INTERACTIVE LIGHTING TO MAINTAIN CONCENTRATION: SALMAN AL FARISI BANDUNG FULL-DAY SCHOOL

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ABSTRACT

Nowadays, the times affect the development of the education system for children. Full-time employment parents and the problem of leaving their children unattended and without essential activities are reasons full-day schools are in great demand. The learning conditions for a relatively long time and the various activities implemented in this full-day school affect the need for unique facilities compared to other schools, especially in maintaining children's concentration in learning. The research employs a mixed method, quantitative and qualitative approach. Quantitative data is in the form of classrooms' lighting data and the implementation of the required lighting, while qualitative data is in the form of activity data, classroom conditions, interview results, and design solutions related to activity problems in the classroom. The research began with an initial literature review and then field surveys and interviews with case studies of Salman Al Farisi Elementary School, a pioneer of full-day school in Bandung with an integrated Islamic education concept. Lighting is an interior architecture element that mainly affects student concentration in the classroom. Due to the existing problems, an interactive lighting system must be implemented in Salman Al Farisi Elementary School classrooms to support activities and maintain student concentration in learning. Research results showed that Arduino devices have the potential to be used in Salman Al Farisi Elementary School classrooms to create an interactive lighting system. The required interactive lighting system is a lighting system that can detect external lighting, equipped with a timer system, and adjust to the activity scenario in the classroom. Then, the lighting system will adjust the room light to maintain student concentration according to the ongoing activity. Further studies to be conducted are trials of implementing an interactive lighting system with Arduino devices in classrooms to validate the impact on student concentration.

Keywords: *full-day school, children, concentration, interactive lighting, Arduino*

INTRODUCTION

The child stage is the most critical stage of human development and has unique characteristics (Rahmi & Hijriati, 2021). Apart from the necessities for clothing, food, and housing supplies, education is necessary for children. Nowadays, the times have affected the development of the education system for children, and the full-day school system is one of them. Full-time employment parents and the problem of leaving their children unattended and without essential activities are reasons full-day schools are in great demand (Rahim, 2018).

Full-day school benefits parents and children; children have more space and time to study, and their parents can leave their children at school while working. In addition, the school provides children with formal general knowledge of moral and spiritual values (Wicaksono, 2018).

The full-day school chosen as a case study is Salman Al Farisi Elementary School in Bandung, Indonesia, which applies the concept of integrated Islamic religious education. The students in this full-day school spend time at school for eight and a half (8.5) hours a day. This school applies the learning concepts of "Learning by doing", "Learning by playing", and "Learning by process" so that it has an impact on the number of activities that occur in one day in each classroom. The learning conditions for a relatively long time and the various activities implemented in this full-day school affect the need for various facilities compared to other schools, especially in maintaining children's concentration and stress levels in learning (Cardiah & Sudarisman, 2019).

Lighting is an essential factor significantly impacting children's concentration (Zulfiani & Zulaikhah, 2021). In addition, based on the discovery of photoreceptors in the eye, it was found that appropriate and convenient lighting conditions in work are crucial because they affect visual and biological effects (Van Bommel, 2006). Appropriate lighting affects human health and performance, minimises errors, and influences work and study safety factors. Convenient and appropriate lighting conditions can increase work and study productivity (Shukur *et al.*, 2021).

As technology develops, the lighting system can also be designed based on artificial intelligence to detect and predict room comfort, especially lighting comfort (Hakim et al., 2021). Interactive lighting systems and scenarios based on artificial intelligence can be customised according to user needs and potentially applied to classrooms. The system is assumed to be able to facilitate lighting according to ongoing activities at a particular time and respond to existing environmental needs.

Based on this background, designing interactive lighting scenarios in full-day school interiors is necessary to increase and maintain students' learning concentration in the classroom. This research focuses on full-day school classes for children aged 6-12 with a case study of Salman Al Farisi Elementary School in Bandung.

