JURNAL IPTEK
MEDIA KOMUNIKASI TEKNOLOGI
homepage URL : ejurnal.itats.ac.id/index.php/iptek

Smart Lighting System for Vocational Campus Workshop Environment

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ARTICLE INFORMATION

Jurnal IPTEK – Volume 29 Number 1, May 2025

Page:
27–36
May 30, 2025

DOI:
10.31284/j.iptek.2025.v29i1.7729

ABSTRACT

AK-Tekstil Solo is a vocational campus with several workshops for lectures, one of which is the Spinning and Weaving Workshop. It has yarn and fabric manufacturing machines and holds the most significant electricity consumption for machine operations, lighting, and other instruments. Hence, a smart workshop room with electrical energy efficiency is crucial. This research aims to design and develop a smart workshop lighting system using an Arduino-based microcontroller circuit and photocell components. The light intensity setting system is performed by determining the measurement point of light intensity and measuring the natural and artificial light intensity as the input for photocell and relay. An automated lighting system for the smart workshop was then developed using a photocell censor based on the Arduino Mega microcontroller. Product testing shows that the automatic switches and relays based on programming successfully work the automated system.

Keywords: *Microcontroller; Photocell; Smart Lighting; Spinning and Weaving Workshop*

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ABSTRAK

AK-Tekstil Solo merupakan salah satu kampus vokasi yang memiliki beberapa *workshop* dan laboratorium untuk perkuliahnnya, salah satunya adalah *Workshop Spinning* dan *Weaving*. *Workshop* tersebut terdiri dari mesin produksi benang dan kain, serta memiliki konsumsi listrik yang terbesar di gedung kampus, tidak hanya untuk operasi mesinnya, namun juga untuk pencahayaan dan instrumen lainnya. Oleh karena itu, konsep ruangan *workshop* pintar dengan efisiensi energi listrik menjadi krusial. Studi ini bertujuan untuk mendesain dan mengembangkan sistem pencahayaan *workshop* pintar menggunakan sirkuit mikrokontroler berbasis Arduino dan komponen *photocell.* Pengaturan intensitas pencahayaan diatur dengan menentukan titik pengukuran intensitas pencahayaan serta pengukuran intensitas pencahayaan alami dan buatan sebagai input untuk *photocell* dan *relay.* Sistem pencahayaan otomatis untuk *workshop* pintar kemudian dikembangkan menggunakan sensor *photocell* berbasis mikrokontroler Arduino Mega. Pengetesan produk menunjukkan bahwa sistem terotomasi sudah dapat berfungsi dengan baik sesuai dengan *relay* dan program yang dirancang.

Keywords: *Mikrokontroler; Photocell; Smart Lighting; Spinning and Weaving Workshop.*

INTRODUCTION

Easily accessible energy sources, including electrical energy, are needed for any activities and applications in modern society. Electrical energy provides light as a source of lighting, heat, comfort, and mechanical work of various industrial equipment [1], [2]. As long as human desires for comfort, convenience, and productivity are met, they must find accessible and affordable energy sources in reasonable quantities with a modest environmental impact [3]. Lighting standard is needed in all workplaces so that operational activities can be performed well. According to regulation of Indonesian Ministry of Labour Number 5 Year 2018 about Occupational Safety and Health in the work environment, lighting is something that gives or illuminates light, including natural lighting and artificial lighting.

Natural lighting is obtained from sunlight while artificial lighting is sourced from electrical energy. Natural lighting from sunlight is sometimes enough to become the only source of lighting for a building during the day. But when the sunlight is unavailable during the day or night, human should use the artificial lighting when performing activities. Artificial lighting needs energy from various sources. The use of natural lighting is less effective than artificial lighting in terms of stability of light intensity. We cannot freely adjust the light intensity of the sunlight. Thus, the setting combination of natural and artificial lighting is needed to design lighting automation system in a workshop, so that we can benefit from electrical energy saving by combining those two types of lighting. Several factors must be considered in using the natural light, namely sunlight intensity variation, lighting distribution, location, light reflection, building geographical location and the building usage for what purpose. Light intensity in the workplace is intended to support the lighting needs of the objects, tools, machines, processes, and work environment. Therefore, optimal light intensity is needed, not only to light the objects, but also the surroundings. Since poor lighting system will affect the human vision, as well as the psychological aspect namely work fatigue, low comfort, lack of awareness to the sever impacts of work-related accidents.

