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Original Article

Lighting System Trainer: Implementation of the Practical using Digital Energy Meter

Muhammad Shahmi Aqmar Baharudin [1], Khairul Rijal Wagiman [2,*], Mohd Faiz Md Adnan [2] and Abd Rahim Kasiman [2]

[1] Department of Vocational Education, Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia.
[2] Renewable Energy Technology (RenTECH) Focus Group, Faculty of Technical and Vocational Education, Universiti Tun Hussein Onn Malaysia, 86400 Parit Raja, Johor, Malaysia.
* Correspondence: khairulrw@uthm.edu.my (K.R.W)

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Abstract: In the current situation, the lecturer had a problem in which the student still needs to be guided by the lecturer to implement the practical using a digital energy meter; the student always takes more time to implement the lighting technology practical task and still using the traditional ways for teaching and learning in the subject. Therefore, a Lighting System Trainer (LST) has been developed. The LST has been developed with two modules of learning: (1) lighting technologies and (2) lighting control. Various parameters, including current, voltage, real power, and power factor, can be measured. Based on the results, the LST performed well for both modules. Also, from the expert evaluation, all the experts agree that LST is suitable as a teaching aid. In addition, the expert also agreed that the LST can function well for lighting technology practical tasks. In conclusion, this study has successfully designed a Lighting System Trainer (LST) that can fully operate as a teaching assistant to help the teaching and learning process. For trainer development, systematic planning is essential to ensure that all activities carried out run well and in an orderly manner. Through the suggestions and comments given by experts on the LST, this study has made some improvements, and some have been proposed for further studies, e.g., improving the trainer. After all, the improvement process involves complex parts and requires a longer time.

Keywords: Lighting technology; Lighting control; Lighting trainer; Energy efficiency.

1. Introduction

Training is an innovative method used as a teaching aid in schools, colleges, and universities (Samsudin et al., 2021; Zaporozhchenko et al., 2022). A learning kit can also be known as a trainer used by lecturers to make teaching and learning easier and more understandable by students. One of the appropriate ways to improve students' skills is through exposure to teaching aids used in class (Hanif et al., 2016). Kit is one of the teaching aids that is very helpful for teachers in knowledge delivery during the

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teaching session (Rosli et al., 2018). Many teaching aids have been developed to improve the quality of teaching delivery, especially during practical sessions in various fields, such as control simulation by Karel and Tomas (Karel & Tomas, 2015), energy storage by Yan et al. (2020), and microcontroller by Laseinde and Dada (Laseinde & Dada, 2023). The lighting system is one of the energy systems in the building, and it represents 18% of the total building's electricity consumption in Malaysia (Birkha Mohd Ali et al., 2021). Based on this fact, the lighting system topics that cover lighting technologies, designs, controls, and optimization are included in the subject of energy efficiency optimization (BBJ21105) in the Bachelor of Technology in Electrical System Maintenance. The course involves theory of 40% and practical of 60%.

The interview session focused on a few issues that may improve the classroom's lighting technology practical task process. According to the lecturer who teaches the subject of energy efficiency optimization, the students need guidance from the lecturer to perform practical tasks using a digital energy meter, resulting in extended implementation time. It affects the teaching schedule, causing time constraints. Additionally, using traditional teaching methods is a common practice among lecturers, and there is a request to shift towards a technology-oriented approach. Therefore, developing the LST project is crucial to address these issues and facilitate more effective and efficient practical tasks in lighting technology and control. On the basis of the market survey, we found KNX education equipment (building automation system) by SEIKOU Systec (Seikousystec, 2023), which has a lighting control module. However, the lighting technologies module is not included in the trainer. Moreover, the lighting control module is not flexible in programming because it uses a configuration-based platform.