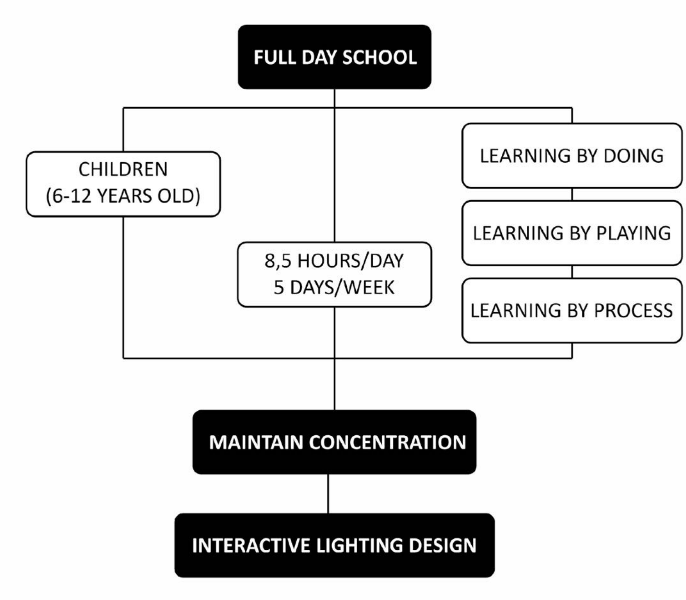

Figure 1. Research Flow
Source: Authors, 2023

THEORY / RESEARCH METHODS

The Importance of Concentration in Full-day School

Concentration level is the main factor determining students' learning success (Mrnjaus & Krneta, 2014). By concentrating, everything can be recorded optimally in the brain's memory and quickly recalled when needed. In learning, concentration focuses all attention on a learning situation or an object to comprehend it (Andita & Desyandri, 2019).

An appropriate and pleasant atmosphere is necessary to achieve students' concentration in learning. It means a relaxed condition is essential, with no physical and mental tension threatening students so that students can concentrate and study optimally (Zulfiani & Zulaikhah, 2021). Therefore, fun and pleasant methods are required to create a relaxed learning environment.

The full-day school programme applies a more extended study time, from 7 a.m. to 3.30 p.m., with an average of 8.5 hours a day, compared to the regular programme that usually starts from 7 a.m. to 1 p.m. with an average time of 6 hours a day. Meanwhile, adequate study time for students in formal conditions is 3-4 hours a day and 7-8 hours in informal conditions (Helmi, 2016). Students get denser lessons over a relatively long time and tend to get bored and exhausted in full-day school (Angela et al., 2021). In addition, children aged 6-12 need to play and cannot spend their time full-time studying. These conditions require full-day schools to implement an informal and non-rigid learning atmosphere to produce an effective learning process. It is necessary to provide a fun learning atmosphere and facilitate children's playing at school (Wicaksono, 2018). A full-day school stimulates children's concentration in learning and provides comfort when carrying out learning and playing activities (Cardiac & Sudarisman, 2019).

The Role of Lighting in Improving Learning Concentration

The learning environment is one of the external factors that can affect student concentration. Environmental factors influencing learning concentration include lighting, sound, temperature, and learning design (Zulfiani & Zulaikhah, 2021). Lighting is an essential external factor affecting physical, physiological, and psychological (Shishegar & Boubekri, 2022).

In human bodies, cortisol and melatonin play an essential role in regulating levels of vigilance and sleepiness (Figueiro & Rea, 2010). The cortisol level increases in the morning, preparing the body for upcoming activities; it remains moderately high on sunny days and decreases to a minimum at night. Melatonin is a sleep hormone that will decrease in a bright environment and increase in a dark environment (Hoffmann *et al.*, 2008). It is crucial to maintain these hormones' rhythm to maintain human health. Lighting can affect the work of the cortisol hormone (stress hormone) and the melatonin hormone (sleep hormone) in the body, which then affects a person's mood, level of alertness, and stress level (Hu *et al.*, 2015).

Active and relaxed moments are necessary for work and study activities, especially for children. In addition to light, the bluish colour of the sky in the morning will biologically activate the alertness effect. In contrast, the reddish colour of the sky in the evening provides a relaxing effect (Shishegar & Boubekri, 2016). Colour and artificial lighting will determine those moments in a work environment. The higher the lighting level required, the cooler the colour must be selected to generate comfortable lighting (Jannah *et al.*, 2022). Bright colours will reflect more light than dark colours, so that the room colour will affect the intensity of lighting (Jannah *et al.*, 2022). Moreover, colour has a psychological effect. It encourages children's cognitive development and must be implemented correctly (Julianto et al., 2019).

The recommended lighting for classrooms with whiteboard media is 250 lux, and the lamps used should be neutral white light with a temperature of around 4000K (Subagyo, 2017). Based on S.N.I. (Indonesian et al.) 03-6197-2000, the recommended lighting level and colour temperature for classrooms is 250 lux with an excellent white colour (3300 – 5300K) or daylight (> 5300K), while for eating activities is 200 lux, with a warm white colour temperature (<3300K) or cool white (3300 – 5300K) (Idrus et al., 2016). Prayer activities require a lighting level of 200 lux with two different types of lighting, namely general lighting with colour temperature daylight and warm light accents (Pertiwi & Gunawan, 2017).