Electrical energy efficiency in a workshop is really important since building sector such as workshop itself accounts for 15%-45% of global energy needs [4], [5]. One of electrical energy saving method is by optimizing the lighting system in the room with possible integration the artificial and natural light. Since campus workshop is a place to perform several activities, for instance student lectures, practicum, and research, lighting factor in the workshop should be well-considered. Lighting intensity of the workshop should be standardized based on Indonesian National Standard (SNI), with calibrated lux meter and measurement point for the lighting measurement. The measurement result is then used as a reference whether the natural light source is adequate or not, if the natural light source is unable to fulfill the amount of light in the workshop room then an artificial light source is needed which comes from the lamps in the workshop room.

AK-Tekstil Solo is a vocational higher education under the Ministry of Industry who has several workshops related to textile production. One of them is 1,375 sqm of spinning and weaving workshop which consists of spinning and weaving production machines, as seen on Figure 1. This workshop is one of the biggest electrical energy consumers in the campus, since the spinning and weaving production includes big-industrial size machines. The workshop is located in the first floor, with several windows which allow natural lighting from sunlight enters the room. It is also supported by several existing artificial lighting using lamps, where the lighting requirements never been analyzed before. The workshop is heavily used in the study period, with various lecture schedules from those two Study Program. Therefore, an optimized lighting system is needed in order to support the overall energy efficiency in the campus.

Various researches on automatic lighting system using microcontroller has been performed, namely for home lighting [6], [7] that is tested on different lighting settings using a light dependent resistor sensor and AVR ATMega 16, both system is tested on a certain room in a house. While Sutono [8] developed automatic switch to operate room lighting which can detect not only lighting intensity but also considered motion sensor. It is applied on a computer laboratory, but there is no information available on its room size. Energy efficiency can also be developed into integrated smart system, where not only lighting automation is designed, but also electricity consumption of numerous electronic devices namely AC, lamp, water pump, etc based on Programmable Logic Controller and photocell censor [9]. Furthermore, the automated system can be connected into WiFi network with real time report on Android application [10]. Arduino Uno is widely used microcontroller to design control system, as used by [11] in designing lighting system which utilizes LDR as input sensor. Arduino Uno can also be used for other automated system of electronic devices [12]. To design larger systems such as smart homes, Arduino Uno can be integrated with other bases, for example with Raspberry Pi [13] and can be monitored in real time and can be accessed by more people by utilizing cloud services [14], [15].

Figure 1. AK-Tekstil Solo Spinning and Weaving Workshop.

Numerous studies have addressed lighting analysis, simulation, and automation technologies, but the application of those approaches has largely remained to campus classrooms, general-purpose rooms, or building in general within educational institutions. For instance, lighting analysis and design performed on a campus building [16], vocational school classroom [17] and vocational electrical engineering laboratory [18], while [19] implemented lighting automation in a classroom to achieve visual comfort and energy savings. Similarly, in non-educational contexts, studies such as lighting analysis and simulation on fashion workshop of a public creative hub [20], and lighting condition analysis in an auto body manufacturer [21]. Moreover, such implementation specifically in a textile workshop are still minimal, with existing studies on textile workshop more focused on thermal comfort [22]. Therefore, this study addresses the gap by integrating lighting analysis and automation in a vocational textile workshop, where this research on smart workshop with lighting automation design is considered new. It considers measurement point design in the workshop room based on the area according to SNI 16-7062-2004. The lighting intensity from combinations of natural and artificial lighting source is measured using lux meter and used as the base of the system design. The workshop lighting automation is also crucial as there are specialized and big spinning and weaving machines with many small details on its operations, making lighting becomes the primary need of the overall process. Moreover, the spinning and weaving workshop holds one of the biggest energy spending on the campus. This research will result in improved workshop process and usable recommendations on the workshop lighting standards. Hence to optimize the lighting system and to perform electrical energy saving, this research aims to design and develop an automatic lighting system in the workshop using Arduino-based microcontroller circuit and photocell components.