Thus, developing a Lighting System Trainer (LST) will help lecturers and students learn about lighting system topics, including lighting technologies, control, and optimization. It works as a tool to help students master the topic of lighting systems while increasing their interest and facilitating their learning through practical application. Teaching aids can stimulate students' desire to learn more about learning content and make learning more exciting and effective (Jamali et al., 2015). Moreover, using a Programmable Logic Controller (PLC) as a control system gives the LST flexibility in programming of control design to meet the desired lux level mentioned in the standards, e.g., The Malaysian Standard MS1525 (Malaysian Standards, 2019).

2. Materials and Methods

The methodology section describes all the necessary information that is required to obtain the results of the study. The methodology of this project consists of project design, project development, and testing the functionality of LST.

2.1. Project Design

The first methodology of the Lighting System Trainer (LST) involves designing the project in terms of architecture, block diagram, flowchart, and circuit. The architecture design considers safety, mobility, module interface, maintenance, neatness, and durability to ensure the product's longevity and adaptability to different working environments. The design process starts with pencil sketches on paper, generating new ideas for the architecture. After finalizing the design, it is transferred to AutoCAD for a more specific and proper representation. The project design includes frame design, component modules, and the complete design of LST. The 3D design of LST combines frame design and all component modules design. Figure 1 shows the 3D design of LST.

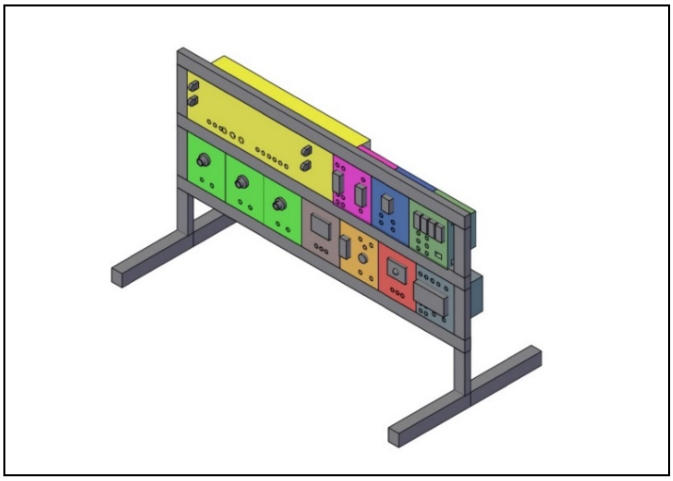


Figure 1. The Design of LST.

Regarding the block diagram, two types were created: one for lighting technology and another for the lighting control system. Each illustrates the respective processes, such as measuring voltage, current, power, power factor, and frequency for lighting technology and dimming control through PLC and light sensor input for the lighting control system. Figure 2 shows the lighting technology block diagram for LST. The lighting control system block diagram is presented in Figure 3.

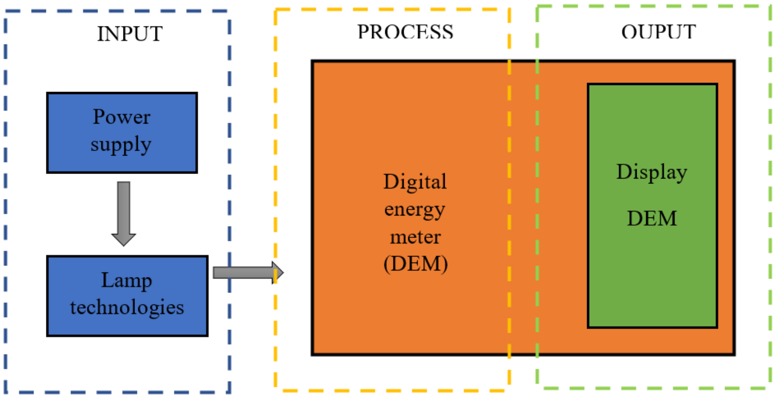


Figure 2. The Diagram of Lighting Technology Module Block of LST.

LST's block diagram of lighting technology consists of four main components: a power supply and lamp as input, a digital energy meter for processing, and an LCD screen digital energy meter as output. The process begins with the power supply energizing the lamp. Then, the lamp's data, including voltage, current, power, power factor, and frequency, is processed by the digital energy meter. The measured data is displayed on the LCD screen of the digital energy meter, providing valuable information for students to complete their lighting technology practice.