Light with 580 nm wavelength can increase concentration optimally (100%), producing a yellowish lighting colour. Light with a wavelength of 550 nm is lighting that can increase visual effectiveness by as much as 75%, and that wavelength produces a greenish colour of light. Light with a wavelength of 500 nm can provide a concentration effectiveness of 50%, and that wavelength produces a bluish light colour. Light with a wavelength of 400 nm provides 0% visual effectiveness, producing a purplish light colour (van Bommel, 2005). Furthermore, higher C.C.T.

(Correlated Colour Temperature) lighting levels, such as 4100K lamps, increase human cortisol levels more than lower C.C.T. levels, such as 3000K lamps (Pulay *et al.*, 2018). So, light wavelength and temperature determine lighting colour, affecting human hormones, behaviour, and concentration.

Case Study of Salman Al Farisi Bandung (Elementary Full-day School)

The Salman Al Farisi Bandung Education Foundation is on Jalan Tubagus Ismail VIII Bandung, established on August 12, 1989. Salman Al Farisi Bandung was chosen as the research object because this school is a pioneer of full-day schools in Bandung. It also implements a specific system, a full-day school based on integrated Islamic education. The learning process applied at Salman Al Farisi is Active, Innovative, Creative, Fun, Happy, and Qualified Learning. This full-day school also implements a national curriculum with integrated thematic learning methods, learning by doing, creative Learning, Active Learning, Cooperative Learning, and scientific methods.

Based on the curriculum and activities requirement, Salman Al Farisi Elementary School needs classrooms that can increase and maintain students' concentration, stimulate their imagination, and enhance creativity. So, this full-day school is an intriguing research object regarding efforts to increase and maintain children's learning concentration in schools with a full-day school system based on integrated Islamic education.

Salman Al Farisi Bandung is in a residential area with hilly land conditions. This condition makes this school conducive and safe for children in a strategic location. Below are photos of the existing condition of the school (Figures 2-7).

Figure 2. Salman Al Farisi Elementary School Façade, Bandung
Source: field survey, 2020

Figure 3. First-grade classroom.
Source: field survey, 2020

Figure 4. Second grade classroom.
Source: field survey, 2020

Figure 5. Third grade classroom.
Source: field survey, 2020

Figure 6. Fourth and fifth-grade classrooms.
Source: field survey, 2020

Figure 7. Sixth grade classroom.
Source: field survey, 2020

Methods

The research employs a mixed method, quantitative and qualitative approach. Quantitative data is in the form of classrooms' lighting data and the implementation of the required lighting, while qualitative data is in the form of activity data, classroom conditions, interview results, and design solutions related to activity problems in the classroom.

The research began with an initial literature review regarding full-day school, concentration problems among students, and interactive technology, especially interactive lighting. In the next stage, a field study was carried out, selecting one of the full-day schools in Bandung City as the case study for further study regarding its activities, problems, and development potential, especially in interactive technology.

The field studies were conducted by observing classroom conditions, measuring classroom lighting conditions, and interviewing the foundation and teachers. Measurement of lighting conditions in classroom areas and observation of activities were conducted using the systematic sampling method, and student interviews were conducted using the simple random sampling method. Next, the data results were analyzed to obtain design solutions and interactive lighting technology designs. This research produced design solutions and methods for using interactive lighting technology, which has the potential to be used as the basis for further research in the form of implementation in the classroom and measuring the impact of this implementation.

RESULTS AND DISCUSSIONS

The Students' Issues on Concentration Related to Lighting Conditions

Observations and lighting measurements were carried out using three classrooms as samples to represent the existing lighting conditions at Salman Al Farisi Elementary School. The observation and measurement process begins from 8 a.m. to 3 p.m., with three classrooms sample classes 1A (first grade), 3C (third grade), and 5B (fifth grade).

Observations of students' conditions were carried out at the same time as measuring classroom lighting. Observations were conducted through behavioural and body language analysis, observing the condition of most students from facial expressions, interactions between students, eye gaze direction, yawning, and changes in body position (Sulaiman et al., 2011). Decreased concentration behaviours that can be detected include blinking, yawning, being distracted by something else, and changes in body angle while studying (Su *et al.*, 2021).