METHOD

The prototype design of smart workshop lighting automation using photocell is summarized on Figure 2 with material and methods described in the following. Based on SNI 03-6197-2000, relay module is used to control the workshop light intensity and photocell censor for light intensity reading both the natural and artificial light. Arduino Mega Microcontroller platform

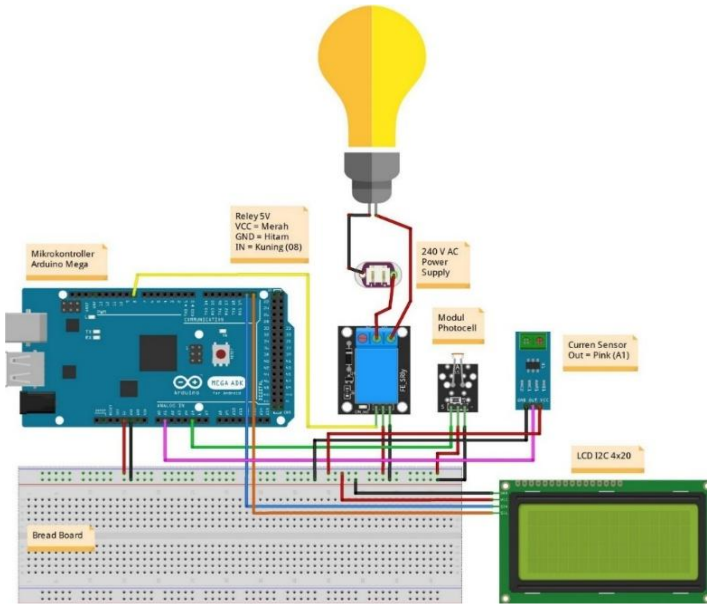

Figure 2. Prototype design of campus workshop lighting automation using photocell.

is utilized for the system. Arduino Uno R3 contains ATmega328P microcontroller to perform programmed instruction and also as a memory for data storage. Arduino is sourced from DC input or USB connection which also used to communicate with computer or laptop.

Various hardware and software are needed to build the prototype. The hardware includes the lamp itself with 50W for the prototype (nevertheless, the module can support up to 1200W lamp), Arduino Uno board, the breadboard which contains columns of connected sockets to position electronic components to create circuits and to connect to the Arduino. The two lines along the left to right of the breadboard are used to connect to the power or ground lines in a circuit. The holes in each short column of the breadboard are connected together, while the center area on the breadboard separates the breadboard into two unconnected parts. There are also 5V relay modules to control the lamp based on the lighting condition/intensity, an AC712 circuit current sensor to monitor the current consumed by the light thus can calculate its energy, and 4×20 LCD to displays the relay status, light intensity, and lamp energy consumption. Finally, one of the main parts for the prototype is the photocell with 10K Ohm resistor to measure the light intensity. Photocell, also known as Light Dependent Resistor (LDR) is one of the light sensors that can convert the amount of light received into the amount of conductance [23]. IT is a type of resistor that can change its resistance when exposed to light or darkness. The characteristics of the LDR sensor is based on its resistance in dark conditions or bright conditions, between hundreds of ohms (Q) to several Mega Ohms (MQ) depending on its type. The LDR resistance in dark places usually reaches around 10 Mega Ohms, and in bright places the LDR has a resistance that drops to around 150 Ohms [24]. In order to control the LDR to suit the need, a microcontroller with several ports can be used, the ports include one port is connected to the equipment to be controlled and another port is connected to the LDR sensor. While the software needed such as the Arduino Integrated Development Environment (IDE) 1.8.19, Arduino IDE Sketch which consists of three parts: the variable definition, `void setup()` function, and `void loop()`. LiquidCrystal library also needed for the program. The automated program is then developed on Fritzing application, with C++ programming language and Qt framework.

