineering Technology (FTKE) that have taken PLT108 course in Universiti Malaysia Perlis (UniMAP) and the CG are another first-year students from the different course and faculty of Universiti Malaysia Perlis (UniMAP) that have not taken PLT108 course in the current semester .

The score gains from the experiment using the Automated Engineer Testing Kit which acquired using the thinking aloud technique between the TG and CG for the Pre-Test and Post-Test Experiment will be analyze using Statistical Package for the Social Sciences (SPSS).

1.5 Research Outline

Altogether, this thesis comprises four primary chapters outlined to establish a structured framework. Each chapter encompasses information, results, or discussions, all intricately linked to the project.

Chapter 2 spotlight an exhaustive literature review encompassing topics relevant to the study in this project. This section aims to provide a comprehensive exploration of existing research and scholarly works related to the project's themes. Chapter 2 specifically delves into a detailed examination and discussion of psychomotor skills and thinking-aloud studies, laying the foundation for a deeper understanding of these subjects in the context of the research.

In chapter 3, the focus is to present the methodology employed in this study. This encompasses the utilization of both software and hardware, along with a detailed outline of the procedures governing the execution of the project. This section specifically highlights any programming, design, or development activities associated with the hardware, providing a comprehensive overview of the technical aspect's integral to the research.

Chapter 4 present a detailed account of the data collected from the results of the kit, accompanied by an in-depth analysis. Moreover, this chapter aims to thoroughly discuss and interpret the findings. On the other hand, Chapter 5 is dedicated to providing a comprehensive summary of the study's outcomes and offering future recommendations for further research in this field.

CHAPTER 2 : LITERATURE REVIEW

2.1 Era of psychomotor skill to Fourth Industrial Revolution

The Fourth Industrial Revolution (IR4.0) represents the current era characterized by automation and seamless data exchange within manufacturing technologies. This revolution encompasses various advanced technologies such as cyber-physical systems, the Internet of Things (IoT), cloud computing, and cognitive computing. In IR4.0, smart factories emerge as modular structured manufacturing facilities. Within these smart factories, cyber-physical systems oversee physical processes, create virtual replicas of the real world, and autonomously make decentralized decisions. These systems engage in real-time communication and collaboration with humans through the Internet of Things.

Moreover, with the development of Industry 4.0, the Government concedes that the country's future does not depend only on educated personnel but having a large pool of skilled workforce to meet the industry's needs. To be in tandem with IR4.0, universities need to adapt and grow, involving advanced digital automation technology. The advent of the IR4.0 presents a host of new challenges, necessitating adaptations from all stakeholders, particularly universities, to stay pertinent and competitive. Universiti Malaysia Perlis (UniMAP) has actively engaged with the industrial sector, not only to produce engineers for the country but also to align its programs with the requirements of IR4.0, thereby producing industry-ready graduates.

UniMAP's collaboration with the private sector has played a crucial role in ensuring the relevance of its study programs and implementing necessary measures to remain aligned with current needs. This proactive approach ensures that graduates are equipped with the skills and knowledge demanded by the evolving job market, thereby enhancing their employability prospects. By continuously adapting to the demands of IR4.0, UniMAP reaffirms its commitment to producing graduates who are well-prepared to thrive in the dynamic landscape of the Fourth Industrial Revolution (The Star, 2020).

The practical components are mostly related to laboratory classes where laboratory experiments become crucial; preparing students for psychomotor skills before graduation. Thus, the university's endeavour to provide engineering technology courses aligns well with the government's Technical Vocational Education and Training (TVET) policy, which prioritizes technical proficiency and practical skills, leveraging industry resources. This initiative is commendable. Emerging trends like the IoT, animation, big data analytics, simulation, robotic system integration, cloud computing databases, and others are poised to drive advancements in the contemporary global landscape.

Laboratory experiments play a crucial role in engineering technology courses, serving as an essential component of engineers' education. Consequently, these experiments are seamlessly integrated into the engineering technology curriculum to ensure that students gain practical engineering experience and skills before they graduate. (Chowdhury et al., 2019). According to Shane J. Lopez (2018), the most efficient way to instruct students in a task is by having them perform it themselves.

Thus, through conducting laboratory experiments, students engage in hands-on practice, acquiring skills that are not easily grasped through theoretical study alone. (Daud et al., 2018). Additionally, participating in laboratory experiments affords students the chance to cultivate and refine their practical and hands-on skills. (Albright & Domenici, 2022).

Unfortunately, all hands-on assessments measure cognitive value; this implicit devaluation of psychomotor perhaps results in a message that psychomotor values are unnecessary. To meet the IR4.0 requirement, this psychomotor assessment should be identified, at the same time to produce 'good industry-graduates' and intellectuals that adhere to the IR4.0. However, unexpected external threats such as the COVID-19 (Corona Virus Disease of 2019) outbreak of traditional co-curricular practices will result in a permanent reduction in the international student market and panic efforts to move to e-learning online; the engineering faculty is at risk of not seeing the vast opportunities that this disruption to 'business as usual' in achieving long-term and continuous innovation of their learning programs (Reidsema et al., 2020).

The ability to effectively manage and execute hands-on laboratory experiments is integral to a person's practical skill set, particularly in the education of engineering technologists. Therefore, this is also a valid reason for Malaysia's Government to introduce an engineering technology program in Malaysia's education system at a higher level (Norehan Haron et al., 2018). Laboratory experiments are seamlessly integrated into the engineering curriculum to furnish students with practical engineering experience and skills vital for their professional development before they graduate.

The Malaysian Qualification Agency (MQA) is also concerned about the 60% of practical components and 40% of theoretical components in Malaysia's engineering technology programs. In order to fulfil the MQA (Malaysian Qualifications Agency) requirements, the laboratory components, which serve as valuable learning experiences and effectively bridge the gap between theory and real-world behaviors of engineering systems, should be assessable (Norehan Haron et al., 2018).

However, assessment practices reliant on reports and tests for evaluating laboratory experiences tend to only assess students' cognitive domain achievements(N. S. S. Mizam, 2021) . Many researchers continue to express concerns regarding the inclusion and assessment of psychomotor skills in engineering laboratory settings. (Huang et al., 2020). Currently, the evaluation method for engineering technology students' laboratory experiences lacks the inclusion of psychomotor skill assessment, primarily due to a lack of appropriate measuring tools. (N. Mizam et al., 2022).

The practical skills exhibited by students in laboratory settings are intricately linked with the psychomotor domain, as emphasized by (Bradley et al., 2022). This domain emphasizes manual tasks involving the manipulation of objects and active involvement in physical activities. According to Bradley, the human mind and body work together during the execution of these tasks. Learning outcomes associated with the psychomotor domain focus on the ability to physically manipulate tools or instruments, such as hands or hammers. Objectives within this domain primarily revolve around changes or improvements in behavior and skills. Therefore, students' practical skills and their experiences in hands-on laboratory settings are closely intertwined with the psychomotor domain, which encompasses manual tasks involving object manipulation and physical engagement (Gao et al., 2021).

In this study, the assessment framework will utilize the psychomotor domain model (PDM) proposed by Ferris and Aziz in 2005. This model offers clear descriptions of skills expected from students at each level, allowing for easy alignment with the laboratory experiments they engage in. Tailored specifically for engineering technology, the PDM serves as an effective tool for evaluating the physical actions performed by engineers (table 2.1 for reference).

Table 2.1 : Psychomotor Domain Model (PDM)(Ferris & Aziz, 2005)

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 holding the tool appropriately for use, and 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.