The majority condition is taken if the condition occurs in more than 50% of the total number of students in the class. If a student actively interacts with the teacher, it is stated as Active, whereas if the student is silent and tends not to interact with the teacher, it is stated as Passive. If most students focus towards the front and pay attention to the teacher, their body position tends to be upright, expressed as Focus. In contrast, if most students turn their gaze to a direction other than the front or the teacher, their body position tends not to be upright, expressed as Decreased Concentration. Suppose most students tend to look away from the front or the teacher. In that case, if their body position is not upright, their eyes are squinted or blinking, they are yawning, or they are doing other activities unrelated to learning activities, they are declared Unfocused.

Table 1. Data on Lighting Conditions in The Classroom Samples - Salman Al Farisi Elementary School, Bandung

Class room	**Time**	**Activity**	**The Average of Natural Lighting (lux)**	**The Average of Artificial Lighting (lux)**	**The Average of Students' Condition**
1A	9 – 11 a.m.	Study, after outdoor activities	392	-	Active, Focus
	11 a.m. – 1.30 p.m.	Study, Prayer, Lunch	48	-	Passive Decreased Concentration
	1.30 – 3 p.m.	Study, After Lunch	22	90	Passive Decreased Concentration
3C	8 – 11 a.m.	Study, Experiment	164	-	Active, Focus
	11 a.m. – 12 p.m.	Study	97	-	Passive Decreased Concentration
	12 – 3 p.m.		78.7	-	Passive Decreased Concentration

Class room	Time	Activity	The Average of Natural Lighting (lux)	The Average of Artificial Lighting (lux)	The Average of Students' Condition
5B	8 – 11 p.m.	Prayer, Lunch, Study	98.5	-	Active, Focus
	11 a.m. – 1 p.m.	Study, Discussion	42	-	Passive Decreased Concentration
	1 – 3 p.m.	Study, Prayer, Lunch	32	-	Unfocused
		Study, After Lunch			

Source: Authors, 2020

Note: The recommended lighting for classrooms with whiteboard media is 250 lux.

Based on the results of observations and lighting measurements (Table 1), the natural lighting at Salman Al Farisi Elementary School began to decrease at 11 a.m., as did the students' focus levels, which started to decrease at 11 a.m. The lighting intensity in classroom 1A was excessive in the morning (9 – 11 a.m.), which was above 250 lux and became deficient after 11 a.m., which was below 50 lux. The lighting intensity in classrooms 3C and 5B throughout the day was below 250 lux, so all existing lighting conditions did not meet the ideal classroom lighting standards.

The results of interviews with eighteen (18) students from the sample classrooms also showed that the average students' concentration began to decrease at 11 a.m. and peaked after lunch. The comparison of lighting levels and the impact on students' conditions are as follows (Table 2).

Table 2. Comparison of Lighting Levels and Impact on Students 'Conditions

Class room	Time	The Average of Natural Lighting (lux)	Lighting Level and Colour	The Results of Students' Conditions Observations	The Results of Students' Interview
1A	9 – 11 a.m.	392	High, Bluish	Active, Focus	Excited, Focus, Overactive
					Getting Sleepy
	11 a.m. – 1.30 p.m.	48	Low, neutral	Passive Decreased Concentration	Sleepy

Class room	Time	The Average of Natural Lighting (lux)	Lighting Level and Colour	The Results of Students' Conditions Observations	The Results of Students' Interview
	1.30 – 3 p.m.	22	Low, reddish	Passive Decreased Concentration	Excited, Focus
3C	8 – 11 a.m.	164		Active, Focus	Sleepy
	11 a.m. – 12 p.m.	97	Mid, bluish	Passive, decreased concentration	Sleepy
	12 – 3 p.m.	78.7	Low, neutral	Passive, decreased concentration	Sleepy Sometimes
5B	8 – 11 p.m.	98.5	Low, reddish	Some Active, Some Passive	Sleepy
	11 a.m. – 1 p.m.	42		Unfocused	Sleepy
	1 – 3 p.m.	32	Low, bluish	Unfocused	
			Extra low, neutral		
			Extra low, reddish		

Source: Authors, 2020

Note: The recommended lighting for classrooms with whiteboard media is 250 lux with neutral white light (4000K).

Based on Tables 1 and 2, the lighting level is one of the determining factors for the children's learning concentration. The data matched the research result (Shishegar & Boubekri, 2016) that the bluish colour will biologically activate the alertness effect, while the reddish colour provides a relaxing effect.