Lighting intensity measurement of the spinning and weaving workshop is based on SNI 16-7062-2004 about lighting intensity measurement on the workplace, so that suitable lighting intensity can be achieved in order to create a safe and comfortable workshop environment thus any accident can be prevented. Machine layout in the workshop is one of the most strategic decision-making consideration, since it will ease the machine operations of the campus workshop in the long term. The smooth flow and operations in processing the raw material to the final product is affected by the workshop layout effectiveness. Therefore, the workshop layout is kept as it is and the machine position stays in the same location in the workshop. The initial light intensity measurement is based on the original workshop layout using lux meter.

The spinning and weaving workshop has 55 meters long and 25 meters wide, therefore it has 1,375 square meters area. The SNI standards requires that the horizontal intersection point of the length and width of the room is at a distance of 6 m for a room larger than 100 square meters. Accordingly, the lighting measurement is conducted in six measurement points. The measurement points settings of the workshop are observed a Figure 3.

The blue diamond on Figure 3 denotes number of 1 to 8 shows the approximate location of the measurement points. Three times replication of measurement is performed in the research. This is the base whether the natural light intensity meets the standards as required. The artificial light is also measured so that the combination of the natural and artificial light can be conditioned for the lighting system automation with the photocell. The combination of natural light intensity and artificial light intensity is a combination that will control the system optimally.

Before deploying on the entire system, relay testing is performed to control the lighting intensity on the workshop. Relay is turned on and off continuously every five seconds to check whether the relay is working and the lamp is connected properly to the project, and plug is connected to the electricity source. Arduino sketch is then uploaded into the program, where the relay must be ensured to be in such a position that it cannot be touched accidentally.

RESULTS AND DISCUSSION

Lighting Intensity Evaluation

Lighting intensity of the spinning and weaving workshop is measured in two ways, first measurement using the natural light only, while the second measurement is combining both natural and artificial light. Intensity is defined in Lux, where it indicates the number of rays received by an object measuring 3 square feet at a distance of 1 yard, by a light source with a power of 1 watt. Lux meter is used by placing it on the workshop table or held it at the height of 75 cm above the floor. Measurement is performed in the morning and afternoon, on each hour from 08:00–16:00, in six different points of measurement each. Table 1 for natural light and Table 2 for natural and artificial light gives a showcase on the lighting intensity measurement results.

Based on the data on Table 1, it is observed that the highest natural light intensity was in the measurement time range at 13:00 WIB (Jakarta time; UTC+7) with an average natural light intensity value of 128.50 Lux and the lowest light intensity was at 15:00 WIB with an average natural light intensity value of 6.83 Lux. It can be seen that at 13:00 WIB, 2nd measurement point has the highest natural light intensity of 278 Lux since it gets maximum natural light from the window in the workshop. It shows that appropriate window area in the workshop is needed in order