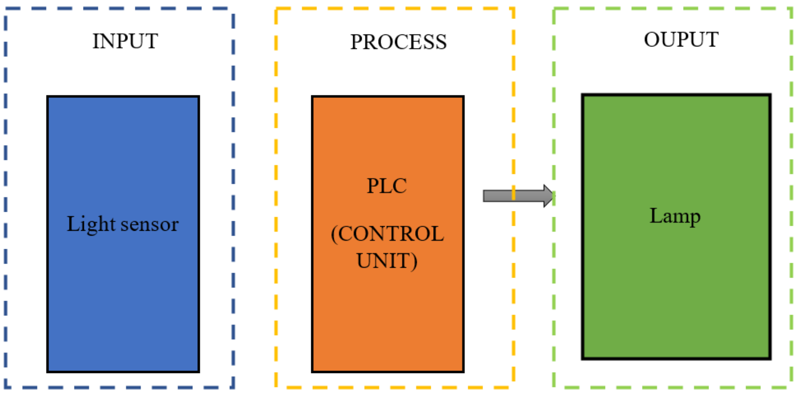
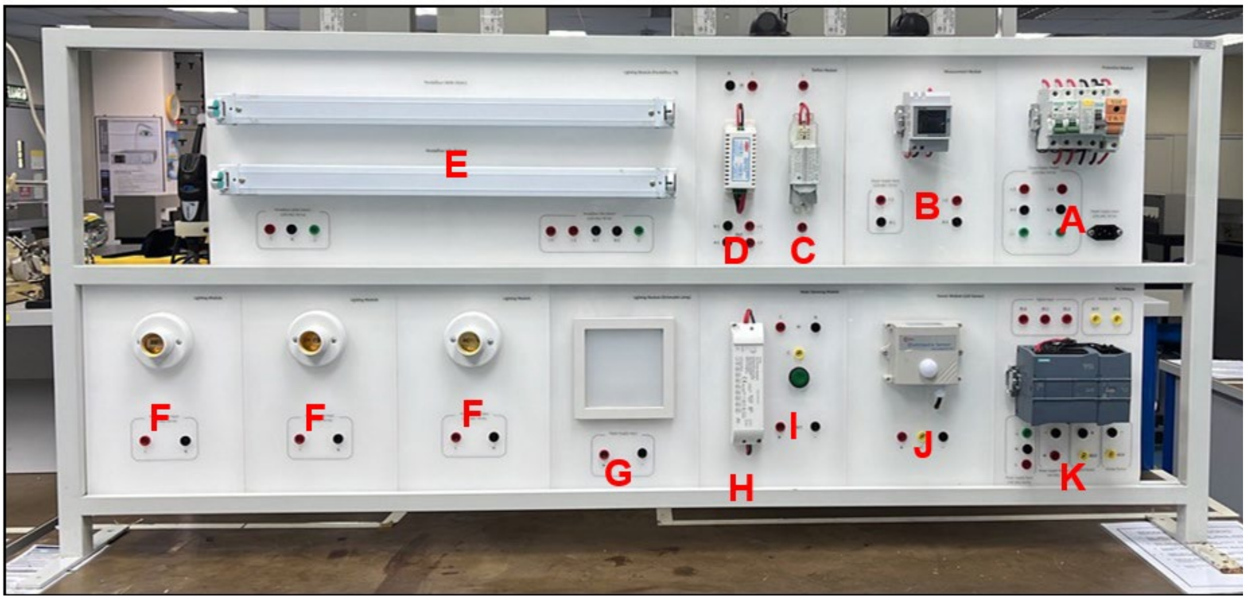


Figure 3. The Diagram of Lighting Control System Module Block of LST.