Table 3. The Ideal Classroom Lighting Conditions

Time	The Average of Activities	Ideal Lighting Requirements (lux)	Ideal Light Colour Temperature	The Expectations of Students' Conditions
8 a.m. – 12 p.m.	Study	250	Bluish, 4100K	Active, Focus
12 – 12.30 p.m.	Prayer	200	Neutral, 3000 - 4000K	Relaxed
12.30 – 1 p.m.	Lunch Break	200		Relaxed
1 – 3.30 p.m.	Study After Lunch	250	Reddish, 3000K Neutral, 4100K	Neutral, Focus
3.30 – 4 p.m.	Prayer, Going Home	200	Reddish, 3000K	Relaxed

Source: Authors, 2023

Note: The ideal lighting requirements are based on S.N.I. (Indonesian National Standard) 03-6197-2000.

Both active and relaxed moments are necessary for work and study activities. Colour and artificial lighting levels have the potential to generate both conditions in the environment. Several classrooms at Salman Al Farisi Elementary School have natural lighting below 150 lux, especially during the afternoon and evening, so artificial lighting is necessary to support activities in the classroom during that time. Interactive lighting is needed to maintain student learning concentration. The required interactive lighting is the light that can adjust the lighting intensity and colour based on the activities or respond to the existing environment.

As the intensity of natural lighting decreases and the natural lighting colour gets reddish, the lighting needs to be set to a higher intensity and bluish colour so that the students remain concentrated on studying. Towards the afternoon, the lighting intensity must still be high, but the colour must be reddish or neutral. It aims to maintain students' concentration while they feel more relaxed simultaneously because afternoon learning activities are prepared to be moderate.

The Potential of Interactive Lighting Technology for Full-day School Classrooms

The interactive lighting system can be designed based on artificial intelligence to detect and predict room comfort, especially lighting comfort (Hakim et al., 2021). Interactive lighting systems and scenarios based on artificial intelligence can be customised according to user needs and potentially applied to classrooms. The system is assumed to be able to facilitate lighting according to ongoing activities at a particular time and respond to existing environmental needs.

Arduino is an electronic prototyping platform that is most widely used and has the potential to be applied as an interactive lighting tool in classrooms. Arduino is a platform consisting of software and hardware that is flexible, open source, has devices at affordable prices, and is easy to use (Banjaransari et al., 2022). Arduino hardware is like a microcontroller, and Arduino software is an open-source software called Arduino IDE used to create and enter program code into Arduino devices (Banjaransari et al., 2022).

The interactive lighting system that must be implemented in Salman Al Farisi Elementary School classrooms urges using automatic light control to increase efficiency and human power. This system can be connected with RGBWW (Red et al.) L.E.D. lamps so that intensity and colour lighting levels can be adjusted. A TSensor system will be required to generate the automatic control devices (Putro & Kambey, 2016). The LDR (Light et al.) light sensor functions to respond to the external lighting intensity, then the data is processed by the Arduino, and the output is the intensity and colour lighting adjustment on the L.E.D. lamps.

The Arduino system can also be equipped with detectors of people entering or leaving a room or activity scenarios to increase the efficiency of lighting usage (Telling et al., 2020). Based on some of the results of Arduino device testing, the device is proven to detect and respond to changes in light intensity from external light so that the system will adjust the lighting of the lights as needed (Telling et al., 2020). Below are interactive lighting schemes that have the potential to be implemented in full-day school classrooms (Figures 8 and 9).

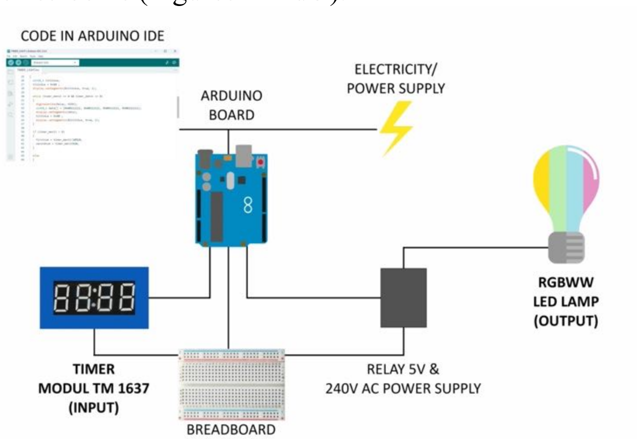

Figure 8. Schematic of Interactive Lighting Method: Timer-Based Activity.
Source: Authors, 2023