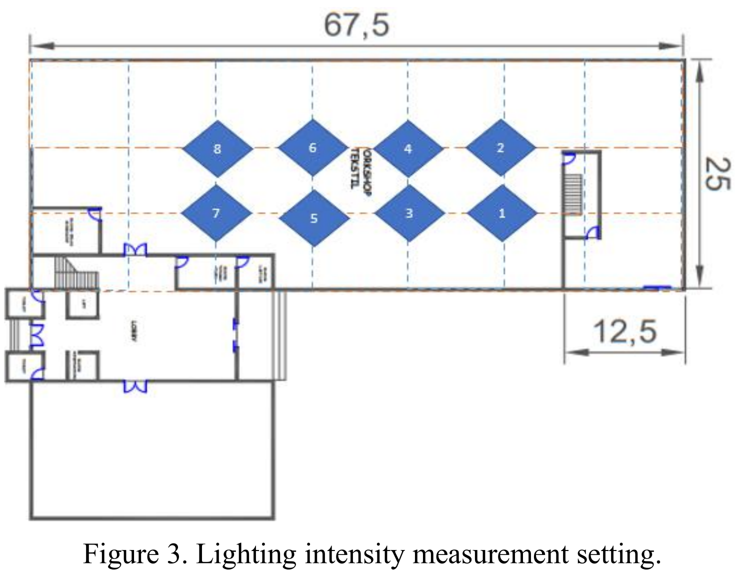

Figure 3. Lighting intensity measurement setting.

Table 1. Natural Light Intensity measurement.

Time	Natural Light Intensity (Lux)						Average
	1st	2nd	3rd	4th	5th	6th	
08:00	50	84	21	19	27	137	56.33
09:00	44	121	24	21	35	215	76.67
10:00	56	105	28	24	37	248	83.00
11:00	40	85	19	12	28	110	49.00
12:00	77	250	42	23	52	188	105.33
13:00	65	278	66	38	82	242	128.50
14:00	44	106	25	17	38	185	69.17
15:00	7	9	2	1	3	19	6.83
16:00	7	14	3	2	4	31	10.17

to get a better light intensity, as it is in line with previous research conducted by Prasetyo et al [25] that a larger window opening will get maximum natural light intensity compared to a smaller window opening at a certain time. While on 15:00 WIB, natural light intensity experienced a decrease in light intensity of less than 50 Lux. Almost all measurement shows similar trend caused by the position of the window and natural light source, also machine positions which affects the reflection of light in the room.

Table 2 showcases measurement results of natural and artificial light intensity combinations. The intensity of natural light and light intensity from lighting sources in the workshop room was the highest in the measurement time range at 13:00 WIB with an average light intensity value of 201 Lux and the lowest light intensity at 15:00 WIB with an average light intensity value amounting to 70.50 Lux. It can be seen that at 13:00 WIB, 2nd measurement point has the highest light intensity of 426 Lux. These measurement results are then used as the references of the decision making in the design and algorithm of the workshop lighting automation with photocells. Average lighting intensity in Lux is showcased on Figure 4 for artificial lighting and Figure 5 for artificial and natural light intensity.

Table 2. Natural and Artificial Light Intensity Measurement

Time	Natural and Artificial Light Intensity (Lux)						Average
	1st	2nd	3rd	4th	5th	6th	
08:00	155	182	43	78	56	206	120.00
09:00	199	219	51	83	66	268	147.67
10:00	158	219	49	73	65	277	140.17
11:00	128	213	66	72	81	276	139.33
12:00	167	295	66	97	85	337	174.50
13:00	157	426	87	98	113	325	201.00
14:00	153	231	69	84	84	340	160.17
15:00	106	117	24	67	32	77	70.50
16:00	110	135	27	67	38	104	80.17

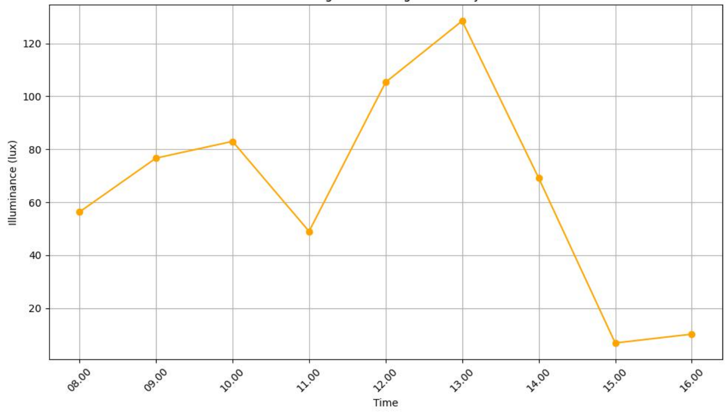

Figure 4. Workshop natural light intensity.