The Lighting System Trainer's control system block diagram includes three key components: a light sensor, a Programmable Logic Controller (PLC) as the control unit, and a light unit. The process begins with the light sensor detecting the illuminance level of the surrounding area. The PLC processes the data from the light sensor. If the data indicates low lighting, the PLC instructs the lamp to dim up (through dimmer). On the other hand, if the data indicates high lighting, the PLC instructs the lamp to dim down.

2.2. Project Development

In the second methodology, the product will start to be developed. It includes the development of architecture and coding of LST. The architecture development process was implemented to develop the component module, including the marking of Acrylic Perspex, the cutting of Acrylic Perspex, the finishing of Acrylic Perspex, and the installation of the component. The component module was constructed using prospect and plastic material. Figure 4 presents the developed LST. On the basis of the figure, Panel A is a protection system that consists of a dual-pole miniature circuit breaker (MCB), a residual current circuit breaker (RCCB), and an MCB. Panel B is a Digital Energy Meter (DEM). The lamp technologies module is represented by Panels C to F—meanwhile, Panels G to K for the lighting control module. Panel G is a Direct Current (DC) LED luminaire.



Legend:

A – Protection systems (DP MCB, RCCB, and MCB)
B – Digital energy meter (DEM)
C – Magnetic ballast
D – Electronic ballast
E – T8 tube casing
F – E27 socket bulb
G – LED luminaire (DC)
H – Dimmer
I – Push button
J – Lux sensor
K – PLC (CPU and analog module)

Figure 4. The Developed LST

The programming development of SIEMENS S7-1200 PLC was developed using the SIEMENS TIA Portal V16. The program controls the dimming level of the LED lamp based on a lux sensor value (as an input for PLC). If the light level is greater than 500 lux, then the LED lamp will dim down until the lux level is equal to 500 lux. If the lux level is less than 500 lux, then the LED lamp will dim up until the lux level is equal to 500 lux. The ladder diagram was used for the lighting control of LST, as shown in Figure 5.

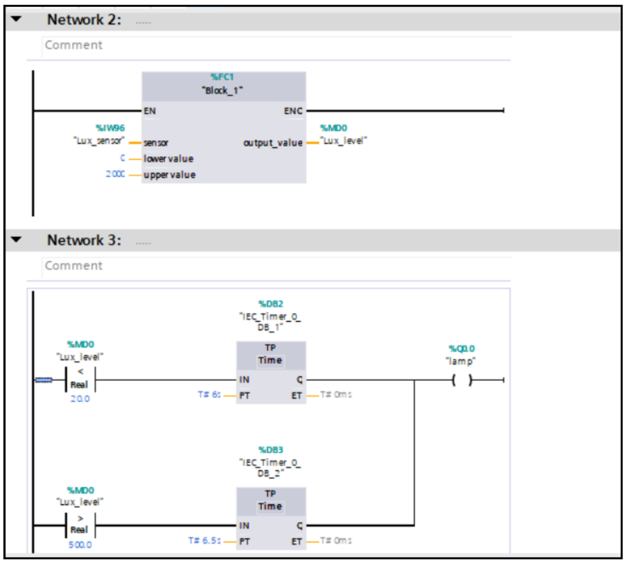


Figure 5. The Ladder Diagram of LST in TIA Portal V16.

2.3. Project Testing

The developed LST has been tested for functionality and conducted according to the task based on the lab sheet of lighting technology. It ensures that the LST can work perfectly and that the practical session is more effective. The testing of LST is divided into two parts: the lamp technologies task and the lighting control system task. Figure 5 shows the functionality testing for one of the lamp technologies modules of LST. The testing involves FL with magnetic ballast, DEM, and, in this case, a protection module. The DEM displays the voltage, current, power, frequency, and power factor values.