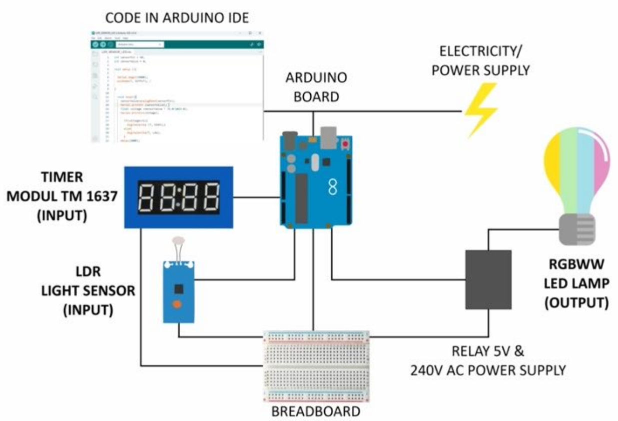

Figure 9. Schematic of Interactive Lighting Method: Timer-Based Activity and Light Sensor System.
Source: Authors, 2023

Table 4. Interactive Lighting Scenario Based on Class Activity

No	Time	The Average of Activities	Lighting Set Up (lux, Kelvin)
1	8 a.m. – 12 p.m.	Study	250, 4100K
2	12 – 12.30 p.m.	Prayer	200, 3000 - 4000K
3	12.30 – 1 p.m.	Lunch Break	200, 3000K
4	1 – 3.30 p.m.	Study After Lunch	250, 3000 - 4100K
5	3.30 – 4 p.m.	Prayer, Going Home	200, 3000K

Source: Authors, 2023
Note: The lighting set-up is based on Table 1 – 3.

Table 5. Interactive Lighting Scenario Based on External Light Conditions and Activities

Time	The Average of Activities	Lighting Setup (lux)	Lighting Colour Set Up (Kelvin)	The Expectations of Students' Conditions
8 a.m. – 12 p.m.	Study	If external light > 250, artificial light off If external light < 250, artificial light 250	If external light > 4100K, artificial light 3000k – 4000K If external light < 4100K, artificial light 4100K	Active, Focus
12 – 1 p.m.	Prayer	If external light > 200, artificial light off If external light < 200, artificial light 200	If external light > 4000K, artificial light <3000K If external light < 3000K, artificial light 3000k – 4000K	Relaxed
12.30 – 1 p.m.	Lunch Break	If external light > 200, artificial light off If external light < 200, artificial light 200	If external light > 3000K, artificial light <3000K If external light < 3000K, artificial light 3000K	Relaxed
1 – 3.30 p.m.	Study After Lunch	If external light > 250, artificial light off If external light < 250, artificial light 250		Neutral, Focus

Time	The Average of Activities	Lighting Setup (lux)	Lighting Colour Set Up (Kelvin)	The Expectations of Students' Conditions
3.30 – 4 p.m.	Prayer, Going Home	If external light > 200, artificial light off If external light < 200, artificial light 200	If external light > 4100K, artificial light 3000k – 4000K If external light < 3000K, artificial light 3000-4100K If external light > 3000K, artificial light <3000K If external light < 3000K, artificial light 3000K	Relaxed

Source: Authors, 2023
Note: The lighting set-up is based on Table 1 – 4.

Table 6. Comparison between Existing Lighting and Proposed Lighting System

Lighting	Light Intensity (Lux)	Light Colour (Kelvin)	Timer	Setting
Conventional/ Existing	One type (90 lux)	One type (6500K)	None	Manual (On/Off)
Interactive/ Proposed System	Adjustable (0 – 250 lux)	Adjustable (0 – 6500K)	Can be set up	Manual (On/Off), Automatic (Timer or based on human/external lighting detection)

Source: Authors, 2023

Tables 4 and 5 describe interactive lighting scenarios to be implemented in full-day school classrooms. Table 6 explains the advantages of the proposed interactive lighting system compared to the existing one. Arduino devices have the potential to be used in Salman Al Farisi Elementary School classrooms to create an interactive lighting system. The required interactive lighting can detect external lighting and is equipped with a timer system that has been adjusted to the activity scenario in the classroom.

The Design Concepts to be Implemented in Full-day School Classrooms

The room colour will affect the intensity of lighting and has a psychological effect based on its visual, such as a warm, cold, or fresh impression (Julianto et al., 2019). Based on the curriculum and activities requirement, Salman Al Farisi Elementary School needs classroom colours and lighting to increase and maintain students' concentration, stimulate their imagination, and enhance creativity.