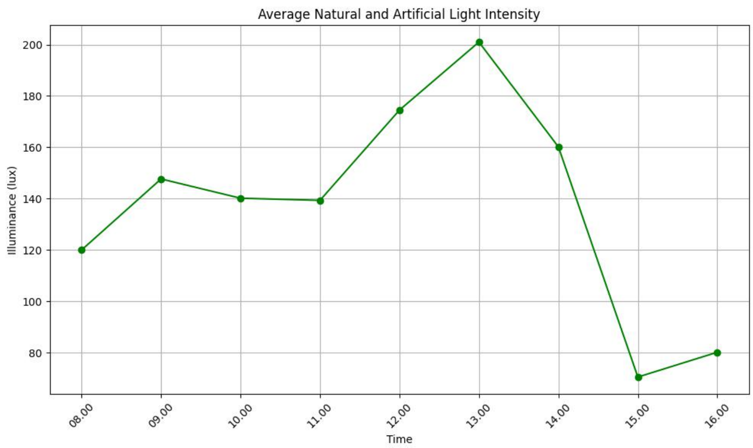

Figure 5. Workshop natural and artificial light intensity.

Figure 4 illustrates the variation in natural lighting intensity within the yarn production workshop from 08:00 to 16:00. The illuminance level starts at 56.33 Lux in the early morning and gradually increases, peaking at 128.50 Lux around midday. After this peak, it declines progressively towards the afternoon, ending at 10.17 Lux. These values demonstrate the natural lighting dependency on sunlight availability, which is insufficient on its own to meet industrial lighting standards throughout the day. Figure 5 presents the artificial lighting levels recorded over the same period. Unlike natural light, the artificial lighting remains relatively stable, ranging from 120 Lux at 08:00 to a maximum of 174.50 Lux around 12:00, then slightly decreasing to 80.17 Lux at 16:00. Although more consistent, these values still fall below recommended levels for precision textile work, indicating that the artificial lighting system requires significant improvement to meet ergonomic and visual comfort standards.

Development of The Workshop Lighting Automation

The measurement of lighting intensity of natural and artificial light is used as the basis whether the lights should be turned on or off by the photocell. The intensity criteria refer to the standard intensity of natural light and artificial light sourced from existing lighting. Photocell decision is based on algorithm shown on Figure 6, including the following conditions: If the natural light intensity is less than 50%, the photocell sensor orders the microcontroller to turn the relay on so that the system is connected, making the microcontroller turns on the artificial light intensity source in the workshop room. If the intensity of natural and artificial light is more than 75%, the photocell sensor orders the microcontroller to turn off the relay so that the system is disconnected so that the microcontroller turns off the source of artificial light intensity in the workshop room. As a limitation in research on lighting automation systems in workshops using photocells, this refers to the workshop's operational schedule, namely Monday through Friday, 08:00–16:00 WIB. During operational times the electrical system in the workshop room will be turned on manually, likewise if outside operational times the electrical system will be turned off by the operator.

The prototype of lighting automation system in the Spinning and Weaving workshop depends on the intensity of light shining on the sensor. Light Dependent Resistor (LDR) sensor or photocell is used, if the light shining on the sensor becomes brighter, the resistance will change down to several hundred ohms, but if the light conditions received by the sensor become darker, the resistance will become quite large. Before the whole circuit is tested, each component is first tested by running the Tinkercad application to look for coding that matched the circuit. The lighting automation for the spinning and weaving workshop is programmed based on Arduino IDE program algorithm.