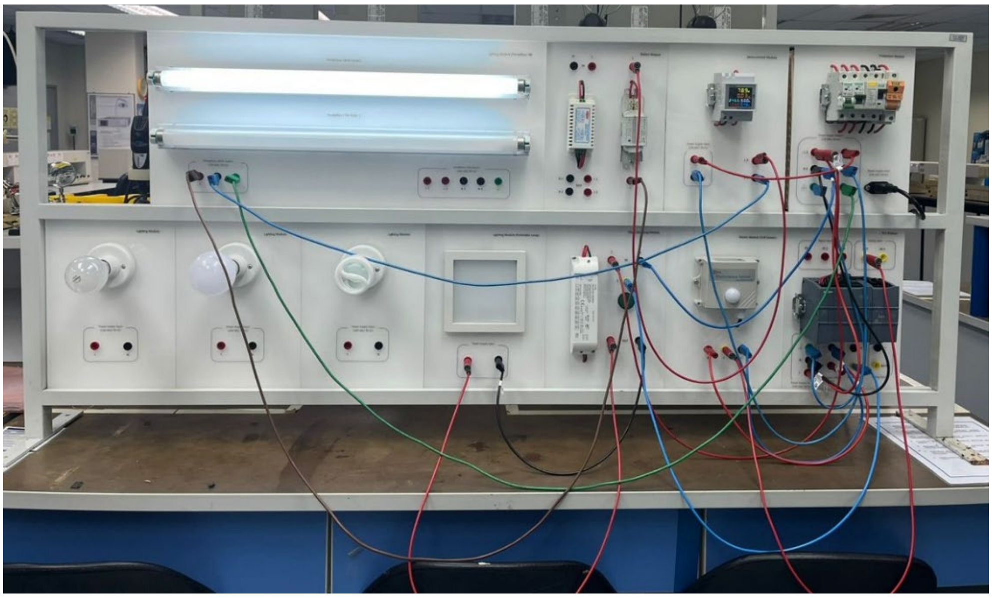
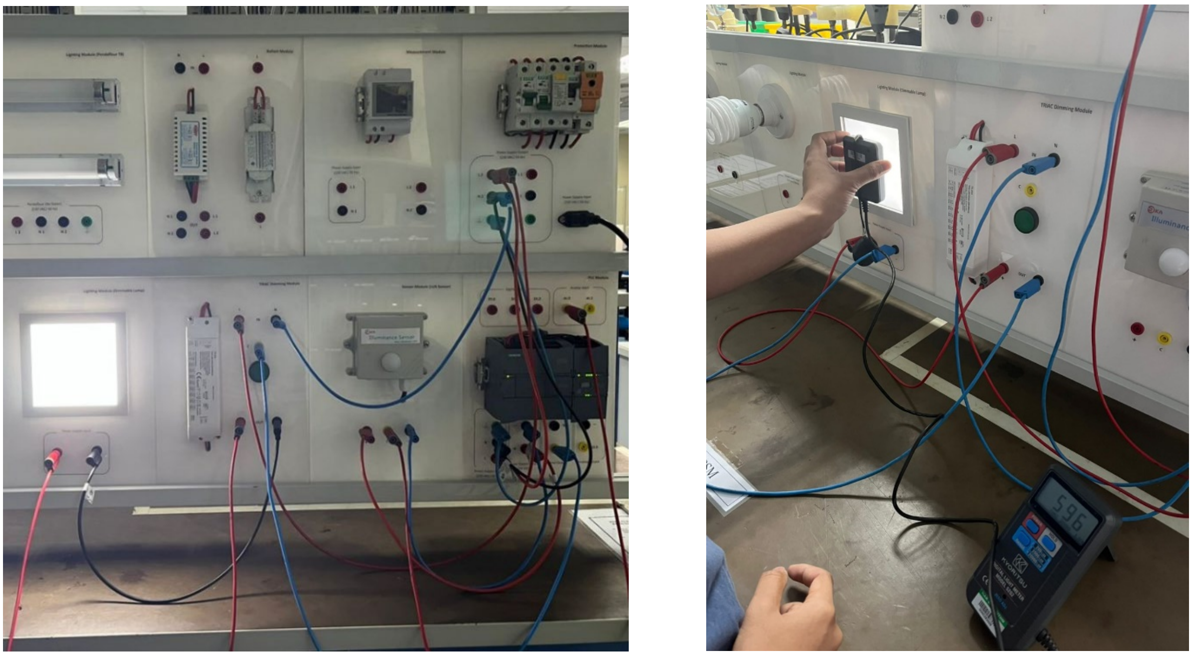