The Colour Concept

Based on (van Bommel, 2005 Julianto, Cahyadi and Artawan 2019) research and according to the needs of Salman Al Farisi Elementary School, the dominant colours selected are yellow and green for classrooms. Ivory yellow, with a wavelength of around 580 nm, improves and maintains children's concentration, provides energy, and stimulates their intellect. Olive green, with a wavelength of around 550 nm, is the colour of the school's identity and is also a colour that can provide calm and comfort to balance the yellow colour. Other supporting colours that are also applied are orange apricot, which can increase enthusiasm, creativity, optimism, and joy; purple plum colour, which can stimulate imagination, creativity, and inspiration; and coffee colour, as a neutral colour, able to give a sense of comfort and intimacy.

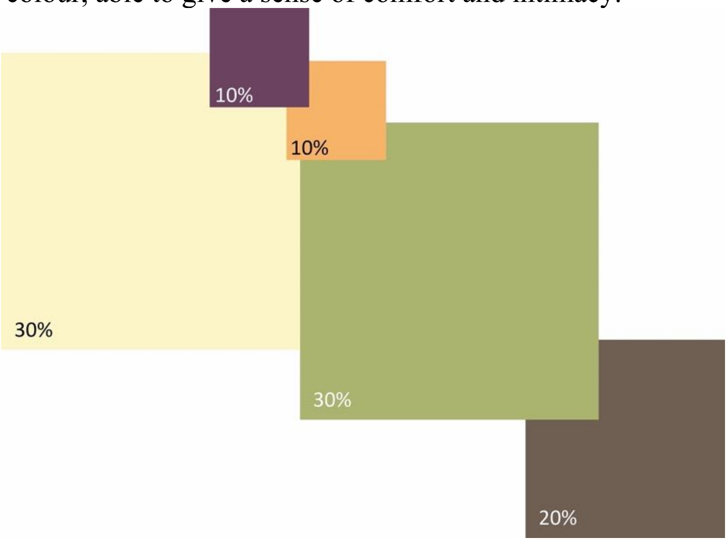

Figure 10. Colour scheme.
Source: Authors, 2023

Lighting Concept

Lighting is divided into natural and artificial lighting. In several classrooms, especially classes that receive natural lighting from the east and west, heat radiation often occurs by direct sunlight, causing glare and disrupting thermal and visual comfort. So, it is necessary to apply roller blinds in several classrooms. The artificial lighting applied is RGBW LEDs as energy efficient and environmentally friendly lighting and utilises interactive lighting based on Arduino devices, which can be adjusted based on Tables 4 and 5.

Figure 11. Interactive lighting implementation: morning study activities.
Source: Authors, 2023

Lighting for study activities in the morning (Figure 11) is set to be 250 lux and 4100 K (neutral colour light) to optimise students' concentration. The bluish environment light in the morning usually supports the morning activities and students' concentration, so the artificial lighting colour will not play an essential role. In case of unsupported weather, such as rain in the morning, the lighting will adjust automatically to set the daylight environment (4100K) to maintain students' concentration in the morning. From 11 a.m., as the intensity of natural lighting decreases, artificial lighting will be necessary to keep the lighting intensity at 250 lux and 4100 K, so the students remain concentrated on studying.

For the noon prayer activity (Figure 12), the students are allowed to be more relaxed, so the lighting is set to be 200 lux, with 4100K general lighting and 3000K (warm colour light) accent lighting. Furthermore, the lunch activity for students must be relaxed and enjoyable, so the lighting needs to be 200 lux and 3000K (Figure 12).

Figure 12. Interactive lighting implementation: noon prayer (left) and lunch activities (right).
Source: Authors, 2023

Figure 13. Interactive lighting implementation: study after lunch (left) and afternoon prayer (right) activities.
Source: Authors, 2023

After lunch, as the intensity of natural lighting decreases, and the natural lighting colour gets reddish, the lighting still needs to be high, but the colour must be reddish or neutral. It aims to maintain students' concentration while they feel more relaxed simultaneously because afternoon learning activities must not be too intense. So, the lighting needs to be at 250 lux, with 4100K for general lighting and 3000K for accent lighting (Figure 13). At last, afternoon prayer time is the most relaxing activity to prepare them to go home, so the lighting needs to be set lower (200 lux) and warmer (3000K) (Figure 13).

Method to Measure the Impact of the Interactive Lighting System on Students' Concentration

The fastest and easiest way to analyze student concentration is through changes in facial expressions (Ekman *et al.*, 2013; Krithika L.B and Lakshmi Priya GG, 2016; Su *et al.*, 2021), gestures, and action behaviour (Su *et al.*, 2021). Decreased concentration behaviours that can be detected include blinking, yawning, being distracted by something else, and changes in body angle while studying (Su *et al.*, 2021).