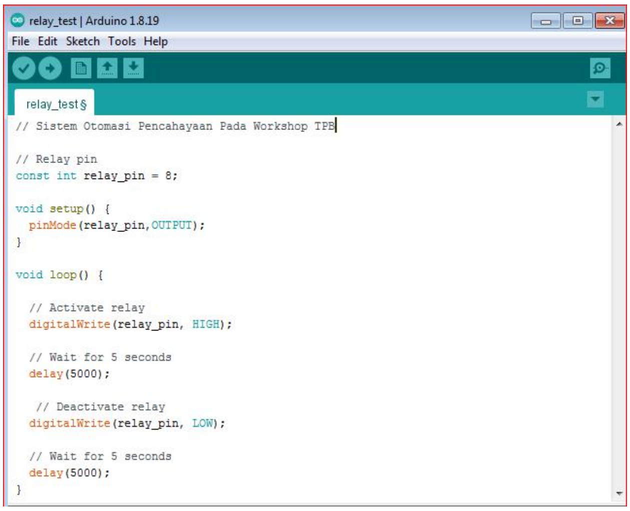

Figure 6. Relay testing algorithm.

Implementation of a photocell sensor-based lighting automation system designed to control artificial lighting switching relays based on ambient light intensity. The actual circuit consists of an LDR (Light Dependent Resistor) sensor that is calibrated and processed through an Arduino Uno, supported by an RTC (Real-Time Clock) module that limits system operation during working hours (08:00–16:00 WIB). The output from the Arduino is controlled through a 5V relay connected to an artificial lighting source. The system is also equipped with current protection using a fuse to avoid damage due to power surges. Prototype testing, as shown in Figure 7 is then carried out by first ensure relays, LCD displays with I2C, and sensors are connected correctly into the microcontroller circuit. After making sure that all connections are made correctly, the prototype testing of lighting automation system of spinning and weaving workshop is performed. When the weather is bright in the morning and light accessed into the workshop, the Arduino microcontroller sent a signal to the relay to be turned off. When the photocell does not receive enough light, the sensor immediately orders the Arduino microcontroller to turn off the relay. This shows that the design works well and ready to be deployed on the workshop. The photocell sensor is able to respond to changes in lighting quite well, but is still influenced by several field factors. Electrical noise from production machines, light reflection from metal surfaces, and fluctuations in natural light due to weather conditions cause variations in sensor readings of up to 15% of the actual value. Calibration and adjustment of the relay threshold are carried out based on field data. The system is configured to activate the relay when the light intensity is <150 Lux (50% of the minimum standard) and

Figure 7. Prototype testing of automation.

deactivate it when the light is >350 Lux (70% of the standard). This setting has been shown to reduce switching oscillations and increase the system's responsiveness to changes in light intensity without compromising the worker's visual comfort. Although this study does not include a direct analysis of energy savings or cost reduction, the implementation of an SNI-compliant lighting automation system aligns with broader sustainability goals through lighting control. Additionally, while this implementation was initially developed for a vocational textile workshop, its modular design allows it adaptable for use in other campus settings with minimal adjustments. Future work will aim to quantify these broader impacts, including long-term energy consumption metrics and cost-benefit analysis of full-campus integration.

CONCLUSION

Lighting automation for a smart workshop in the vocational campus was designed in this research using a photocell. The prototype was built and performed successfully in the spinning and weaving workshop by setting the relay based on the Arduino IDE coding that had been created. The prototype includes a lamp, Arduino Uno board, photocell, relay modules, circuit current sensor, and LCD. The lighting automation system benefits the campus in terms of electrical energy efficiency and saving by integrating both natural and artificial light sources. This system also gives an advantage in supporting and ensuring that the lighting condition in the workshop is according to the SNI 16-7062-2004 standard for the workshop. Automation for other important aspects of the workshop, namely electricity use, machine control, temperature control, etc., should be developed for future research to achieve the smart workshop concept. All those automation controls can be organized in one integrated system, accessed easily and without hassle.

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