Figure 6. The Functionality Testing for One of the Lamp Technologies Modules of LST

Figure 6 (a) illustrates the functionality testing for LST's lighting control module. A LED luminaire, a dimmer, a light sensor, and a PLC are connected in the testing. PLC calculates the dimming value of the LED luminaire based on the light sensor value. Meanwhile, Figure 6 (b) presents the illuminance level measurement using a lux meter.



(a) (b)

Figure 7. The Functionality Testing for the Lighting Control Module of LST. (a) LED Dimming Control. (b) Lux Level Measurement

Moreover, the expert also tested the LST to ensure that LST worked and met the objective of the trainer development. The expert's evaluation is based on the evaluation form provided by researchers.

3. Results

Data analysis is a type of research aimed at various sectors of engineering that is carried out using multiple methodologies or analyses that examine the functioning of the project and determine whether the study's objectives are satisfied. The researcher analyzed data for this project, including project design, project development, and project testing. The researcher has carried out practical testing based on the lab sheet paper that was developed to analyze the results related to the results of practical assignments using the LST. The results are analyzed, and the results obtained are compared to the actual theory. Two types of tasks have been developed in the lab sheet paper of LST. The functionality of LST to implement the tasks on the lab sheet has been tested in this stage. The tasks tested were the Lighting technology task and the lighting control system task. In the last part of LST testing, the expert evaluation was done with the expert to confirm the functionality of LST. Table 1 shows the result of lamp technologies module testing.

Table 1. Results of lighting technologies module testing

No.	Type of Lamps	Power (W)	Voltage (V)	Current (A)	Frequency (Hz)	Power Factor
1	LED bulb	12.30	246.90	0.05	50	0.92
2	CFL (spiral)	22.20	246.80	0.09	50	0.86
3	CFL (3U)	17.20	246.10	0.07	50	0.83
4	Incandescent	110.60	245.90	0.45	50	1.00
5	T8 LED Tube	7.40	247.70	0.03	50	0.87
6	T8 FL Tube (magnetic ballast)	78.90	246.70	0.32	50	0.46
7	T8 FL tube (electronic ballast)	24.60	246.70	0.10	50	0.84

The result of the lighting control system module is presented in Table 2.

Table 2. Result of lighting control system module.

No.	Pressing time of push-button (s)	Illuminance level (lux)	Power (w)	Voltage (V)	Current (A)	Frequency (Hz)	Power factor
1	2	0	0	247.5	0	50	1
2	4	530	2.4	248.1	0.01	50	1
3	6	1860	4.9	248.2	0.02	50	1
4	8	3150	7.4	247.9	0.03	50	1
5	10	4260	9.9	248.1	0.04	50	1

Tables 3 and 4 present the results of expert evaluation for Sections A and B, respectively.

Table 3. Result of expert evaluation section A.

No.	Product Design and Development	Yes		No		Comment Section	
		No	%	No	%	No	%
1.	The product design for the Lighting System Trainer is suitable for use as a teaching aid to help students complete lighting technology practical tasks for the subject of energy efficiency optimization.	3	100%	0	-	0	-
2.	The acrylic prospect material that is used for the front cover of the trainer's module is steady and gives a neat look.	3	100%	0	-	0	-
3.	The font and size of the label on the trainer's module can be seen clearly and are easy to understand.	3	100%	0	-	0	-
4.	The size of the trainer is suitable to be placed in the laboratory as a teaching aid or for student use in lighting technology practical tasks.	3	100%	0	-	0	-
5.	The back cover for each trainer's module that can be removed and stuck back makes it easy to do maintenance if a problem happens to the trainer.	3	100%	0	-	0	-
6.	The design of the trainer's module that can be moved on the trainer frame makes it easy to change the placement of the module to follow the desired placement for practical task use.	3	100%	0	-	0	-

Table 4. The result of the expert evaluation section B.