There are several techniques to detect the effectiveness of an interactive lighting system on students' concentration levels. The first technique is through behavioural and body language analysis, observing the condition of most students from facial expressions, interactions between students, eye gaze direction, yawning, and changes in body position (Sulaiman et al., 2011), which need to be carried out on at least two consecutive days in the same class, with the same students involved in almost the same activities. The room setting tends to be the same. Observations must be conducted on the first day when the interactive lighting system was not installed. On the second day, observations must be re-conducted when the interactive lighting system has been installed. Interviews with students can also be conducted utilizing personal brain investigation assessments related to concentration, attention, and investigating the relationships between emotions, sensations, and thoughts (Levit-Binnun & Tarrasch, 2014).

In psychology and neuroscience, a person's cortisol level due to environmental influences can also be measured by measuring salivary cortisol. This method is ideal and easy to demonstrate for human research subjects because it can be self-sampled under different conditions (Kalman & Grahn, 2004). Apart from that, the use of facial detection technology also makes it possible to become a tool to measure the success of an interactive lighting system. Facial orientation estimation can train a CNN to convert 2D facial feature points into corresponding 3D models to analyze concentration (Su *et al.*, 2021).

Utilization of Arduino in the fields of Architecture, Environment, and Education

Arduino devices can be used in architecture as intelligent systems and ingenious lighting systems that can be implemented in various rooms and buildings. Arduino can be the central controller for lighting systems in buildings and environments; the automation and detection system can be used to become a future intelligent control lighting system (Li *et al.*, 2020). Meanwhile, regarding environmental design, Arduino can be applied to systems in park lights, street lighting systems, and headlights of automobiles (Rath, 2016).

Using Arduino, especially as an interactive lighting system, can maintain student concentration adjustable and flexible in the educational sector. In an active learning classroom, instructional interactions, movement, and use of technology are important factors that can influence activities. Active learning activities require flexible space and lighting adjustment between activities (Basdogan & Morrone, 2021). Prior research also stated that the space requirements for active learning activities are related to the versatility and flexibility of learning space, technology, lighting, furniture, acoustics, and temperature (Lam et al., 2019). Therefore, using Arduino as an interactive lighting system with flexible and adjustable features will support active learning activities.

In project-based learning, students can investigate and solve the project problems freely. It also stimulates students' courage and creativity in expressing their ideas, and students also have responsibilities for the result of the group discussion (Hanif et al., 2019). There is also student demand for flexible learning in a flipped or blended classroom (Brown *et al.*, 2013). Arduino is a versatile and flexible technology that can support various space needs ranging from lighting, noise, temperature, and many more. Therefore, Arduino has the potential to support various types of learning pedagogy in education, such as active learning, project-based learning, flipped classrooms, and blended learning.

CONCLUSIONS

The full-day school programme is one of the innovations in implementing educational programmes to develop students' creativity. The integrated Islamic education implemented at Salman Al Farisi Elementary School aims to improve science, technology, and faith. However, the learning conditions at full-day school are relatively long, and the various activities implemented at this school cause this school to require unique facilities from other schools, especially in maintaining children's learning concentration.

Subject to the results of a case study at Salman Al Farisi Elementary School, it was found that there were many areas for improvement in the arrangement and implementation of interior elements in the classroom, especially in the lighting elements. Lighting is an interior architecture element that mainly affects student concentration in the classroom. On average, the existing lighting condition needs to meet the ideal classroom lighting requirements, maintain students' concentration in learning, and support other activities.

Due to the existing problems, an interactive lighting system must be implemented in Salman Al Farisi Elementary School classrooms to support activities and maintain student concentration in learning. The selection of interactive lighting and colours that consider the needs of children's physical and psychological conditions has the potential to solve the problem of maintaining students' concentration in learning. In addition, the interactive lighting system is also flexible and can provide comfort for children when carrying out learning and playing activities.

Research results showed that Arduino devices have the potential to be used in Salman Al Farisi Elementary School classrooms to create an interactive lighting system. The required interactive lighting system is a lighting system that can detect external lighting, equipped with a timer system, and adjust to the activity scenario in the classroom. Then, the lighting system will adjust the room light to maintain student concentration according to the ongoing activity.

Further studies to be conducted are trials of implementing an interactive lighting system with Arduino devices in classrooms to validate the impact on student concentration.

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