No.	Product Functionality	Yes		No		Comment Section	
		No	%	No	%	No	%
1.	The use of the banana connecter for joining the wires from the equipment to other equipment on the trainer's module offers convenience, safety, and equipment protection	3	100%	0	-	0	-
2.	Using the banana connector offers a quick and easy way to join wires and makes the student understand the connection between the equipment effectively through their wiring experience.	3	100%	0	-	0	-
3.	Using the MCB, ELCB, and Main Switch on the protection module as protection for the trainer if there is a short circuit on the trainer is essential to make the trainer safe to use.	3	100%	0	-	0	-

4.	The various types of lamps, such as LED, CFL, FL, and Incandescent, can be used on this trainer to help the student implement the lighting technology practical task more efficiently and smoothly.	3	100%	0	-	0	-
5.	Using an LED Dimmer Driver helps the student understand new acknowledgment about the lighting dimming system easily.	3	100%	0	-	0	-
6.	Using a digital energy meter with various colors for each form of measurement reading value makes it exciting to read and simple to identify between reading types.	3	100%	0	-	0	-
7.	Using a Programmable Logic Controller (PLC) to control the lighting technology system helps the student understand how the use of PLC can control the lighting technology system.	3	100%	0	-	0	-

4. Discussion

The development of the LST requires meticulous planning to make it suitable as a Teaching Aid. Design selection is crucial, considering cost, safety, mobility, interface, maintenance, neatness, and durability. The design process is divided into three parts: architecture design, block diagram design, and flowchart design. The LST includes two types of circuits: lighting technology measurement and lighting control system circuits. During the project development of the LST, three crucial aspects were focused on: module casing, circuit, and lab sheet. The researcher meticulously designed the module casing, dividing it into normal and long sizes, each with specific dimensions. The front part utilized 4 mm Perspex for its lightweight property, but obtaining a neat cut required skillful use of a grinder. Meanwhile, the back part was constructed with a plastic case attached using magnets for easy removal and reassembly. In the circuit development phase, changes were made to ensure suitability for teaching while avoiding unnecessary complexity for students. The circuit incorporated color-coded banana sockets, simplifying connection identification for components. It encompassed two circuits: one for measuring lighting technology and another for controlling the lighting system. Overall, the project development of LST addressed various aspects to create an effective and efficient teaching aid.

After all, the result for lighting technology measurement functionality has been achieved. All the results have been combined in one table to see the difference between the results from the LED bulb and T8 FL (electronic ballast). Therefore, the comparison between the theory and practical task result can be determined to make a clear conclusion on the success of the trainer functionality. The results showed that LED bulbs have the most energy efficiency, followed by the CFL (spiral and 3U), T8 tube with electronic ballast, T8 tube with magnetic ballast, and the Incandescent bulb. The results were determined by looking at the different results of their power and current used. The result can also be determined similarly to the theory: LED lamps are significantly more energy-efficient than equivalent incandescent lamps and can outperform most fluorescent lamps. So, the functionality of lighting technology measurement in LST can be defined as successful.

5. Conclusions

Overall, this study has successfully designed a Lighting System Trainer (LST) that can fully operate as a teaching aid to help the teaching and learning process. For trainer development, systematic planning is essential to ensure that all activities carried out run well and in an orderly manner. Through the suggestions and comments given by experts on the LST, the researcher has made some improvements, and some of them have been proposed in further studies. It is because the researcher could not improve the trainer. After all, the improvement process involves complex parts and requires a longer time. It is hoped that the next researcher will refer to the suggestions submitted to improve this trainer's weaknesses in the future. The researcher can conclude that the trainer developed meets the lecturer's requirements. Although there were obstacles and challenges throughout the development of the LST, the researcher managed to complete it at the planned time. In addition, this study can provide knowledge and creative ideas that have improved the researcher's skills to develop a product as a trainer that can be used as a teaching aid.

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